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Prompting Guide

CODE V 10.2

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OPTICAL RESEARCH ASSOCIATES

3280 East Foothill Boulevard, Suite 300
Pasadena, California 91107
Phone: (626) 795-9101
Fax: (626) 795-0184
E-mail: service@opticalres.com
http://www.opticalres.com

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Note: This Prompting Guide is a part of the CODE V documentation set that consists of:

CODE V Introductory User's Guide
CODE V Test Drive
CODE V Prompting Guide
CODE V Reference Manual
CODE V Photonics Modeling Guide

It is intended that this Prompting Guide serve two purposes:

1. For the new user, show the scope of CODE V so that the features available are visible; first exposure to their use can be found in the Introductory User's Guide or the Reference Manual.
2. For the user who is experienced with a section, trigger recollection of what is needed to operate CODE V without using the Reference Manual, except on the more subtle points.

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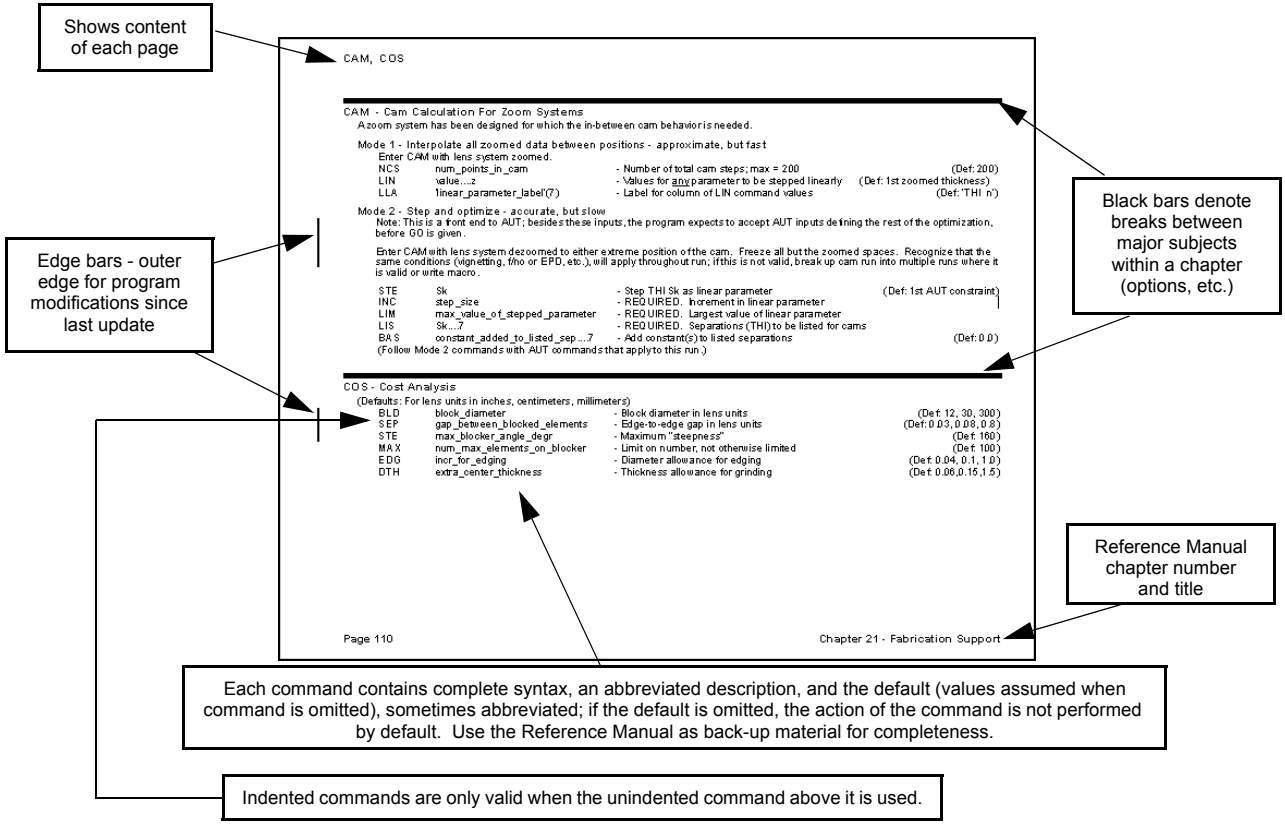
Contents

How To Use This Guide

- For the new user, as a quick look at the scope and organization of CODE V
- For quick reference to recall known commands

This *CODE V Prompting Guide* is organized, by chapters and arrangement, to match the *CODE V Reference Manual*.

Format for Chapters 2 - 25



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Operating CODE V

Commands for Starting and Operating CODE V

Important Commands

Ctrl-BREAK will exit the current major CODE V option as soon as possible, to the LDM, ready for the next input

Starting CODE V

Click on CODE V program group menu item, OR double click on CODE V desktop shortcut icon,
OR double click on lens file in Windows Explorer, OR from DOS window:

C:\CODEV102\CODEV - Enters CODE V in GUI mode
or C:\CODEV102\CODEV /qualifiers [filespec]

where "qualifiers" are:

/B	- Start background process of CODE V, running sequence in filespec (default type .SEQ).
/C	- Enters CODE V in command mode instead of GUI mode
/R=recfile	- Recovers, using RECFILE as input file (default type .REC); if RECFILE is omitted, uses CODEV.REC.
/D=deffile	- Loads defaults from DEFFILE instead of DEFAULTS (default type SEQ).
/H=lines	- Runs CODE V in a window of H lines high (default = 24 lines)
/W=columns	- Runs CODE V in a window W columns wide (default = 80)

Operating within CODE V

Besides the LDM and option commands, see Chapter 24, *Defaults and Utilities* on page 143 for the following subjects:
- Command Processing
- Option Processing
- Exit from CODE V
- Immediate Commands/Defaults including:
  - HELP
  - Configuring your environment for I/O devices and optical assumptions
  - Input of prepared files, printing and plotting of output files
  - Establishing your environment as a default file, read each time you enter CODE V

Prompts

CODE V>	(LEN in screen corner)	-Ready for LDM inputs
XYZ>	(XYZ in screen corner)	-Ready for inputs in XYZ option

Printing/Plotting Outside of CODE V

CVPRINTFILE [-print] [-noprompt] print_file - Uses Windows printer driver to print print_file (default extender .lis)
- print: print_file is printed without preview
- noprompt: print_file is printed using default print setup

CVGUI [-print] [-noprompt] [-device plot_driver] plot_file|raster_file
- Uses Windows or CODE V printer/plotter driver to plot plot_file or raster_file (default extender .plt or .ras)
  - print: plot_file or raster_file is plotted without preview
  - noprompt: plot_file or raster_file is plotted using default print setup
  - device: specifies CODE V printer/plotter driver (implies -noprompt)

CODE V File Usage

File types addressable by user

SEQ	-	file of any CODE V commands (user editable)
LEN	-	saved library lenses (binary) (not editable)
MUL	-	saved multilayer stacks (user editable)
LIS	-	files of output for printing (user editable)
PLT	-	files of output for plotting - neutral plot file (user editable)
RAS	-	files for plotting shaded display on raster device - neutral picture file (user editable)
BLD	-	CODE V generated input file to MOVIE.BYU (SLD option) (user editable)
SOL	-	Intermediate file generated by SLD option (user editable)
DIS	-	CODE V generated input file to MOVIE.BYU (SLD option) (user editable)
REC	-	the session record of all user inputs (user editable)
INT	-	files for intensity and NASTRAN deformation input, interferogram input/output, and PSF grid output **(user editable)**
BUF	-	saved Worksheet Buffer (binary) (not editable)
DAT	-	text file for Worksheet Buffer import and export (user editable)
xxx	-	option save file for option xxx (user editable)
TMP	-	working files deleted by CODE V after exit
V3D	-	visualization file generated by V3D option
STP	-	STEP file generated by the CXP option
IGS	-	IGES file generated by the CXP option
SAT	-	SAT file generated by the CXP option
ENV	-	environment file containing lens-specific environment settings

PNG - Image data file generated by the IMS option

File names

filespec	Includes both the path_name and the file_description
path_name	The file path. The file path can start with an environment variable or a drive letter followed by a colon (:). A total of 256 characters are allowed in the file path and file_description; if the path includes spaces, enclose path and file_description in quotation marks. Note that case is preserved. Directories and subdirectories in the path are separated by forward slashes (/) or backward slashes (\ ); they can be used interchangeably.
file_description	The file_name, file_version, and file_type in the format **name.version.type**. The latest version of a file does not have a version number, and uses the format **name.type**. A total of 256 characters are allowed in the path_name and file_description; note that case is preserved. File_description can include letters, numbers, dashes (-), and underscores (_); do not use special characters. If file_description does not start with a letter or contains spaces, enclose path and file_description in quotation marks. File_version is a number, 1 or greater. If the version number is omitted, the latest version of the file is used. Special version numbers: 0 = oldest version -1 = previous version File_type is a standard CODE V file type (LEN, SEQ, PLT, etc.). If file_type is omitted, the type is assumed from the command or context.

Syntax/Entry Rules

Command Entry Rules

To enter commands means that you need to:

- understand how to interpret the commands as written here
- supply user-defined items
- type in the completed command

Rules For Interpreting Command Notation

CODE V can accept both upper and lower case inputs; however, we use both in the command descriptions to distinguish between what you must type (CAPS) and what you make substitutions for (lower case).

CAPITAL LETTERS — are to be typed, as in: WFR, S, F, W, Z, R, G, C, L

The single letter prefix means the following:

A - user-defined aberration number	I - row number in buffer; derivative increment number	R - ray number
B - buffer number		S - surface number
C - coefficient number	J - column number in buffer	T - through-focus position number
E - entrance pupil position number	L - label (1 to 3 character alphanumeric string)	U - Macro-PLUS I/O unit number
F - field number		W - wavelength number
G - global reference surface number	P - plotting window number	Z - zoom postion number
H - NSS hit number	Q - Macro-PLUS format string	

Qualifiers using these may be in any order.

lower case letters — are to have contents supplied by you, as in:
k, i, j, max, min, increment

THUS: Sk means you should type: S7 or S56 (where 7 or 56 is the desired surface number)

lowercase_words_joined_by_underscore — mean a single quantity to be supplied by you, as in:
lines_per_mm, decrease_in_performance

If the first word is num_, then enter it as an integer, as in:
NRD num_rays_across_diameter

UNITS: Usually clear from the context or in lens units; otherwise included in the lower case words.
Abbreviations used: degr=degrees
nm=nanometers
per_scale_bar=uses plotted scale bars (when printed or plotted, 25mm long for millimeter or centimeter lens units, 1 inch long for inch lens units)

blanks — are used as delimiters, as shown in each command; you may use more than one for readability.

commas — are never entered except if you wish to include them in titles.

. . — means a range of values; it IS to be typed, as in:
Si..j, Zi..j

THUS: Si..j means you should type: S7..12 to indicate that an OAL, for example, extends from surfaces 7 to 12

'abcdefg' — means a string of characters that YOU choose, typed with the quote marks ('); you can also use double quote marks (") as long as they are used at both ends of the string. This is done when you wish to include a quote within the string; choose the opposite one as the string delimiter. Characters can be upper and/or lower case, numbers and any punctuation except the string delimiter (' or ") you have chosen. Each allowable type of character string has a maximum number of characters (between the quotes) denoted as follows:
'system_title'(80) - up to 80 characters are allowed
'temporary_title'(20+20) - the total of 40 characters are split into two lines of 20 each

THUS: 'temporary_title'(20+20) means you can type 'This is my lens in the 5th zoom position' - exactly 40 characters, which splits between t and h of 'the'. The numbers and parentheses (20+20) are NOT typed.

Rules For Interpreting Command Notation (con't.)

....6	is NOT typed; it means that up to that number (6, in this case) of entries may be made. There is no qualifier to alter specific elements or a sub-range.		
....z	is NOT typed; ....z means that multiple entries may be made up to the total number of zoom positions allowed or active.		
....f	This also means that a specific zoom position or range of positions can be used by including the qualifier Zk|Zi..j		
....w	prior to the value. Similarly for wavelength (....w) and field (....f).		
THUS: IFR incr_lines_per_mm....z	means you can enter all zoom position values in one record, if they are the same, with: IFR 10		
	or IFR 10 10 10 10 10 10 (for 6 positions)		
	If the values are different, use, for example: IFR 10 10 20 20 20 20 (for 6 positions)		
	But, you also can modify the 3rd zoom position with IFR Z3 30		
	or the 4th through the 6th can be modified with IFR Z4..6 50		
....f,z	is NOT typed; it shows that a 2-dimensional table is enterable. Using WTF (....f,z) as an example, acceptable formats are:		
....w,z	If the system is not zoomed:	WTF Fk field_weight	- fills Fk
		WTF field_weight....f	- fills each field
	If the system is zoomed:	WTF Fk Zk field-zoom_weight	- fills Fk,Zk field
		WTF Fk field-zoom_weight	- fills Fk, all zoom positions the same
		WTF Fk field-zoom_weight....z	- fills Fk in each zoom position
		WTF Zk field-zoom_weight....f	- fills each field of Zk
		WTF Zk field-zoom_weight	- fills all fields the same
	Similarly for ....w,z. Use of ranges (Zi..j,Fi..j,Wi..j) allows the filling of any submatrix of the 2-D table, with a single value. Example: WTF Z3..5 F2..3 1.0 would fill fields 2 and 3 in zoom positions 3-5 with 1.0.		
|	is NOT typed; it means 'or' as in:Yes|No, Yes|No|color, degrees|RAD|TAN		
Yes	can be typed Y or YES; if all entries are YES, they need not be typed.		
No	can be typed N or NO		
color	can be typed BLA, RED, GRE, YEL, BLU, MAG, CYA, WHI, COM		
[ ]	are NOT typed; they indicate optional qualifiers that change the action of the command as in: [SUP]-suppresses the labeling of contours for CON command in PSF		
	[Sk]-applies the action of the command only to surface k or optional values		
Indented command	indicates that this command is only valid when the preceding non-indented command is used; the indenting does not need to be typed.		

Syntax/Entry Rules

Additional rules that only apply locally to one option or small area of the program will be given there.

Additional Rules for the LDM

[....z]	is NOT typed; it is shown in the LDM to mean that the parameter is zoomable; only after it has been zoomed by use of the ZOO command can changes be made in the zoomed formats implied by ....z
....w[,z] ....f[,z]	is NOT typed; it is shown in the LDM to mean that the parameter is zoomable; only after it has been zoomed by use of the ZOO command can changes be made in the zoomed formats implied by ....w,z or ....f,z
Selective changes after zooming	After a parameter has been zoomed with, for example, ZOO CUY S3 value1 value2 value3 it may be changed at any time with CUY S3 new_value1 new_value2 new_value3 Using No for any of these values will leave it unchanged: CUY S3 N new_value2 new_value3 would leave the first position value unchanged. NOTE: To avoid undue complexity, the use of No is not shown in the LDM command statements. To dezoom to the first position value, DEZ CUY S3 If you are dealing with parameters that allow an array in zoom and field or wavelength, e.g. YAN, you can also dezoom all of the fields/wavelengths at once. For example: DEZ YAN F1..4 dezooms all 4 field angles; DEZ YAN F2..3 would dezoom only field angles 2 and 3.
Sk or Sk|Si..j	are required; either you provide them or the pointer to the current surface will be used. You can always include the surface designator if you wish; if the command is intended to alter data, it will move the pointer at the same time to the single designated surface Sk or to the first surface Si of the range. If the command is only for display or testing, the pointer will NOT be moved.
Exception:	On INS (insert) and DEL (delete) you must supply the surface number(Sk) or range(Si..j) to prevent accidental loss of data from too simple a command.
[Si..j] or [Sk|Si..j]	are optional; in the LDM, these only occur in Operations on Lens Data, Displaying Data, and in Testing Data. Omission means either SO..I or S1..I-1, as appropriate.

Rules For Command Entry

1. Always separate parts of a CODE V instruction with one or more spaces.
2. Never put spaces inside command words, qualifier words, index qualifiers or ranges, or numbers. Leading blanks and extra spaces between items are acceptable.
3. Always precede a surface number, wavelength number, field number, zoom number, etc. with its proper index qualifier prefix (S for surface, W for wavelength, Z for zoom, etc.), without spaces.
   O, S, and I (for object, stop and image) are valid surface numbers. L can be used for the last surface, wavelength, field or zoom number. Examples: W3, F2, S17, Z4, FL. Addition and subtraction can be used (SI-1, SS+2, FL-1, etc.)
   When a command is processed, CODE V determines which zoom position(s) is(are) being referenced, and the S, I, and L keywords refer to that zoom position, or to the first zoom position in the range if a range of zoom positions is specified. If no zoom position is explicitly specified, then the first position is assumed.
4. Never add additional characters to a one or two character command or qualifier word. You may add additional characters to any three character command or qualifier as desired for readability.
5. When a range of surface numbers or other qualifiers is called for, enter the lower and upper value separated by two periods and no spaces, such as S67..129 or F1..L, L can be used for last. A (for all) can be used in place of 1..L, as in FA.
6. Numeric data, alphanumeric data, strings, or (when permitted) expressions are defined as follows:
   a. Numerics: Integers or floating point values, with or without leading signs (+,-) or leading zeros (.5,0.5), or power of ten exponents (1E10, -2.0E-7, etc.). No spaces are permitted within numerics.
   b. Alphanumerics: any permitted number of alphanumeric and/or printing special characters. For glasses, a catalog name is appended using an underscore, e.g., ADF1_HOYA, BPH8_OHARA.
   c. Strings: any permitted number of alphanumeric and/or printing special characters. If spaces or semi-colons(;) are included (e.g., in titles), the entire string must be enclosed in single or double quotes (e.g.,'This is a title',"As is this").
   d. Expressions: user data that include mathematical operations and/or references to operands - CODE V data items (THI, CUY, etc.) that appear in the LDM or specific constraints in AUTOMATIC DESIGN. If an expression contains any operands they must be enclosed in parentheses. For example, (CUY S5 Z3), (EFX S2..8 Z2), etc. See Chapter 25, *Macro-PLUS* on page 153 for details.
7. Upper and lower case letters can be used as desired; CODE V ignores case (ThIs = THIS = this).
8. Continue a command onto the next line by ending the previous line with an ampersand (&). Combine commands onto one line by separating them with a semi-colon (;). Comments are any string of characters beginning with an exclamation point (!), and including semicolons (;). They can be a separate line or at the end of any CODE V instruction.
9. When defining something (user defined constraint in AUTO, etc.), use the ASSIGNMENT OPERATOR (==).
10. When entering an AUTO constraint, use the = sign alone or < and > signs to specify the desired relationship between the constraint and its target.

CODE V Glass Names

Definitions:

glass_name = predefined_glass or nnnnnn or xxx.yyy or 'glass_label'

where:

predefined_glass is a 1 to 13 character alphanumeric code from one of the manufacturer's catalogs. If the catalog is to be designated, it is appended using an underscore, e.g. BK7_SCHOTT

= AIR (or blank)(Index = 1.0 at all wavelengths)

nnnnnn = a six digit glass code (e.g. 517642) corresponding to one of the glass catalog glasses - alternate to designating by the predefined_glass name.

xxx.yyy = a fictitious code. .xxx = n_d-1, .yyy = V_d/100

'glass_label'(8) = a user-defined or gradient index material entered via the Private Catalog

Note: For convenience, 'predefined_glass' can also be two of the reflective/refractive modes:

REFL - Reflecting surface - all rays are reflected, like a metallic mirror.

TIRO - Total internal reflection only - rays that meet TIR conditions are reflected (others are ray failures), like a glass prism face.

In the lens data, for either of these types of reflecting surfaces, material following the surface is identical to that preceding it. All thicknesses following the REFL/TIRO surface must also be reversed to track the direction of light. See RMD command for changing modes.

Note: In the command descriptions that follow, the command notation is given first; additional description follows the dash (-) in the middle of the page; the effect of omitting the command (if any) is given as (Def: . . . .) at the right edge of the page.

The Lens Data Manager

Saving/Restoring Data

Note: In each case, the omission of the filename will use the same default filename, either LENS or the last user entry.

Save & Restore Data (uses .LEN files)

SAV	[filespec]	- Save lens in filespec. (.LEN default filetype)
RES	[filespec]	- Restore lens from filespec. (.LEN default filetype)
CSA	[filespec] [err_fun]	- Save lens in filespec (.LEN default filetype) if current err_fun is less than stored lens err_fun; if [err_fun] is supplied, it is used for stored value in test

(See COP command as a means to insert part of a saved lens into the current lens)

Converting Lens to Sequence Data

WRL	[filename]	- Convert lens to commands and save in filename.SEQ

Re-starting for New Lens

LEN	[NEW]	- Initialize data for new lens. NEW qualifier executes supplied macro *cvnewlens.seq*.

Entering System Data

Wavelength Specification

WL	wavelength_nm....w	- REQUIRED. Enter in descending order (long to short)	
REF	num_of_ref_wl[....z]	- Number of reference wavelength	(Def: center or left of center)
WTW	wl_weight....w[,z]	- Wavelength weight	(Def: 1 for all wavelengths)
CWL	wl_for_qtr_wave_coating_nm	- 1-layer coating defining wavelength	(Def: REF wavelength)
FGG	glass_name....20	- Set of glasses that define the dispersion model for fictitious glasses in the lens system.	(Def: Default set built into CODE V)
FGW	long_wavelength mid_wavelength short_wavelength	- Specify wavelength range (3 values required) for the fictitious glass model.	(Def: C, d, and F)

Pupil Specification

(REQUIRED: One of EPD, FNO, NA, or NAO)

	EPD	entr_pupil_diam[....z]	- Entrance pupil diameter
or	**FNO**	f_ratio[....z]	- F/no of the image space cone (adjusts EPD)
or	**NA**	numerical_aperture_image[....z]	- Numerical aperture in the image space (adjusts EPD)
or	**NAO**	numerical_aperture_object[....z]	- Numerical aperture in the object space (adjusts EPD)

Pupil Apodization - See Chapter 10, *Defining Pupil Apodization and Surface Deformations* on page 47

Polarized Beams - See Chapter 9, *Defining Polarization* on page 43

Field Specification

(Use one of ..IM, ..AN, ..OB, ..RI. Each form is used to set the object heights. Designation of first of X or Y form determines the other. Default is one field of XAN=YAN=0.0, maximum of 25 fields allowed)

	XIM	x_image_ht....f[,z]	- Paraxial X image height (compute XOB)	
	YIM	y_image_ht....f[,z]	- Paraxial Y image height (compute YOB)	
or	**XAN**	x_object_ang_degr....f[,z]	- X angle (degrees) in object space (compute XOB)	
	YAN	y_object_ang_degr....f[,z]	- Y angle (degrees) in object space (compute YOB)	
or	**XOB**	x_object_ht....f[,z]	- X object height	
	YOB	y_object_ht....f[,z]	- Y object height	
or	**XRI**	x_real_img_ht....f[,z]	- Real X image height (compute XOB, YOB)	
	YRI	y_real_img_ht....f[,z]	- Real Y image height (compute XOB, YOB)	
	WID	Yes|No	- Use wide angle mode for systems with any field angles greater than 90° (use with XAN,YAN only)	(Def: No)
	WTF	field-zoom_weight....f[,z]	- Default field weights	(Def: 1.0)
	INS	Fk|Fi..j [x_value y_value]	- Insert field(s)	(Def: 0,0)
	DEL	Fk|Fi..j	- Delete field(s)	

Reference Ray Aiming

CRA [Sk] [Wk|Wi..j] [Zk|Zi..j] [Fk|Fi..j] x_intercept y_intercept [x_aim_point y_aim_point]
- Define chief ray as ray passing through intercept points on surface Sk. Use aim points to start iteration. If Sk is SI, use as ideal reference point only.
(Def: iterate from program-determined aim points to center of stop surface)

RRA Fk | Fi..j [Rk] [Wk | Wi..j] [Zk | Zi..j] [Sk] x_intercept y_intercept [x_aim_point] [y_aim_point]
- Define reference ray as ray passing through intercept points on surface Sk. Use aim points to start iteration. If Sk is SI, use as ideal reference point only.
(Def: iterate from program-determined aim points to center of stop surface)

Vignetting

(see diagram on page 93)

VUY	y_vign_pos_aper_fract....f[,z]	- Fraction of ent. pupil radius clipped off for +Y direction	(Def: 0.0)
VLY	y_vign_neg_aper_fract....f[,z]	- Fraction of ent. pupil radius clipped off for -Y direction	(Def: 0.0)
VUX	x_vign_pos_aper_fract....f[,z]	- Fraction of ent. pupil radius clipped off for +X direction	(Def: 0.0)
VLX	x_vign_neg_aper_fract....f[,z]	- Fraction of ent. pupil radius clipped off for -X direction	(Def: 0.0)

Depth of Focus

(Specifies range of focus positions to be used in options CEF, GLS, LSF, MTF, PAR, PMA, PSF, QUA, RAD, SPO, WAV)

FFO	first_foc_pos[....z]	- First focus position of range	(Def: 0.0)
IFO	incr_in_focus[....z]	- Increment in focus	(Def: 0.0)
NFO	num_of_focus_pos[....z]	- Number of focus steps - up to 18	(Def: 1)

Miscellaneous

AFC [Zk|Zi..j] Yes|No - Operation mode: focal (No) or afocal (Yes) (Def: No)

ACM [Fk|Fi..j] [Zk|Zi..j] accommodation_value (Def: 0.0)
- Accommodation value

ADM RAD|DEG|MIN|SEC|MR|UR|NR - Afocal mode units (Def: MR)

RAD	Radians
DEG	Degrees
MIN	Arcminutes
SEC	Arcseconds
MR	Milliradians
UR	Microradians
NR	Nanoradians

AFI efl_perfect_lens|No[....z] - Afocal system: Keep perfect for infinity object (Def: No)

or **AFO** efl_perfect_lens|No[....z] - Afocal system: Keep perfect for used object (Def: No)

TEL Yes|No[....z] - Telecentric entrance pupil (No: Use actual EP) (Def: No)

	XZF	Yes|No[....z]	- Use X-Z plane for first order (No: Use normal Y-Z)	(Def: No)
	RSL	INF|DEF|ref_sphere_location[....z]	- Reference sphere location for OPD calculations INF - set to infinity for all fields DEF - use program default (real exit pupil location) ref_sphere_value - use specified value for all fields	(Def: DEF)
	TIT	[Zk|Zi..j] 'lens_system_title'(80)	- Lens system title	(Def: blank)
	TEM	lens_temp_degrees_c	- System temperature for result of ENV option only	(Def: 20)
	PRE	lens_pressure_mm_hg	- System pressure for result of ENV option only	(Def: 760)
	DIM	I|C|M	- Override default lens units (DDM)	
	INI	'initials'(3)	- Override default initials (DIN)	
	STO		- Designate pointer surface as stop surface	(Def: S1)
or	**STO**	Sk[....z]	- Designate stop surface	(Def: S1)
	FOC	Si[....z]	- Redefine focal surface to a shorter system	(Def: SI)
	ASF	delta_f_microns[....z]	- Astigmatic object focus shift in microns	(Def: 0.0)
	ASO	orientation_angle_degr[....z]	- Orientation of astigmatic object focus shift	(Def: 0.0)

Output Fiber Location

(Specifies output fiber location to be used in coupling efficiency calculations in CEF, TOR, AUT and GAUSSBEAM)

FLO	[FIX|CMP] [Fk|Fi..j] [Zk|Zi..j] [Wk|Wi..j] [fbx [fby [fbz [fba [fbb]]]]] - Specify fiber location in either a fixed (FIX) or compensated (CMP) position.	(Def: FLO FIX 00000)
FBX	[Fk|Fi..j] [Zk|Zi..j] [Wk|Wi..j] x_displacement - Specify the X direction offset of the fiber (in lens units).	(Def: FBX 0.0)
FBY	[Fk|Fi..j] [Zk|Zi..j] [Wk|Wi..j] y_displacement - Specify the Y direction offset of the fiber (in lens units).	(Def: FBY 0.0)
FBZ	[Fk|Fi..j] [Zk|Zi..j] [Wk|Wi..j] z_displacement - Specify the Z direction offset of the fiber (in lens units).	(Def: FBZ 0.0)
FBA	[Fk|Fi..j] [Zk|Zi..j] [Wk|Wi..j] alpha_tilt_degrees - Specify the rotation angle (in degrees) of the fiber in the YZ plane.	(Def: FBA 0.0)
FBB	[Fk|Fi..j] [Zk|Zi..j] [Wk|Wi..j] beta_tilt_degrees - Specify the rotation angle (in degrees) of the fiber in the XZ plane.	(Def: FBB 0.0)

Defining Surface Shape and Position

Shorthand Surface Entry

(y_rad_curv is either radius or curvature depending on RDM designation; see “Immediate Commands/Defaults” on page 144).

General form:

S|Sk|Si..j [y_rad_curv thickness [glass_name|REFL|TIRO [glass_name]]]

Examples:

Sk		- Set surface pointer=k
S	y_rad_curv thickness [glass_name]	- Increment surface pointer and replace data
Sk	y_rad_curv thickness [glass_name]	- Set surface pointer=k and replace data
Si..j	y_rad_curv thickness [glass_name]	- Replace data on surfaces i thru j, leave surface pointer at i
Sk	y_rad_curv thickness REFL	- Reflecting surface
Sk	y_rad_curv thickness TIRO [glass_name]	- Reflection by Total Internal Reflection Only; glass_name is material following surface and determines whether rays fail in TIR

Surface Labels

SLB Sk 'label' (32) - Attach label to surface for use in place of surface number

To remove:

DEL SLB Sk|Si..j - Delete surface labels from the specified surfaces

Surface Groupings

SGP RIG|POR|PEN|DOV Si..j - Identify surface grouping for *LightTools* export

RIG - right angle prism
PEN - penta prism
POR - porro prism
DOV - dove prism

or **SGP** EXT Si..j list_of_order_of_surfaces_in_range [depth]
- Export extruded prism to *LightTools*

or **SGP** LEN Si..j - In NSS ranges, specify complete lens prior to export to *LightTools*

To ungroup:

DEL SGP Si..j - Ungroup all surface groupings of any type matching the range

Inserting Surfaces

(inserts ahead of Sk, Si, or Sn)

(y_rad_curv is either radius or curvature depending on RDM designation; “Immediate Commands/Defaults” on page 144).

INS Sk|Si..j [y_rad_curv thickness [glass_name]]
- Inserts one or more surfaces (Sk|Si..j required)

BRE Sk - Insert 1 surface of identical shape - break cemented interface (Sk required)

Surface Descriptors

COP Sk|Si..j Sn [* | filespec [FLX|FLY|NEG|FNX|FNY] [final_thickness]]
- Copy surfaces Sk|Si..j in source lens, inserting ahead of Sn in current lens (Sk|Si..j, Sn required):
  - * - source lens is current lens
  - filespec - source lens is library lens (.LEN default file type)
  - FLX, FLY - flip source lens surfaces about X or Y axis
  - NEG - negate (scale by -1) – for matching to current lens light direction
  - FNX, FNY - flip and negate
  - final_thickness - override last copied thickness

To remove:

DEL Sk|Si..j - Delete one or more surfaces (Sk|Si..j required)

To designate ray intersection side:

SID Sk|Si..j DEF|POS|NEG[....z] - Specify ray intersection side for a surface:
- DEF - default; side is automatically selected using the chief ray at the first field
- POS - selects side facing the positive Z axis (i.e., ray is incident on the surface from the positive Z side)
- NEG - selects side facing the negative Z axis (i.e., ray is incident on the surface from the negative Z side)

SLI Sk|Si..j [ALL][....z] - Produce a listing of ray intersection sides in a lens. By default, lists only user-specified settings.
- ALL - lists both default and user-specified settings.

Surface Descriptors

(First input is usually by S command - shorthand data entry - but can be done by individual command; individual commands are more often used for making changes; default shape is spherical.)

Thickness/Separation

THI Sk thickness[....z] - Distance along axis to next surface

TIN Sk thickness_incr....z - Increment distance (THI) immediately

Glass Change

GLA Sk [P] [glass_name[....z]] - Glass after surface; AIR (or blank) is valid
- P - change curvature(s) to keep the same power

RMD Sk REFL|REFR|TIR|TIRO[....z]
- Refractive, reflective mode change (Def: REFR)

GCH Sk GLA|glass_name[....z] - Alter glass characteristics other than index and dispersion to those of glass_name; GLA - set back to match GLA glass (Def: GLA)

GDP Sk NOR|glass_name[....z] - Use partial dispersion properties of glass_name to model fictitious glass; NOR - use properties of normal glass (Def: NOR)

Sphere/Cylinder

SPH	Sk	- Change surface type to spherical
CYL	Sk	- Change surface type to cylindrical
CUY	Sk y_curvature[....z]	- Spherical curvature; Y-curvature for non-rotational symmetry
CUX	Sk x_curvature[....z]	- X-curvature for non-rotational symmetry
RDY	Sk y_radius[....z]	- Input Y-radius; convert to Y-curvature (CUY)
RDX	Sk x_radius[....z]	- Input X-radius; convert to X-curvature (CUX)
CIY	Sk y_curvature_incr....z	- Increment Y-curvature (CUY) immediately
CIX	Sk x_curvature_incr....z	- Increment X-curvature (CUX) immediately

Non-spherical Surfaces - See “Non-Spherical Surfaces” on page 18

Solves

Surface Solves

THI	Sk ET edge_thi semi_diameter	- Edge thickness solve, done separately in each zoom position
THI	Sk OAL Si..j length	- Overall length solve, done separately in each zoom position
THI	Sk HMX x_mar_height_next_sur	- Height on next surface; done in 1st position, value used in all
THI	Sk HMY y_mar_height_next_sur	- Height on next surface; done in 1st position, value used in all
THI	Sk HCX x_chief_height_next_sur	- Height on next surface; done in 1st position, value used in all
THI	Sk HCY y_chief_height_next_sur	- Height on next surface; done in 1st position, value used in all
CUX	Sk UMX x_mar_angle	- Exit angle; done in 1st position, value used in all
CUY	Sk UMY y_mar_angle	- Exit angle; done in 1st position, value used in all
CUX	Sk UCX x_chief_angle	- Exit angle; done in 1st position, value used in all
CUY	Sk UCY y_chief_angle	- Exit angle; done in 1st position, value used in all
CUX	Sk IMX x_mar_incidence	- Angle of incidence; done in 1st position, value used in all
CUY	Sk IMY y_mar_incidence	- Angle of incidence; done in 1st position, value used in all
CUX	Sk ICX x_chief_incidence	- Angle of incidence; done in 1st position, value used in all
CUY	Sk ICY y_chief_incidence	- Angle of incidence; done in 1st position, value used in all
CUX	Sk AMX	- Aplanatic surface solve; done in 1st position, value used in all
CUY	Sk AMY	- Aplanatic surface solve; done in 1st position, value used in all
CUX	Sk ACX	- Aplanatic surface solve; done in 1st position, value used in all
CUY	Sk ACY	- Aplanatic surface solve; done in 1st position, value used in all

To remove (Sk|Si..j required where shown):

DEL SOL	Sk|Si..j	- Delete all solves on designated surface(s)
DEL SOL	THI Sk|Si..j	- Delete all THI solves on designated surface(s)
DEL SOL	CUX Sk|Si..j	- Delete all CUX solves on designated surface(s)
DEL SOL	CUY Sk|Si..j	- Delete all CUY solves on designated surface(s)

Pickups

System Solves

RED	reduction_ratio|No[....z]	- Solve for paraxial object distance in each zoom position with reduction_ratio entered
PIM	Yes|No[....z]	- Solve for paraxial image distance in each zoom position with Yes entered

To remove:

DEL RED	- Leaves object distances unsolved
DEL PIM	- Leaves image distances unsolved

Pickups

Entry of individual or group pickups

	PIK	XXX Sk [YYY] Sj [A [B]]	- Pickup parameter XXX for surface Sk from parameter YYY on surface Sj. If YYY is omitted, matches XXX. A - multiply by value A (default 1.0) B - add offset B (default 0.0)
or	**PIK**	XXX Sk Zi [YYY] Sj Zm [A [B]]	- Pickup parameter XXX on surface Sk for zoom position Zi from parameter YYY on surface Sj for zoom position Zm. If YYY is omitted, matches XXX. A - multiply by value A (default 1.0) B - add offset B (default 0.0)
or	**PIK**	PRO Sk Sj [A]	- Pickup surface profile for surface Sk from surface Sj. A - scale surface profile terms by scale factor A (default 1.0)
or	**PIK**	DEC Sk Sj [A]	- Pickup decenter data for surface Sk from surface Sj. A - scale decenter data terms by scale factor A (default 1.0)
or	**PIK**	DIF Sk Sj [A]	- Pickup diffractive data for surface Sk from surface Sj. A - scale diffractive data terms by scale factor A (default 1.0)

To list pickups

PKL	[XXX] [Sk|Si..j] [Zk|Zi..j] [Ck|Ci..j]	- List all pickups or those for specified parameter in the specified surface, zoom, and coefficient ranges

To remove pickups

DEL PIK	[XXX] [Sk|Si..j] [Zk|Zi..j] [Ck|Ci..j]	- Delete all pickups or those for specified parameter in the specified surface, zoom, and coefficient ranges

Non-Spherical Surfaces

Conic/Asphere

Uses CUY/RDY plus:

CON	Sk	- Change surface type to conic
ASP	Sk	- Change surface type to asphere
K	Sk conic[....z]	- Conic constant (CON, ASP, GRT, XTO, YTO, THG)
A	Sk 4th_order_coef[....z]	- 4th order coefficient (ASP, GRT, XTO, YTO, THG)
B	Sk 6th_order_coef[....z]	- 6th order coefficient (ASP, GRT, XTO, YTO, THG)
C	Sk 8th_order_coef[....z]	- 8th order coefficient (ASP, GRT, XTO, YTO, THG)
D	Sk 10th_order_coef[....z]	- 10th order coefficient (ASP, GRT, XTO, YTO, THG)

E	Sk 12th_order_coef[....z]	- 12th order coefficient (ASP only)
F	Sk 14th_order_coef[....z]	- 14th order coefficient (ASP only)
G	Sk 16th_order_coef[....z]	- 16th order coefficient (ASP only)
H	Sk 18th_order_coef[....z]	- 18th order coefficient (ASP only)
J	Sk 20th_order_coef[....z]	- 20th order coefficient (ASP only)
IC	Sk Yes|No|ANY|CLO|FAR[....z]	- Select ray intersection (Def: Yes) (Yes/No apply to ASP, GRT, XTO, YTO, THG, UDS, UD1, and SPS type surfaces. ANY, CLO, and FAR apply to XTO, YTO, UDS, SPS, UD2, and UD3 surfaces.)
CUF	Sk fresnel_base_curvature[....z]	- Fresnel surface with designated base curve

X-Toroid

Uses CUX/RDX, CUY/RDY, K, A, B, C, D, IC plus:

XTO	Sk	- Change surface type to X-toroid

Y-Toroid

Uses CUX/RDX, CUY/RDY, K, A, B, C, D, IC plus:

YTO	Sk	- Change surface type to Y-toroid

Thermal Gradient

Uses CUY/RDY, K, A, B, C, D plus:

THG	Sk	- Change surface type to thermal gradient
TA1	Sk therm_grad_alpha1	- 2nd order temperature increase coefficient
TA2	Sk therm_grad_alpha2	- 4th order temperature increase coefficient
TBE	Sk Wj therm_grad_beta_j	- Absolute dn/dT (x10**6) for system wavelength j (WL Wj)

Spline

Uses CUY/RDY plus:

SPL	Sk	- Change surface type to spline
SP0	Sk spline_slope0[....z]	- Axial slope (axicon)
SP1	Sk spline_slope1[....z]	- Spline slope at radial zone height of H1
SP2	Sk spline_slope2[....z]	- Spline slope at radial zone height of H2
SP3	Sk spline_slope3[....z]	- Spline slope at radial zone height of H3
SP4	Sk spline_slope4[....z]	- Spline slope at radial zone height of H4
H1	Sk spline_height1[....z]	- Radial zone height corresponding to spline slope of SP1
H2	Sk spline_height2[....z]	- Radial zone height corresponding to spline slope of SP2
H3	Sk spline_height3[....z]	- Radial zone height corresponding to spline slope of SP3
H4	Sk spline_height4[....z]	- Radial zone height corresponding to spline slope of SP4

Anamorphic Asphere

Uses CUX/RDX, CUY/RDY plus:

AAS	Sk	- Change surface type to anamorphic asphere
KY	Sk y_conic[....z]	- Y conic constant
AR	Sk 4th_ord_rot_sym[....z]	- 4th order rotationally symmetric coefficient
BR	Sk 6th_ord_rot_sym[....z]	- 6th order rotationally symmetric coefficient
CR	Sk 8th_ord_rot_sym[....z]	- 8th order rotationally symmetric coefficient
DR	Sk 10th_ord_rot_sym[....z]	- 10th order rotationally symmetric coefficient
KX	Sk x_conic[....z]	- X conic constant
AP	Sk 4th_ord_asym[....z]	- 4th order asymmetric coefficient
BP	Sk 6th_ord_asym[....z]	- 6th order asymmetric coefficient
CP	Sk 8th_ord_asym[....z]	- 8th order asymmetric coefficient
DP	Sk 10th_ord_asym[....z]	- 10th order asymmetric coefficient

Lens Module ("Black box" lens)

MOD	Sk [CHR|ACH]	- Change Sk and Sk+1 to lens module. CHR - chromatic (single glass type - BK7) ACH - achromat (standard glasses) neither - no chromatic aberration. Use MWL and MCO (C1 - C8) to enter chromatic properties.	
MFL	Sk module_focal_length[....z]	- Focal length. Required.	
MRD	Sk principal_reduction_ratio[....z]	- Reduction ratio at principal (corrected) conjugates	(Def: 0)
MFF	Sk front_focal_distance[....z]	- Front vertex to front focal point	(Def: - MFL value)
MBF	Sk back_focal_distance[....z]	- Rear vertex to rear focal point	(Def: + MFL value)
MEN	Sk entrance_pupil_distance[....z]	- Front vertex to entrance pupil	(Def: 0)
MFD	Sk [OBJ|IMG] max_field_spec[....z]	- Maximum field specification: OBJ - object height IMG - image height neither - object space angle (degrees) Required for CHR|ACH or if MCO is used.	
MED	Sk entrance_pupil_diameter[....z]	- Entrance pupil diameter. Required for CHR/ACH or if MCO is used.	
MWL	Sk 1st_wl_nm 2nd_wl_nm 3rd_wl_nm	- Defining wavelengths for MCO chromatic coefficients (C1 - C8). Overrides CHR|ACH (Def: 656.27, 587.56, 486.13)	
MCO	Sk Cj coefficient[....z]	- Aberration coefficients: Chromatic (waves defocus/tilt): C1 - axial color, 1st wavelength C2 - axial color, 2nd wavelength C3 - axial color, 3rd wavelength C6 - lateral color, 1st wavelength C7 - lateral color, 2nd wavelength C8 - lateral color, 3rd wavelength Image (waves at edge of pupil, field): C11 - 4th order SA C12 - coma	(Def: 0.0)

C13 - astigmatism
C14 - distortion
C15 - Petzval curvature
Pupil (waves at edge of image):
C27 - 4th order SA (of pupil)

User-defined Surface

UDS	Sk	- Change surface type to user-defined surface
UD1	Sk	- Change surface type to user-defined surface type 1
UD2	Sk [num_user_storage_locations]	- Change surface type to second form of user-defined surface. Default number of storage locations is 613.
UD3	Sk [num_user_storage_locations]	- Change surface type to user-defined surface type 3. Default number of storage locations is 613.
UCO	Sk Cj coefficient[....z]	- Coefficient j (j < 85) for user-defined surface k (uses user-written Fortran sub-routine). C81 is grating order and allocates C77-81. C82-84 are dimensions of the bounding box to limit surface intersections.
UMR	Sk UDS|UD1|UD2|UD3 name	- Specifies UDS, UD1, UD2, or UD3 subroutine or macro function to be applied to the designated surface.
UMF	Sk UDS|UD1|UD2|UD3 name	- Specifies a data file to be read by the UDS, UD1, UD2, or UD3 subroutine or macro function on the designated surface.
UMN	Sk UD1|UD3 number_of_coefficients	- Set number of coefficients for a UD1 or UD3 type surface.
UMO	UD1|UD3 Sk Cj coefficient[....z]	- Specify coefficients for describing a UD1 or UD3 type surface.
BDX	Sk size[....z]	- Set the X half-width of the bounding box for the user-defined surface.
BDY	Sk size[....z]	- Set the Y half-width of the bounding box for the user-defined surface.
BDZ	Sk size[....z]	- Set the Z half-width of the bounding box for the user-defined surface.

Special Surfaces

Uses CUY/RDY and IC plus special surface parameters specified by coefficient (SCO Ck) or coefficient alias (SCO coef_alias). This listing shows the alias names only; refer to “Defining Special Surfaces” on page 4-97 of the *CODE V Reference Manual* for equivalent coefficient numbers.

SPS	Sk XXX	- Change surface to special surface type XXX

All special surface types XXX use the following common parameters plus type-specific parameters.

SCO	Sk GRS grating_space[....z]	- Grating space - the space between generating planes in lens units
SCO	Sk GRX grating_x_dir_num[....z]	- X direction number of the normal to the generating planes
SCO	Sk GRY grating_y_dir_num[....z]	- Y direction number of the normal to the generating planes
SCO	Sk GRZ grating_z_dir_num[....z]	- Z direction number of the normal to the generating planes
SCO	Sk GRO grating_order[....z]	- Grating order
SCO	Sk BDX bounding_box_x_dim[....z]	- X semi-dimension of bounding box
SCO	Sk BDY bounding_box_y_dim[....z]	- Y semi-dimension of bounding box
SCO	Sk BDZ bounding_box_z_dim[....z]	- Z semi-dimension of bounding box

Codes for special surface type XXX and type-specific parameters

SPS	Sk SCN	- Superconic surface
SCO	Sk K conic[....z]	- Conic constant
SCO	Sk USn nth_order_linear_term[....z]	- Nth order term for coefficient linear in z (n even, 2 through 20)
SCO	Sk VSn nth_order_const_term[....z]	- Nth order term for coefficient constant in z (n even, 4 through 22)
SPS	Sk ODD	- Odd power polynomial surface
SCO	Sk K conic[....z]	- Conic constant
SCO	Sk ARn nth_order_coef[....z]	- Nth order coefficient (n = 1 to 30)
SCO	Sk NTERMS num_terms[....z]	- Number of terms to use(Def: Use all terms)
SCO	Sk NRADIUS norm_radius[....z]	- Normalizing radius(Def: Do not normalize)
SPS	Sk ZRN	- Standard Zernike surface
SCO	Sk K conic[....z]	- Conic constant
SCO	Sk ZPn nth_zernike_coef[....z]	- Nth Zernike polynomial coefficient (n = 1 to 66)
SCO	Sk NTERMS num_terms[....z]	- Number of terms to use (Def: Use all terms)
SCO	Sk NRADIUS norm_radius[....z]	- Normalizing radius (Def: Do not normalize)
SPS	Sk XYP	- XY polynomial surface
SCO	Sk K conic[....z]	- Conic constant
SCO	Sk XnYm xn_ym_coef[....z]	- Coefficient for term of form $x^n y^m$ (n, m maximum value = 10, use n and/or m only when when >1)
SCO	Sk NTERMS num_terms[....z]	- Number of terms to use (Def: Use all terms)
SCO	Sk NRADIUS norm_radius[....z]	- Normalizing radius (Def: Do not normalize)
SPS	Sk ESP	- Extended spline surface
SCO	Sk SP0 spline_slope0[....z]	- Axial slope (axicon)
SCO	Sk SPn spline_slope_n[....z]	- Spline slope at radial zone n (n can be from 1 to 35)
SCO	Sk HTn spline_height_n[....z]	- Radial zone height corresponding to spline slope SPn (n can be from 1 to 35)
SPS	Sk CPC	- Compound parabolic concentrator surface
SCO	Sk TYPE type[....z]	- Source type 1 spherical source 2 cylindrical source aligned with y-axis 3 cylindrical source aligned with x-axis
SCO	Sk ANGLE angle_degr[....z]	- Maximum acceptance angle (in degrees) of the CPC
SCO	Sk RADIUS radius[....z]	- Source or absorber radius for which the CPC is optimized
SCO	Sk ITOL iter_tol[....z]	- Iteration tolerance (lens units)(Def: 1.0e-7)

SPS	Sk CN1	- Fresnel surface on a right circular cone (parallel back cuts)	
SCO	Sk CUX base_cone_x_curv[....z]	- X curvature of the base cone	
SCO	Sk SLOPE base_cone_y_slope[....z]	- Y slope of the base cone	
SCO	Sk Kconic[....z]	- Conic constant	
SCO	Sk A3rd_order_coef[....z]	- 3rd order aspheric coefficient	
SCO	Sk B4th_order_coef[....z]	- 4th order aspheric coefficient	
SCO	Sk C5th_order_coef[....z]	- 5th order aspheric coefficient	
SCO	Sk D6th_order_coef[....z]	- 6th order aspheric coefficient	
SCO	Sk E7th_order_coef[....z]	- 7th order aspheric coefficient	
SCO	Sk F8th_order_coef[....z]	- 8th order aspheric coefficient	
SCO	Sk G9th_order_coef[....z]	- 9th order aspheric coefficient	
SCO	Sk H10th_order_coef[....z]	- 10th order aspheric coefficient	
SCO	Sk I 11th_order_coef[....z]	- 11th order aspheric coefficient	
SCO	Sk J12th_order_coef[....z]	- 12th order aspheric coefficient	
SCO	Sk ZONESAG zone_sag[....z]	- Sag of all zones (except center zone)	(Def: 0.1)
SCO	Sk ZONE0SAG cent_zone_sag[....z]	- Sag of center zone	(Def: ZONESAG)
SPS	Sk CN2	- Fresnel surface on a right circular cone (non-parallel back cuts)	
SCO	Sk CUX base_cone_x_curv[....z]	- X curvature of the base cone	
SCO	Sk SLOPE base_cone_y_slope[....z]	- Y slope of the base cone	
SCO	Sk Kconic[....z]	- Conic constant	
SCO	Sk A3rd_order_coef[....z]	- 3rd order aspheric coefficient	
SCO	Sk B4th_order_coef[....z]	- 4th order aspheric coefficient	
SCO	Sk C5th_order_coef[....z]	- 5th order aspheric coefficient	
SCO	Sk D6th_order_coef[....z]	- 6th order aspheric coefficient	
SCO	Sk E7th_order_coef[....z]	- 7th order aspheric coefficient	
SCO	Sk F8th_order_coef[....z]	- 8th order aspheric coefficient	
SCO	Sk G9th_order_coef[....z]	- 9th order aspheric coefficient	
SCO	Sk H10th_order_coef[....z]	- 10th order aspheric coefficient	
SCO	Sk I11th_order_coef[....z]	- 11th order aspheric coefficient	
SCO	Sk J 12th_order_coef[....z]	- 12th order aspheric coefficient	
SCO	Sk ZONESAG zone_sag[....z]	- Sag of all zones (except center zone)	(Def: 0.1)
SCO	Sk ZONE0SAG cent_zone_sag[....z]	- Sag of center zone	(Def: ZONESAG)
SCO	Sk BCUT_DIS back_cut_dist[....z]	- Distance from center of cone radius to common origin of back cut zones	
SCO	Sk POS_ZNBR num_zones_pos_y[....z]	- Maximum number of discrete zones in positive Y direction (maximum 99)	
SCO	Sk NEG_ZNBR num_zones_neg_y[....z]	- Maximum number of discrete zones in negative Y direction (maximum 99)	

Diffractive Properties

SPS	Sk FRS	- Fresnel surface on planar substrate	
SCO	Sk Kconic[....z]	- Conic constant	
SCO	Sk Q2nd_order_coef[....z]	- 2nd order aspheric coefficient	
SCO	Sk A4th_order_coef[....z]	- 4th order aspheric coefficient	
SCO	Sk B6th_order_coef[....z]	- 6th order aspheric coefficient	
SCO	Sk C8th_order_coef[....z]	- 8th order aspheric coefficient	
SCO	Sk D10th_order_coef[....z]	- 10th order aspheric coefficient	
SCO	Sk E12th_order_coef[....z]	- 12th order aspheric coefficient	
SCO	Sk F 14th_order_coef[....z]	- 14th order aspheric coefficient	
SCO	Sk G16th_order_coef[....z]	- 16th order aspheric coefficient	
SCO	Sk H18th_order_coef[....z]	- 18th order aspheric coefficient	
SCO	Sk I20th_order_coef[....z]	- 20th order aspheric coefficient	
SCO	Sk J22nd_order_coef[....z]	- 22nd order aspheric coefficient	
SCO	Sk MAX_ZNBR num_zones_pos_y[....z]	- Maximum number of discrete zones (maximum 199)	
SCO	Sk ZONESAG zone_sag[....z]	- Sag of all zones except center zone	(Def: 0.1)
SCO	Sk ZONE0SAG cent_zone_sag[....z]	- Sag of center zone	(Def: ZONESAG)
SPS	Sk SEG	- Segmented conic surface	
SCO	Sk K conic[....z]	- Conic constant	
SCO	Sk RAD_INC rad_incr[....z]	- Radial zone width	
SCO	Sk AZI_ZNBR num_zones_azim[....z]	- Number of azimuthal zones	

Diffractive Properties

Linear Gratings

Uses CUY/RDY, K, A, B, C, D, IC plus:

DIF	Sk GRT	- Specifies linear diffractive grating on surface
GRO	Sk grating_order[....z]	- Grating order
GRS	Sk grating_space[....z]	- Grating space - the space between generating planes in lens units
GRX	Sk grating_x_dir_num[....z]	- X direction number of the normal to the generating planes
GRY	Sk grating_y_dir_num[....z]	- Y direction number of the normal to the generating planes
GRZ	Sk grating_z_dir_num[....z]	- Z direction number of the normal to the generating planes
BLT	Sk IDL|KIN|SIN|STE[....z]	- Specifies blazed grating structure. IDL - Ideal KIN - Kinoform SIN - Sinusoid STE - Step approximation to a kinoform
BLD	Sk value_in_lens_units[....z]	- Specifies blaze depth of the linear grating.
BNS	Sk value[....z]	- Used only for STE blaze type. Specifies number of steps used for the step approximation.
BWL	Sk blaze_wavelength[....z]	- Specifies wavelength used to set the blazed grating structure groove depth.

Diffractive Optical Element Properties (phase function definition only)

DIF Sk DOE - Specifies diffractive optical element on surface

HOR Sk num_diff_order[....z] - Diffraction order (usually +1 or -1)

HWL Sk cons_wavelength_nm[....z] - Construction wavelength

HCT Sk XY|R|AXY|XAY|XYA|AR|USR|US2 - Specifies parameters of phase polynomial:

- XY - a general polynominal in X,Y (default)
- R - a rotationally symmetric polynomial in $R^2 = X^2 + Y^2$
- AXY - same as XY, except it uses absolute value of X
- XAY - same as XY, except it uses absolute value of Y
- XYA - same as XY, except it uses absolute values of X and Y
- AR - polynomial in powers of absolute value of R
- USR - user-defined phase function programmed in subroutine (default name is USERHOE)
- US2 - user-defined phase function type 2 programmed in subroutine (default name is USERHOE2)

HCO Sk Cj coefficient[....z] - Coefficients for describing phase function for DOE

BLT Sk IDL|KIN|SIN|STE[....z] - Specifies blazed grating structure.

- IDL - Ideal
- KIN - Kinoform
- SIN - Sinusoid
- STE - Step approximation to a kinoform

BLD Sk value_in_lens_units[....z] - Specifies blaze depth of the diffraction grating.

BNS Sk value[....z] - Used only for STE blaze type. Specifies number of steps used for the step approximation.

UMR Sk HOE|HO2 name - Specifies user-defined phase function subroutine or macro function to be applied to designated surface

UMF Sk HOE|HO2 name - Specifies data file to be called by user-defined phase function subroutine or macro function on designated surface

UMN Sk HO2 number_of_coefficients - Set the number of coefficients for the HO2 type surface Sk.

UMO HO2 Sk Cj coefficient[....z] - Specify coefficients for describing HO2 type surface Sk.

Holographic Optical Element Properties (2-point construction and phase function definition)

Uses BLD, BNS, HOR, HWL, HCT, HCO, UMR, and UMF, plus:

DIF Sk HOE - Specifies holographic optical element on surface.

BLT Sk IDL|KIN|SIN|STE|VHO[....z] - Specifies blazed grating structure.

- IDL - Ideal
- KIN - Kinoform
- SIN - Sinusoid
- STE - Step approximation to a kinoform
- VHO - Volume hologram

HX1 Sk x_obj_pt_source[....z] - X-coordinate of object point source

HY1 Sk y_obj_pt_source[....z] - Y-coordinate of object point source

HZ1 Sk z_obj_pt_source[....z] - Z-coordinate of object point source

Array Elements

HV1	Sk REA|VIR[....z]	- Defines object point source as real (REA) or virtual (VIR)
HX2	Sk x_ref_pt_source[....z]	- X-coordinate of reference point source
HY2	Sk y_ref_pt_source[....z]	- Y-coordinate of reference point source
HZ2	Sk z_ref_pt_source[....z]	- Z-coordinate of reference point source
HV2	Sk REA|VIR[....z]	- Defines reference point source as real (REA) or virtual (VIR)
HTH	Sk volume_hoe_thickness_microns[....z]	- Thickness (in microns) for volume hologram
HIN	Sk volume_hoe_base_index[....z]	- Base index for volume hologram
HDI	Sk volume_hoe_index_mod[....z]	- Index modulation for volume hologram
HSW	Sk volume_hoe_swelling[....z]	- Thickness swelling for volume hologram
HDN	Sk volume_hoe_index_shift[....z]	- Index shift for volume hologram

Array Elements

ARR	Sk x_spacing y_spacing y_offset max_x max_y	- Start array with pattern data
EAR	Sk	- This surface ends the array
ARX	Sk x_spacing	- Change x_spacing
ARY	Sk y_spacing	- Change y_spacing
ARS	Sk y_offset	- Change y_offset
AMX	Sk max_x	- Change max_x
AMY	Sk max_y	- Change max_y
AEL	Sk x y z alpha_degr beta_degr gamma_degr	- Start element array with decenter data; make one AEL entry for each defined element
AEX	Sk Cj x_coord	- Change x on element Cj
AEY	Sk Cj y_coord	- Change y on element Cj
AEZ	Sk Cj z_coord	- Change z on element Cj
AEA	Sk Cj alpha_tilt_degr	- Change α on element Cj
AEB	Sk Cj beta_tilt_degr	- Change β on element Cj
AEG	Sk Cj gamma_tilt_degr	- Change γ on element Cj
APD	Sk xp1 xp2 xp3 yp1 yp2 yp3	- Start polynomial array with decenter coefficients
or **APD**	Sk Cj dec_coeff	- Change decenter coefficient Cj (j=1..6)
APT	Sk ap1 ap2 ap3 bp1 bp2 bp3	- Start polynomial array with tilt coefficients
or **APT**	Sk Cj tilt_coeff	- Change tilt coefficient Cj (j=1..6)
DEL DDA	Sk|Si..j	- Delete decenter data from surface(s) Sk|Si..j; must be applied to starting and ending (EAR) surfaces.

Defining Lens Materials

Private Glass Catalog Data

```
PRV                                          - Start private catalog entries
  PWL   wavelength_nm....21                  - Wavelengths for next indices
  'glass_label'(8)  index....21              - Indices for user-defined glass_label
  'glass_label'(8)  index....21              - Indices for user-defined glass_label
    :
  PWL   wavelength_nm....21                  - Different wavelengths for next indices
  'glass_label'(8)  index....21              - Indices for more user-defined glass_labels
    :
  'glass_label'(8)  MLT [num_terms] reference_glass index....21
                                             - Specify a melt fit to specified number of terms
                                               (1, 2, or 3 - default 2) to reference_glass
    :
  'glass_label'(8)  LAU|GML|GMS|SLM|CAU|HAR coefficients....12
                                             - Specify glass_label by a dispersion formula
                                                 LAU -  Laurent
                                                 GML -  Glass manufacturer's Laurent
                                                 GMS -  Glass manufacturer's Sellmeier
                                                 SLM -  Standard Sellmeier
                                                 CAU -  Cauchy
                                                 HAR -  Hartmann
    :
  END                                        - REQUIRED. End private catalog entries and return to LDM
To remove all, or individual glasses:
  DEL PRV   ALL|'glass_label'(8)             - Delete ALL or selected glasses from private catalog
```

Gradient Index Materials - See “Gradient Index Materials” on page 28

Other Properties

```
Bulk Transmission:
  TRN       Sk  5mm_transmission....w        - Transmission (5 mm thick)                    (Def: catalog or 1.0)
Specific gravity:
  SPG       glass_name   spec_grav          - Set all of glass_name type to spec_grav value
or SPG      Sk|Si..j  glass_name|spec_grav   - Set surf(s) to s.g. of glass_name or spec_grav value  (Def: catalog or n,V formula)
Price of material:
  PRC       glass_name  strip_dollars_per_pound  [slab_dollars_per_pound]
                                             - Set all of glass_name type to prices
or PRC      Sk|Si..j  glass_name             - Set surface(s) to price of glass_name
```

Gradient Index Materials

or **PRC** Sk|Si..j strip_dollars_per_pound [slab_dollars_per_pound]
- Set surface(s) to prices (Def: catalog or 0.0)

To remove (Sk|Si..j required where shown):
DEL TRN Sk|Si..j - Delete TRN data (use default: catalog or 1.0)
DEL SPG Sk|Si..j - Delete SPG (use default: catalog or n,V formula)
DEL PRC Sk|Si..j - Delete PRC (use default: catalog or 0.0)

Gradient Index Materials

Private glass catalog data for GRIN:

PRV - Start private catalog entries

PWL wavelength_nm....21 - Wavelengths for next indices
'glass_label'(8) base_index....21 - Base indices for each GRIN glass_label
SEL|**AXG**|**URN**|**LUN**|**SPG**|**MAX**|**UDG** [gradient_step_size [k]]
- Select formula type, step size, and global reference surface (Def: 0.1)
SEL|**AXG**|**URN**|**LUN**|**SPG**|**MAX**|**UDG** Cj coefficient_value[....21]
- Enter each formula coefficient (may vary with wavelength)
:
'glass_label'(8) base_index....21 - More.....
SEL|**AXG**|**URN**|**LUN**|**SPG**|**MAX**|**UDG** [gradient_step_size [k]]
SEL|**AXG**|**URN**|**LUN**|**SPG**|**MAX**|**UDG** Cj coefficient_value[....21]
:
:
END - Terminates the PRV entry

GGS Sk [GL1|GL2] n - Define a global reference point
GRN Cj 'glass_label'(8) coefficient_value[....21]
- Change a previously defined grin coefficient
GRC Cj 'glass_label'(8) 0|100 - GRN control (Def: 100)
GSS Sk [GL1|GL2] gradient_step_size - Override grin step size given with private catalog
LRM Sk [GL1|GL2] OPA|REF|TIR - Specify light pipe refract mode (Def: LRM OPA)

User-defined GRIN subroutine or macro function entry:

UMR Sk [GL1|GL2] GRN name - Specifies the user-defined GRIN subroutine or macro function to be applied to the designated surface. GL1|GL2 specifies the designated glass for the surface.
UMF Sk [GL1|GL2] GRN name - Specifies a data file to be called by the user-defined GRIN subroutine or macro function.

To remove all, or individual glasses:

DEL PRV ALL|'glass_label'(8) - Delete ALL or selected glasses from private catalog

Menu

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Defining Tilts/Decenters

Global Surface Coordinates - Input

GLB	Sk Gj	- Global input - Interpret coordinate data for surface Sk as specified with respect to the local coordinates of surface Gj
DEL GLB	Sk|Si..j	- Remove global interpretation of surface coordinates; revert to local decentered surfaces.

Global Reference Coordinates - Output

GLO [Sk [x_dist_from_surf y_dist_from_surf z_dist_from_surf]] |Yes|No (Def: No)

- Global reference coordinates for all surfaces; affects RSI, SIN, GSC in the LDM, SSP in ANA and GSC in FAB.
  Defaults - S1; X=Y=Z=0
  Yes - restore previous Sk and x, y, z
  No - turn off global reference

Surface Tilts/Decenters

XDE	Sk x_displacement[....z]	- x displacement of new axis
YDE	Sk y_displacement[....z]	- y displacement of new axis
ZDE	Sk z_displacement[....z]	- z displacement of new axis
ADE	Sk alpha_tilt_degr[....z]	- α tilt of new axis (rotate y-z plane about -x axis)
BDE	Sk beta_tilt_degr[....z]	- β tilt of new axis (rotate x-z plane about -y axis)
CDE	Sk gamma_tilt_degr[....z]	- γ tilt of new axis (rotate x-y plane about +z axis)
XOD	Sk x_displacement[....z]	- x offset point relative to the surface origin about which the surface tilt is applied
YOD	Sk y_displacement[....z]	- y offset point relative to the surface origin about which the surface tilt is applied
ZOD	Sk z_displacement[....z]	- z offset point relative to the surface origin about which the surface tilt is applied
DAR	Sk	- This is a decenter-and-return surface
RET	Sk Sj	- Return to coordinate system of surface Sj
BEN	Sk	- This is a decenter-and-bend surface (for mirrors)
REV	Sk	- This is a reversed decenter surface

To remove (Sk|Si..j required where shown):

DEL DDA	Sk|Si..j	-Delete decenter data
DEL DAR	Sk|Si..j	-Convert decenter-and-return to decentered surface
DEL BEN	Sk|Si..j	-Convert decenter-and-bend to decentered surface
DEL REV	Sk|Si..j	-Convert reversed decenter to decentered surface

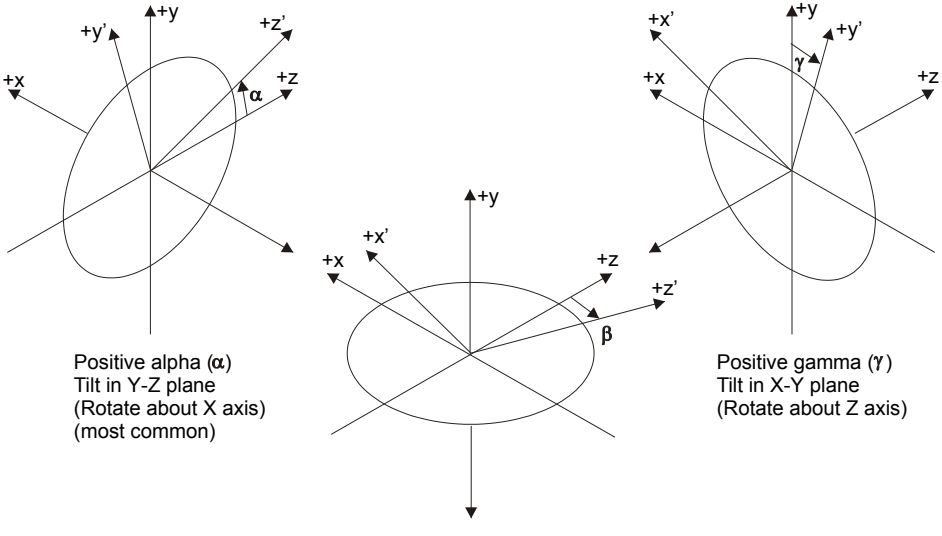
Menu

Search

Array Elements - See “Array Elements” on page 26

Non-sequential Surfaces - See “Non-Sequential Surfaces” on page 31

Tilt Sign Conventions



Notes:
- Tilts are in degrees
- X, Y, Z decenters are in lens units
- Decentrations are performed first, then ADE, then BDE, then CDE, then refract/reflect
- For REV surface first refract/reflect, then tilt -CDE, then -BDE, then -ADE, then decenter with reversed signs (-XDE, -YDE, -ZDE)

Non-Sequential Surfaces

Notes:

1. Light is passed through normal surfaces in sequential order – S0, S1, S2...SI-1, SI; ray failures can occur by missing a surface, total internal reflection (TIR) when it is supposed to refract, and transmitting when it should TIR. Non-sequential (NS) surfaces, however, describe a physical configuration without regard to the order light strikes them – e.g. corner cube reflector light passes through the system in the order which the light strikes the surfaces; they are useful for modeling prisms, cavities, beamsplitters, etc., but are more complicated to use.
2. Each NS surface needs to have a material defined on both sides of the surface; ray tracing succeeds only when the material following one surface matches the material preceding the next one struck.
3. Four modes of action at a surface are allowed:
   - REFR - refraction
   - REFL - reflection
   - TIRO - Total Internal Reflection Only; ray fails if refracted
   - TIR - Total Internal Reflection; follow each ray as traced, refract or TIR

   A special glass, OPAQUE, can be used to allow light to REFL from only one side.
4. A span of NS surfaces can follow and/or precede a span of sequential surfaces, or another NS span.
5. All NS surfaces (which are like decentered surfaces of DAR type) are positioned with XDE, YDE, ZDE commands, not thicknesses; since the image distance must be on a sequential surface, SI-2 is the last allowed NS surface. S2 is the first allowed NS surface.
6. Each group of NS surfaces has an exit port (designated by NSP), allowing the light to leave under specified conditions.
7. User conveniences:
   - NSS - will convert a sequential surface range into its NS equivalent
   - CCR - shorthand generator of NS surfaces for a corner cube reflector
   - ROO - shorthand generator of NS surfaces for a roof prism

Related Sequential Surface Commands

S|**Sk**|**Si..j** y_rad_curv thickness [glass_name|REFL|TIRO [glass_name]]
- Allows TIRO (with following glass), in addition to REFL and glass_name (implied REFR)

RMD Sk REFL|REFR|TIR|TIRO[....z] - Refractive, reflective mode change

Also, GLA, GCH, GLC have corresponding commands to enter/change each of the two glasses.

Pre-defined Modules
(Other, user-defined modules can be stored as .SEQ files and scaled to size after inclusion).

CCR [Sk] apex_length [glass_name [REFL|TIR|TIRO] [error12_arcsec error13_arcsec error23_arcsec]]

- Generates 4 NS surfaces comprising corner cube, with joint between one pair of reflecting faces in +Y direction.

Sk	- entry face and exit port, Sk+1..Sk+3 as REFL faces	
apex_length	- Z axis length from entry face (Sk) to apex; match sign to light direction, for corner cube function	
glass_name	- material inside cube.	Def: AIR
REFL|TIR|TIRO	- reflective mode.	Def: REFL
error12_arcsec error13_arcsec error23_arcsec	- dihedral angle errors relative to 90°, as viewed in direction of light travel, face 1 is to left of Y-Z plane, face 2 to the right and face 3 is below.	Def: 0

Although no explicit default apertures exist, no rays are passed outside the triangles that the surface intersections form. Face centers are at the center of the inscribed circle so that apertures or power tolerances are centered on faces.

ROO Sk apex_length [glass_name [REFL|TIR|TIRO] [error12_arcsec]]

- Generates 3 NS surfaces comprising roof prism, with joint between reflecting faces in Y direction.

Sk	- entry face and exit port, Sk+1..Sk+2 as REFL faces	
apex_length	- Z axis length from entry face (Sk) to apex; match sign to light direction, for roof function .	
glass_name	- material inside prism	Def: AIR
REFL|TIR|TIRO	- reflective mode.	Def: REFL
error12_arcsec	- roof angle error relative to 90°; as viewed in direction of light travel, face 1 is to left of Y-Z plane, face 2 is to the right.	Def: 0

Although no explicit default apertures exist, no rays are passed outside the rectangles that the surface intersections form, with prism ends open. Face centers are at the center of the inscribed circle so that apertures or power tolerances are centered on faces.

Converting to Non-sequential Surfaces

NSS Si..j - Converts sequential surfaces in designated range to equivalent non-sequential surfaces; last surface (Sj) becomes exit port. All surfaces in the range must be sequential for conversion.

Constructing Non-sequential Modules – NS Primitives

N|Nk y_rad_curv [glass_name1] [REFR|TIR|TIRO|REFL] [glass_name2] (Def: REFR)
- Shorthand NS surface entry. Each surface is of DAR type; use XDE, YDE... to position it relative to the coordinate origin of the first surface in this group.
  - glass_name1 - glass on side pointing in -Z direction
  - REFR|TIR|TIRO|REFL - refractive, reflective mode
  - glass_name2 - glass on side pointing in +Z direction

NSS Si..j
- Designates Si..j as this group of NS surfaces. All surfaces in the range must be non-sequential.

DEL NSS Si..j
- Removes NS designation from surfaces Si..j, leaving decenters, glasses, etc., unmodified.

NSP Sk [GL1|GL2] [FOR|REV] [exit_port_thickness]
- Designates Sk as exit port; overrides any previous exit port, changing only the parameters included. Light will leave this NS group through this surface if light passes through GL1 or GL2 (first or second) after leaving surface Sk (default: GL1). Otherwise, tracing continues.
  - FOR|REV - allows choice of Z axis sign for next surfaces:
  - FOR - same direction as Sk (default)
  - REV - opposite to Sk
  - exit_port_thickness - Z-axis distance to next surface after exit port (default=0)

RMC Sk #_of_hits mode [#_of_hits mode]
- Allows change of mode (up to twice) on surface Sk when specified number of hits in original/prior mode is reached; useful for cavities, prisms.
  - #_of_hits - hit number when switch occurs to new mode
  - mode - REFR|TIR|TIRO|REFL – mode after switching

DEL RMC Sk|Si..j
- Delete multiple hit mode change

MXH max_number_hits_per_surf
- Maximum number of hits allowed for any surface in an NS group before declaring a ray failure. (Def: 5)

RMD Sk REFR|TIR|TIRO|REFL [....z]
- Change reflective/refractive mode

GL1 Sk [P] [glass_name[....z]]
- Change glass_name 1.
  - GL1 is a synonym for GLA.
  - P - change curvature(s) to keep the same power.

GL2 Sk [P] [glass_name[....z]]
- Change glass_name 2.
  - P - change curvature(s) to keep the same power.

GP1 Sk GLA|glass_name[....z]
- Assign glass properties (glass characteristics) other than index and dispersion to those of glass_name;
  - GLA - set back to match material designated by GL1.
  - GP1 is a synonym for GCH.

GP2 Sk GLA|glass_name[....z]
- Assign glass properties (glass characteristics) other than index and dispersion to those of glass_name;
  - GLA - set back to match material designated by GL2.

GD1 Sk NOR|glass_name[....z] - Use partial dispersion properties of glass_name (Def: NOR)
NOR - use properties of normal glass
GD1 is a synonym for GDP.

GD2 Sk NOR|glass_name[....z] - Use partial dispersion properties of glass_name to (Def: NOR)
NOR - use properties of normal glass

GC1 Sk|Si..j [A|B|C|D|E|IND|DLN] 0|100|num_of_coupling_group[....z]
- Glass control code for GL1; (Def: 100)
A, B, C, D, E - constrain to map boundary
IND - vary index only
DLN - vary dispersion only
(Setting GC1 to 0 on real glass will convert it to the equivalent fictitious glass and allow it to vary). GC1 is a synonym for GLC.

GC2 Sk|Si..j [A|B|C|D|E|IND|DLN] 0|100|num_of_coupling_group[....z]
- Glass control code for GL2; (Def: 100)
A, B, C, D, E - constrain to map boundary
IND - vary index only
DLN - vary dispersion only
(Setting GC2 to 0 on real glass will convert it to the equivalent fictitious glass and allow it to vary).

TR1 Sk 5mm_transmission....w,z - Bulk transmission (excluding surface reflection losses) for material GL1 for 5mm thick sample, as a fraction of 1 at each of the system wavelengths.

TR2 Sk 5mm_transmission....w,z - Bulk transmission (excluding surface reflection losses) for material GL2 for 5mm thick sample, as a fraction of 1 at each of the system wavelengths.

Defining the Lens Element Structure

Apertures/Edge Definitions

CA Yes|No|APE - Use entered apertures/edges (default apertures elsewhere) for option functions (Def: Yes)
- YES - use user-defined and default apertures
- NO - use default apertures only, ignoring user-defined apertures
- APE - use entered apertures only, ignoring default apertures

In the next commands:

[CLR|EDG|OBS|HOL] - omitted or CLR: clear aperture; EDG: edge of element; OBS: obscuration; HOL: edge of obscuration hole (Note: HOL only applies currently to non-sequential (NSS) surfaces)
(Note: EDG apertures do not block rays. If standard apertures are not also applied to the surface, the CODE V default aperture is used)

[L'label'(3)] - optional label to allow unambiguous reference to any given aperture on a surface

CIR	Sk [CLR|EDG|OBS|HOL] [L'label'(3)] radius[....z]	- Circular
REX	Sk [CLR|EDG|OBS|HOL] [L'label'(3)] x_half_rect[....z]	- Rectangular, X dimension
REY	Sk [CLR|EDG|OBS|HOL] [L'label'(3)] y_half_rect[....z]	- Rectangular, Y dimension
ELX	Sk [CLR|EDG|OBS|HOL] [L'label'(3)] x_half_ell[....z]	- Elliptical, X dimension
ELY	Sk [CLR|EDG|OBS|HOL] [L'label'(3)] y_half_ell[....z]	- Elliptical, Y dimension
ADX	Sk [CLR|EDG|OBS|HOL] [L'label'(3)] x_dec[....z]	- X-decenter for designated aper|EDG|OBS|HOL
ADY	Sk [CLR|EDG|OBS|HOL] [L'label'(3)] y_dec[....z]	- Y-decenter for designated aper|EDG|OBS|HOL
ARO	Sk [CLR|EDG|OBS|HOL] [L'label'(3)] ang_rot_degr[....z]	- Rotate X,Y definition for designated aper|EDG|OBS|HOL
CIG	Sk [CLR|EDG|OBS|HOL] [L'label'(3)] radius x_dec y_dec ang_rot_degr	- General decentered circular
REG	Sk [CLR|EDG|OBS|HOL] [L'label'(3)] x_half y_half x_dec y_dec ang_rot_degr	- General decentered rectangular
ELG	Sk [CLR|EDG|OBS|HOL] [L'label'(3)] x_half y_half x_dec y_dec ang_rot_degr	- General decentered elliptical
ORA	[Si [L'label'] [CLR|EDG|HOL|OBS]	- Logical OR between the group above and aperture following

To remove (Sk|Si..j required where shown):

DEL APE	Sk|Si..j [CLR|EDG|OBS|HOL] [L'label'(3)]	- Delete all or specific apertures for designated surface

Back Surface Curvature, Thickness, and Material of 1st Surface Mirrors

CUM	Sk curvature_mirror_back	- Spherical curve for back of 1st surface mirror
THM	Sk thickness_mirror	- Center thickness to back of 1st surface mirror
GLM	Sk glass_name	- Material for substrate of 1st surface mirror. Use SPG and PRC to modify specific gravity and price.

To remove (Sk|Si..j required where shown):

DEL CUM|**THM**|**GLM**	Sk|Si..j	- Any one of CUM, THM, GLM deletes all three

Coating/Cement Data

(Active in TRA option always; also included in all calculations on polarized beams - options CEF, LSF, MTF, PMA, PSF, PAR, and single rays - RSI, SIN; see POL, etc., commands.)

DEF COA	Sk|Si..j	- Change coatings back to default (Def: 1/4 wave, MgF_2 at CWL wavelength)	
CIN	Sk|Si..j coating_refr_index	- 1-layer coating index at He d line	(Def: 1.38-MgF_2)
CTH	Sk|Si..j coating_thickness_waves	- 1-layer coating thickness at CWL	(Def: 0.25)
MLT	Sk|Si..j coating_filename[.MUL]	- Multilayer coating from coating library; up to 100 different/system	
POP	Sk|Si..j JMX	- Assigns a Jones matrix to the selected surface. (Def: Not applied)	
GPO	Sk|Si..j Yes|No	- Specifies how CODE V divides the phase change that occurs at a coating when polarization ray tracing is active. GPO Yes incorporates into the optical path length (OPL) the phase change attributable solely to the overall optical thickness of the coating. GPO No incorporates into the OPL the phase change attributable to both the overall optical thickness of the coating and the multiple partial reflections at the boundaries between coating layers.	(Def: GPO Yes)
THV	Sk Cn coefficient_value	- Coefficient of r^n for coating thickness variation Coefficient number must be even (0, 2....)Others = 0.0)	(Def: C0 = 1.0;
THV	XDE|YDE Sk x_or_y_displacement	- Decentration of coating thickness variation in x or y direction	(Def: 0.0)
CEM	Sk|Si..j cement_refr_index	- Cement refractive index at He d line	(Def: 1.5585)

To remove (Sk|Si..j required where shown):

DEL COA	Sk|Si..j	- Delete (CIN, CTH) or MLT - uncoated
DEL CEM	Sk|Si..j	- Delete CEM (use default)

Interferometric Deformations/Intensity Apodization - See “Interferometric Deformation/Intensity Apodization” on page 47

NASTRAN-generated Deformations - See “NASTRAN-Generated Deformations” on page 49

Defining Tolerances

[Zk] - Limits the tolerance to the specified zoom position; if omitted, the tolerance applies to all zoom positions.

[V|F] - For INV sensitivity in TOR option, specifies whether tolerance is to be changed (scaled):
- V - vary to adjust tolerance(s) according to sensitivity, limits, and rounding (default)
- F - frozen to entered tolerance value(s)
- neither - same as V

[C] - Part of a coupled group; such a group is identifiable because, on input, it forms a series of successive tolerances all carrying the C; the last of the coupled group does not have the C. Thus the break in the series sets off the group.

[R] - Reverse order of surfaces; the range of surfaces (Si..j) must always be in ascending order; use R to reverse the interpretation of this order, allowing the group to tilt or roll about either end surface.

[L'label'(3)] - Identifies a subset of tolerances and compensators. Duplicate compensators may be entered with different labels. If omitted, a blank label is assigned.

[x_, y_, z_offset] - Defines tilt center relative to local origin and coordinate system for Sk, Si (or Sj if R is used). Also apply to compensators.

Omitting value for tolerance the first time generates default tolerances; after the first, leaves tolerance unchanged.

(0.001,0.0025,0.025) - Tolerance defaults (for lens units: inches, centimeters, millimeters) when value is omitted or included by DEF TOL.

Centered Tolerances

DLF	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_fringes_waves] [x_offset y_offset]	- Tolerance on test plate fit	(Def: 5 fringes at FRW)
DLT	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_thickness]	- Tolerance on thickness	(Def: .001,.0025, .025)
DLN	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_index]	- Tolerance on index of refraction	(Def: .001)
DLV	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_fract_V_number]	- Tolerance on fractional V-number	(Def: .008)
DLR	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_radius] [x_offset y_offset]	- Tolerance on radius	(Def: .001,.0025, .025)
DLS	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_sag_at_ca] [x_offset y_offset]	- Alt to DLR-Tol on surface sag at CA	(Def: .001,.0025, .025)
DLC	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_curvature] [x_offset y_offset]	- Alt to DLR-Tol on curvature	(Def: .001,.001, .0001)
DAK	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_conic_constant]	- Tolerance on conic constant	(Def: .001)
DAA	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_aspheric_a]	- Tolerance on aspheric A term	(Def: 1.E-4)
DAB	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_aspheric_b]	- Tolerance on aspheric B term	(Def: 1.E-6)
DAC	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_aspheric_c]	- Tolerance on aspheric C term	(Def: 1.E-8)
DAD	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_aspheric_d]	- Tolerance on aspheric D term	(Def: 1.E-10)
DAE	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_aspheric_e]	- Tolerance on aspheric E term	(Def: 1.E-12)
DAF	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_aspheric_f]	- Tolerance on aspheric F term	(Def: 1.E-14)
DAG	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_aspheric_g]	- Tolerance on aspheric G term	(Def: 1.E-16)

Irregularity Tolerances

DAH	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_aspheric_h]	- Tolerance on aspheric H term	(Def: 1.E-18)
DAJ	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_aspheric_j]	- Tolerance on aspheric J term	(Def: 1.E-20)
HOM	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [inhomogeneity]	- Tolerance on non-refocusable inhomogeneity	(Def: 5.E-6)
AXG	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [axial_index_gradient]	- Tolerance on axial linear index gradient	(Def: .001)
RAG	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [radial_quad_index_gradient]	- Tolerance on radial quadratic index gradient to CA	(Def: .001)

Irregularity Tolerances

IRR	Sk|Si..j [Zk] [V|F] [L'label'(3)] [nor_&_diag_cyl_irr_fringes] [x_offset y_offset]	- Combination of CYN and CYD	(Def: 1 fringe at FRW)
CYN	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)][normal_cyl_irr_fringes] [x_offset y_offset]	- Cylindrical irregularity over CA - 0° azimuth	(Def: 1 fringe at FRW)
CYD	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [diagonal_cyl_irr_fringes] [x_offset y_offset]	- Cylindrical irregularity over CA - 45° azimuth	(Def: 1 fringe at FRW)

Single Surface Decenter and Displacement Tolerances

DEC	Sk|Si..j [Zk] [V|F] [L'label'(3)] [disp_x_&_y]	- Combination of DLX and DLY	(Def: .001,.0025, .025)
DLX	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [disp_x]	- Surface displacement in X	(Def: .001,.0025, .025)
DLY	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [disp_y]	- Surface displacement in Y	(Def: .001,.0025, .025)
DLZ	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [disp_z]	- Surface displacement in Z	(Def: .001,.0025, .025)
TIL	Sk|Si..j [Zk] [V|F] [L'label'(3)] [tilt_alpha_&_beta_radians [x_offset y_offset z_offset]]	- Combination of DLA and DLB	(Def: .001 radians)
DLA	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [tilt_alpha_radians [x_offset y_offset z_offset]]	- Surface tilt about X axis	(Def: .001 radians)
DLB	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [tilt_beta_radians [x_offset y_offset z_offset]]	- Surface tilt about Y axis	(Def: .001 radians)
DLG	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [tilt_gamma_radians [x_offset y_offset z_offset]]	- Surface tilt about Z axis	(Def: .001 radians)
TIR	Sk|Si..j [Zk] [V|F] [L'label'(3)] [tir_x_&_y_ca]	- Combination of TRX and TRY	(Def: .001,.0025, .025)
TRX	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [tir_x_ca]	- Alternate to DLB - TIR in X at CA	(Def: .001,.0025, .025)
TRY	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [tir_y_ca]	- Alternate to DLA - TIR in Y at CA	(Def: .001,.0025, .025)

Group Decentering Tolerances

STI	Si..j [Zk] [V|F] [L'label'(3)] [shear_tilt_grp_xz_&_yz_radians]	- Combination of STX and STY	(Def: .001 radians)
STX	Si..j [Zk] [C] [V|F] [L'label'(3)] [shear_tilt_grp_xz_radians]	- Tilt each surface of group in XZ plane	(Def: .001 radians)
STY	Si..j [Zk] [C] [V|F] [L'label'(3)] [shear_tilt_grp_yz_radians]	- Tilt each surface of group in YZ plane	(Def: .001 radians)
BTI	Si..j [Zk] [V|F] [R] [L'label'(3)] [bar_tilt_grp_xz_&_yz_radians [x_offset y_offset z_offset]]	- Combination of BTX and BTY	(Def: .001 radians)
BTX	Si..j [Zk] [C][V|F] [R] [L'label'(3)] [bar_tilt_grp_xz_radians [x_offset y_offset z_offset]]	- Tilt group about Si [Sj] in XZ plane	(Def: .001 radians)
BTY	Si..j [Zk] [C] [V|F] [R] [L'label'(3)] [bar_tilt_grp_yz_radians [x_offset y_offset z_offset]]	- Tilt group about Si [Sj] in YZ plane	(Def: .001 radians)
BRL	Si..j [Zk] [C] [V|F] [R] [L'label'(3)] [grp_rot_z_axis_radians [x_offset y_offset z_offset]]	- Rotate group about Z axis	(Def: .001 radians)
DIS	Si..j [Zk] [V|F] [R] [L'label'(3)] [grp_disp_x_&_y]	- Combination of DSX and DSY	(Def: .001,.0025, .025)
DSX	Si..j [Zk] [C] [V|F] [R] [L'label'(3)] [grp_disp_x]	- Displacement of group in X	(Def: .001,.0025, .025)
DSY	Si..j [Zk] [C] [V|F] [R] [L'label'(3)] [grp_disp_y]	- Displacement of group in Y	(Def: .001,.0025, .025)
DSZ	Si..j [Zk] [C] [V|F] [R] [L'label'(3)] [grp_disp_z]	- Displacement of group in Z	(Def: .001,.0025, .025)
ROL	Si..j [Zk] [V|F] [R] [L'label'(3)] [roll_grp_x_&_y]	- Combination of RLX and RLY	(Def: .001,.0025, .025)
RLX	Si..j [Zk] [C] [V|F] [R] [L'label'(3)] [roll_grp_x]	- Roll group on Si [Sj] in X	(Def: .001,.0025, .025)
RLY	Si..j [Zk] [C] [V|F] [R] [L'label'(3)] [roll_grp_y]	- Roll group on Si [Sj] in Y	(Def: .001,.0025, .025)
DOL	Si..j [Zk] [C] [V|F] [L'label'(3)] [del_overall_length]	- Stretch THI's of group equally	(Def: .001, .0025, .025)

Polarization Tolerances

BMA	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [tilt_alpha_radians]	- Tilt about the X-axis of the crystal axis orientation	(Def: .01 radians)
BMB	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [tilt_beta_radians]	- Tilt about the Y-axis of the crystal axis orientation	(Def: .01 radians)
BMG	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [tilt_gamma_radians]	- Tilt about the Z-axis of the crystal axis orientation	(Def: .01 radians)
BMN	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_index_difference]	- Index difference	Def: $(N_e-N_o)(.0001)$
PPA	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_transmittance]	- Amplitude transmittance of the X-axis for the ideal linear polarizer	(Def: .001)
PPF	Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_rotation_radians]	- Rotation angle for an ideal Faraday rotator	(Def: .001 radians)

General Surface Deformation Tolerances

PPO Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_rotation_radians] - Rotation angle for the polarizing element. For ideal linear polarizers, is applied to the rotation of the transmitting axis. For ideal retarders, is applied to the rotation of the fast axis. (Def: .001 radians)

PPR Sk|Si..j [Zk] [C] [V|F] [L'label'(3)] [delta_retardation_waves]
- Retardation for the ideal retarder (Def: .003 waves)

General Surface Deformation Tolerances

ZRN Sk|Si..j Cm [Zk] [C] [V|F] [L'label'(3)] [zernike_coefficient] [x_offset y_offset]
- Surface sag in waves at the fringe wavelength (FRW) over the clear aperture, defined by Zernike polynomial term for the material following each of the designated surfaces Sk|Si..j, for all zoom positions. (Def: .05 waves at the FRW wavelength)

ZFR Sk|Si..j Cm [Zk] [C] [V|F] [L'label'(3)] [zernike_coefficient] -[x_offset y_offset]
- Surface sag in waves at the fringe wavelength (FRW) over the clear aperture, defined by Fringe Zernike polynomial term for the material following each of the designated surfaces Sk|Si..j, for all zoom positions. (Def: .05 waves at the FRW wavelength)

RPA Sk|Si..j [Cn] [Zk] [C] [V|F] [L'label'(3)] amplitude_waves period_lens_units [x_offset y_offset]
- Defines a tolerance/compensator that is a rotationally symmetric cosine sag variation, where the parameter is the amplitude of the variation. The period of the cosine is also specified, but fixed. (Def: 0.05 waves)

RPS Sk |Si..j [Cn] [Zk] [C] [V|F] [L'label'(3)] max_slope_radians period_lens_units [x_offset y_offset]
- Defines a tolerance/compensator that is a rotationally symmetric cosine sag variation, where the variable parameter is the maximum slope of the variation. The period of the cosine is also specified, but fixed. (Def: 0.001 radians)

RSE Sk|Si..j [Cn] [Zk] [V|F] [L'label'(3)] rms_surface_error period lens units
- Defines a tolerance as a random, correlated surface error defined by a RMS surface error in waves at the fringe wavelength (FRW) and a correlation parameter. (Def: 0.05 waves)

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Other

ALL - Includes all subset(s) of tolerances or compensators.

DEF TOL	Sk|Si..j [Zk] [L'label'(3)]	- Generate default tolerances	
VAR TOL	Sk|Si..j [Tk|Ti..j] [Zk] [L'label'(3)|ALL]	- Vary tolerances	
FRZ TOL	Sk|Si..j [Tk|Ti..j] [Zk] [L'label'(3)|ALL]	- Freeze tolerances	
TSF	[CMP] [Tk|Ti..j] scale_factor	- Scale all following tolerances/compensators or tolerance(s)/compensator(s) designated by T qualifier by this factor; CMP qualifier scales compensators.	(Def: 1.0)
TSF	[CHA] [Tk|Ti..j] scale_factor	- Changes the lens to correspond with the values of the selected tolerances/compensators. A scale factor value of 0 causes TSF CHA to apply a random value between -1 and 1.	
TSF	[CHA] TA [G2D|U2D] 0	- In this form of the TSF CHA command, G2D applies a truncated Gaussian probability distribution for the magnitude of 2D decenter tolerances, with equal probability on the orientation. U2D applies a uniform probability distribution for both magnitude and orientation for 2D decenter tolerances. These keywords are only supported on all tolerances with a scale factor of 0.	(Def: components scaled separately)
CMP	tol_code Sk|Si..j [Zk] [C] [R] [L'label'(3)] [V|F|D] [value [x_offset y_offset z_offset]]	- Designate compensators; tol_code is any of the tolerance mnemonics. Compensator use controls (V, F, or D) specify set of possible compensators in tolerancing: V - May be used F - Always used D - Dropped Value (if provided) shows its relation to other members of the same coupled group; for TOR and ALI, value is the change limit. Default value is 20X the corresponding tolerance default. Default offset values are zero.	
INC	Yes|No	- Independent compensation over field and zoom	(Def: No)
FRW	fringe_wl_nm	- Wavelength for fringe measurement	(Def: 546.1 nm)
SVT	[SVD_threshold]	- Threshold value for the Singular Value Decomposition (SVD) calculation.	(Def: 1.0e-10)
MCP	[max_#_compensators]	- Maximum number of compensators to use in the system.	(Def: 0, uses all compensators)

Other

To remove (Sk|Si..j required where shown):

	DEL TOL	Sk|Si..j [Zk] [L'label'(3)|ALL]	- Delete tolerances on designated surface(s)
or	**DEL**	tol_code Sk|Si..j [Zk] [C] [R] [L'label'(3)|ALL]	- Delete tolerances on designated surface(s)
	DEL CMP	Sk|Si..j [Zk]	- Delete all compensators on designated surface(s)
or	**DEL CMP**	[tol_code] Sk|Si..j [Zk] [C] [R] [L'label'(3)|ALL]	- Delete compensators on designated surface(s) Use tol_code to identify 1 compensator type

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Defining Polarization

Activating Polarization Ray Tracing

(Active only in options AUT, CEF, LSF, MTF, PMA, PSF, PAR, TRA and single rays - RSI, SIN; see POP command for polarizers/retarders on surfaces.)

POL	Yes|No	- Include polarization in ray tracing	(Def: No)
RVT	Yes|No	- Reverse polarization ray tracing	(Def: No)

Specifying the Polarization State

Source Model

PST	IDL|DIP	- Specify polarization source type IDL - ideal lens model DIP - dipole source	(Def: DIP)

Source Model

PCS	STD|COL	- Specify polarization coordinate system STD - standard coordinate system COL - collimated beam coordinate sytem	(Def: STD)

Geometrical Representation

PFR	fraction_of_polarization....f[,z]	- Fraction of polarized light to total light	(Def: 0, unpolarized)
PTP	LIN|CIR	- Polarization type:	(Def: LIN)
or **PTP**	ratio....f[,z]	- linear (ratio = 0) CIR - circular (ratio = 1) ratio - elliptical	
POR	orientation_angle_degr....f[,z]	- Polarization orientation of major axis (or LIN) with respect to Y pupil axis	(Def: 0.0)
PRO	LT|RT....f[,z]	- Polarization rotation of E vector (circular or elliptical): LT - left handed (counterclockwise) RT - right handed (clockwise) viewing the field as it "approaches."	(Def: RT)

Jones Vector Representation

JXM	magn_of_x_comp....f[,z]	- Magnitude of X component of Jones field vector	(Def: 0)
JYM	magn_of_y_comp....f[,z]	- Magnitude of Y component of Jones field vector	(Def: 0)
JXP	magn_of_x_comp....f[,z]	- Phase of X component of Jones field vector	(Def: 0)
JYP	magn_of_y_comp....f[,z]	- Phase of Y component of Jones field vector	(Def: 0)

Stokes Parameter Representation

ST1	Stokes_param_s1....f[,z]	- First Stokes parameter (difference between horizontal and vertical intensity components)	(Def: 0)
ST2	Stokes_param_s2....f[,z]	- Second Stokes parameter (difference between 135° oriented and 45° oriented intensity components)	(Def: 0)

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ST3	Stokes_param_s3....f[,z]	- Third Stokes parameter (difference between right circularly polarized and left circularly polarized intensity components)	(Def: 0)

Assigning Polarization Operators

Surface Polarizers/Retarders

(Active in all calculations on polarized beams - options CEF, LSF, MTF, PMA, PSF, PAR, TRA and single rays - RSI, SIN; see POL, etc., commands. Only one element (LIN, RET) is allowed per surface).

POP	Sk | Si..j FAR [rotation_degrees]	- Specifies a Faraday rotator at Sk, with the polarization rotated by rotation_degrees. Default rotation is 45 degrees. A positive angle is clockwise when looking along the positive z axis.
POP	Sk | Si..j LIN [attenuation_factor]	- Specifies a linear polarizer (analyzer) at Sk. Intensity of light polarized in X direction is (1.0 - attenuation_factor) for all wavelengths (default: 1.0).
POP	Sk | Si..j RET [retardation_waves]	- Specifies a retarder at Sk. "Slow," retarded axis is X direction; retarded the same at all wavelengths, by retardation_waves (default 0.25).
POP	Sk | Si..j JMX	- Assigns a unit Jones vector to the selected surface. This command deletes any coatings currently defined on the surface and is equivalent to a perfect coating. You can also define the real and imaginary components of the Jones matrix, using the JR1-JR4 and JI1-JI4 commands.

To remove (Sk|Si..j required where shown):

DEL POP	Sk|Si..j	- Delete all polarizers/retarders on designated surface(s).

Jones Matrix Components

JR1|JR2|JR3|JR4	Sk value	- Define the four real components of the Jones matrix assigned with the POP JMX command.
JI1|JI2|JI3|JI4	Sk value	- Define the four imaginary components of the Jones matrix assigned with the POP JMX command.

User-Defined Surface Properties

POP	Sk USP	- Assigns a user-defined surface properties subroutine on designated surface.
UMR	Sk USP name	- Specifies the user-defined surface properties subroutine assigned to the designated surface.
UMF	Sk USP name	- Specifies a data file to be read by the user-defined surface properties subroutine on the designated surface.
UMO	USP Sk Cj value[....z]	- Specifies coefficients associated with the user-defined surface properties subroutine on the designated surface.
UMC	USP Sk Cj coupling_code[....z]	- Vary/freeze/couple the coefficient value for the user-defined surface properties subroutine on the designated surface.
UMN	Sk USP number_of_coefficients	- Specify the number of coefficients for the USERUSP subroutine on the designated surface.

Defining Pseudo-Birefringent Material

(Active in all calculations on polarized beams - options CEF, LSF, MTF, PMA, PSF, PAR, TRA, and single rays - RSI, SIN; see POL, etc., commands.)

NEO [UNI|CUB] Sk index_difference....w - Value of N_e-N_o for material following the surface; can be positive or negative. (Def: not applied)
UNI specifies modeling of uniaxial birefringent crystals;
CUB specifies modeling of intrinsic birefringence of cubic crystals.
For UNI, a positive index_difference specifies that the fast axis is orthogonal to the crystal axis; a negative value specifies the fast axis along the crystal axis. For CUB, a positive index_difference specifies that the e-ray corresponds to the higher index mode; a negative value (used for CaF(2)), specifies that the e-ray corresponds to the lower index mode.

CAO Sk axis_orientation_degr - Angle (in degrees) between crystal axis and surface Y axis (for crystal axis in XY plane) (Def: 0.0)

or **CAD** [UNI] Sk x_dir_num y_dir_num z_dir_num
- Direction number for crystal axis. (Def: CAO 0)
UNI qualifier specifies orientation of the crystal axis for uniaxial birefringent crystals.

or **CAD CUB** Sk ly_dir my_dir ny_dir lz_dir mz_dir nz_dir (Def: CAD CUB 0 1 0 0 0 1)
- For cubic crystal intrinsic birefringence, specify direction number for crystal axis. To align crystal axes so that the [100] direction is along the z-axis: CAD CUB Sk 0 1 0 -1 0 0 To orient the crystal so the z-axis of the lens corresponds to the [110] direction: CAD CUB Sk 1 0 1 0 1 0
To orient the crystal so the z-axis of the lens corresponds to the [111] direction, use: CAD CUB Sk (-1/sqrtf(2)) (1/sqrtf(6)) (1/sqrtf(3)) 0 (-sqrtf(2/3)) (1/sqrtf(3))

BIR Sk EXT|ORD|AVE|AVO|ORO|EXO [....z] (Def: BIR ORD)
- For both uniaxial and cubic birefringent materials, specifies the ray trace mode:
EXT - trace extraordinary ray
ORD - trace ordinary ray
AVE - trace extraordinary ray, geometrical optical path is computed using the average of the ordinary and extraordinary refractive indices
AVO - trace ordinary ray, geometrical optical path is computed using the average of the ordinary and extraordinary refractive indices
ORO - trace ordinary ray and eliminate the extraordinary field component

EXO - trace extraordinary ray and eliminate the ordinary field component

For cubic crystals, the e-ray corresponds to either the higher or lower index mode, depending on whether the index_difference (NEO command) is positive or negative.

To remove (Sk|Si...j required where shown):

DEL NEO [UNI|CUB] Sk|Si..j - Delete all birefringent data on designated surface(s).
UNI qualifier deletes only the uniaxial birefringence;
CUB qualifier deletes only the intrinsic birefringence.

Defining Pupil Apodization and Surface Deformations

Pupil Apodization

(Apodization is active only in options AUT, BPR*, CAM, CEF*, LSF, MTF, PAR, PMA, PSF, TES, TOR, TRA, WAV. See INT command (INTerferogram or INTensity filter) for user-defined apodization.)

PUI	gaussian_apo_intensity[....z]	- Intensity (0<value<1) at PUX, PUY - Gaussian apodization. PUI 1.0 deletes apodization	(Def: 1.0)
PUX	gaussian_apo_x_int_pt[....z]	- Relative X pupil coordinate for PUI value (1 = pupil radius)	(Def: 1.0)
PUY	gaussian_apo_y_int_pt[....z]	- Relative Y pupil coordinate for PUI value (1 = pupil radius)	(Def: 1.0)

Interferometric Deformation/Intensity Apodization

Notes:

1. Assumes that interferogram/intensity files exist with filespec int_filename.INT - see “Defining Interferometric Deformations and Intensity Apodization” on page 10-9 of the *CODE V Reference Manual* for details of creation and format (including user-defined INT files).
2. Qualifiers:

   ENP - Deformation/apodization applied to entrance pupil, instead of surface.
   EXP - Deformation/apodization applied to exit pupil, instead of surface.
   L'label'(3) - Optional label to discriminate between multiple deformations/apodizations on a surface.
3. Deformations can either be surface deformations, with the resultant wavefront change dependent on ray angles of incidence, or wavefront deformers, with the resultant wavefront change independent of ray angles, depending on file format (SUR or WFR interferograms). Only the latter (WFR) should be used for ENP and EXP.
4. Interferograms affect all ray tracing.
5. Intensity apodization is active whenever Gaussian apodization (see PUI command) can be active - options AUT, BPR*, CAM, CEF*, LSF, MTF, PAR, PMA, PSF, TES, TOR, TRA, WAV. In AUT, TES, CAM, only ENP apodization is recognized; surface apodization is ignored. In PAR, ENP apodization affects only the source distribution, not the pupil filtering.
6. Each interferogram/apodization on a surface is treated in order. Thus, multiple interferograms are added algebraically; multiple apodizations reduce remaining intensity sequentially.
7. See option ALI - Alignment Optimization - to use system wavefront measurements in realigning for optimum performance.

Attach deformation/apodization to surface:

	INT	Sk [L'label'(3)] int_filename	- Assign interferogram/intensity data file to Sk or to	(Def: None)
or	**INT**	ENP|EXP [Fk] [Zn] [L'label'(3)] int_filename	entrance or exit pupil	
	DEL INT	Sk|Si..j [L'label'(3)|ALL]	- Remove deformation/apodization; ALL - all subsets	
or	**DEL INT**	ENP|EXP [Fk] [Zn] [L'label'(3)|ALL]		
	ISF	Sk [L'label'(3)] scale_factor	- Scale file deformations/apodizations	(Def: 1.0)
or	**ISF**	ENP|EXP [Fk] [Zn] [L'label'(3)] scale_factor		

* In the BPR and CEF options, apodization (both Gaussian and general per INT ENP) is disabled if any of the following commands are issued: BIN, BPH, INB, WRX, WRY. In CEF only, general apodization per INT EXP is also disabled.

Interferometric Deformation/Intensity Apodization

Orient interferogram/apodization (Hierarchy: mirror image, rotation, translation):

	IMI	Sk [L'label'(3)] XC|YC|No	- Mirror image:	(Def: No)
or	**IMI**	ENP|EXP [Fk] [Zn] [L'label'(3)] XC|YC|No	XC - reverse X lateral coordinate YC - reverse Y lateral coordinate No - remove mirror image reversal	
	IMI	Sk [L'label'(3)] XC|YC|No	- Mirror image:	(Def: No)
or	**IMI**	ENP|EXP [Fk] [Zn] [L'label'(3)] XC|YC|No	XC - reverse X lateral coordinate YC - reverse Y lateral coordinate No - remove mirror image reversal	
	IRO	Sk [L'label'(3)] ang_rot_degr	- Rotate interferogram/apodization	(Def: 0.0)
or	**IRO**	ENP|EXP [Fk] [Zn] [L'label'(3)] ang_rot_degr		
	INR	Sk [L'label'(3)] radius	- Surface aperture radius at unit circle of file data	(Def: clear semi-diameter or exit pupil semi-diameter)
or	**INR**	ENP|EXP [Fk] [Zn] [L'label'(3)] radius		
	INX	Sk [L'label'(3)] x_dec	- X coordinate, on surface, of interferogram/apodization center	(Def: 0.0)
or	**INX**	ENP|EXP [Fk] [Zn] [L'label'(3)] x_dec		
	INY	Sk [L'label'(3)] y_dec	- Y coordinate, on surface, of interferogram/apodization center	(Def: 0.0)
or	**INY**	ENP|EXP [Fk] [Zn] [L'label'(3)] y_dec		

NASTRAN-Generated Deformations

This process allows deformations of surfaces generated by MSC/NASTRAN (a proprietary product of MacNeal-Schwendler Corporation) to be converted to CODE V interferometric deformation files, and then attached to the surfaces as required.

1. Run NASTRAN, using the MSC/0POLY feature to generate Zernike polynomial deformation coefficients in an output file whose name is determined by the user (default extender: .pch).
2. Run the CODE V stand-alone conversion program (under operating system) using:
   cvnas [-units units] [-out output_file_prefix] [-phase phase_lag_degr] input_file

   where:

units	- i, c, m for inches, centimeters, millimeters. Units of NASTRAN data. Default: i
output_file_prefix	- first 6 characters in .int filenames to be generated. Default: First 6 characters of NASTRAN output filename
phase_lag_degr	- phase lag value for dynamic cases in frequency domain only, for analyzing, in CODE V, the effect of deformations as a function of time and frequency
input_file	- NASTRAN output filename, to be used as input to CVNAS. Default extender: .pch

   Notes:

   a. Can be run under operating system or from within CODE V

   b. Converts deformations from NASTRAN units to wave length units and generates one file for each surface for each case with names in the format:

prefixsscc.int	- for static cases
orprefixssccff.int	- for dynamic cases

   where:

prefix	- output_file_prefix (6 characters)
ss	- NASTRAN surface number (2 digits)
cc	- NASTRAN subcase number (2 digits)
ff	- NASTRAN frequency designator (2 digits)

3. Assign deformation files to corresponding CODE V surfaces with INT commands, using ISF, IMI, IRO, INR, INX, INY commands as necessary.

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Defining Zoom (Multi-Configuration) Systems

Defining positions:

ZOO	num_total_pos	- Designates number of total positions (99 maximum)
DEZ	num_of_desired_pos	- Dezooms to designated position
POS	Zk|Zi..j [ONL] Yes|No	- Designates active zoom positions for options
COP	Zi Zj	- Copy zoom position parameters
INS	Zk|Zi..j	- Insert zoom position(s)
DEL	Zk|Zi..j	- Delete zoom position(s)

Zoom specific parameters by:

ZOO	parameter	- Zooms the parameter and extends current value to all defined positions
or **ZOO**	parameter values....z	- Zooms the parameter and fills values into all defined positions

Dezoom specific parameters by:

DEZ	parameter	- Restores the parameter to non-zoomed status with 1st position value where "parameter" is the mnemonic + surface/field/wave-length number (if required)

Change previously zoomed parameters by:

	parameter [values....z]	- Fills values into all defined positions; one value fills the rest; for numeric values, No leaves that position unchanged.

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Defining Variables and Control Codes

Shorthand Designation of Variables by Groups (Applies to AUT, TES, CAM options):

DEF VAR	Sk|Si..j	- Set up default variables on designated surface(s), freeze others
VAR	Sk|Si..j	- Vary all possible variable parameter(s) on designated surface(s)
FRZ	Sk|Si..j	- Freeze all variable(s) on designated surface(s)

Individual Variables/Couplings (Applies to AUT, TES, CAM, TOR, TOD, TOL options):
If num_of_coupling_grp is the same (or opposite in sign) on 2 or more parameters, these parameters are changed as one variable with changes in the same (or opposite, respectively) direction.

0 - Free to vary independently
100 - Frozen; this is the default for all control codes

CCM	Fk|Fi..j 0|100|num_of_coupling_grp[….z]	- ACM control	(Def: 100)
CCY	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- RDY, CUY control	(Def: 100)
CCX	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- RDX, CUX control	(Def: 100)
THC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- THI control	(Def: 100)
GLC	Sk|Si..j [A|B|C|D|E|IND|DLN] 0|100|num_of_coupling_grp[....z]	- GLA control; A,B,C,D,E - constrain to map boundary IND - vary index only; DLN - vary dispersion only (Setting GLC to 0 on a catalog glass will convert it to the equivalent fictitious glass and allow it to vary)	(Def: 100)
GC1	Sk|Si..j [A|B|C|D|E|IND|DLN] 0|100|num_of_coupling_grp[....z]	- GL1 control - non-sequential surfaces	(Def: 100)
GC2	Sk|Si..j [A|B|C|D|E|IND|DLN] 0|100|num_of_coupling_grp[....z]	- GL2 control - non-sequential surfaces	(Def: 100)
GRC	Cj 'glass_label'(8) 0|100	- GRN control	(Def: 100)
HCC	Sk Cj 0|100|num_of_coupling_grp[....z]	- HCO control	(Def: 100)
UCC	Sk Cj 0|100|num_of_coupling_grp[....z]	- UCO control (user-defined surface)	(Def: 100)
BLC	Sk 0|100|num_of_coupling_grp[....z]	- BLD control	(Def: 100)
ROC	Sk 0|100|num_of_coupling_grp[....z]	- DIF GRT control	(Def: 100)
RSC	Sk 0|100|num_of_coupling_grp[....z]	- GRS control	(Def: 100)
RXC	Sk 0|100|num_of_coupling_grp[....z]	- GRX control	(Def: 100)
RYC	Sk 0|100|num_of_coupling_grp[....z]	- GRY control	(Def: 100)
RZC	Sk 0|100|num_of_coupling_grp[....z]	- GRZ control	(Def: 100)
KC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- K control	(Def: 100)
AC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- A control	(Def: 100)
BC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- B control	(Def: 100)
CC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- C control	(Def: 100)
DC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- D control	(Def: 100)
EC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- E control	(Def: 100)
FC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- F control	(Def: 100)
GC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- G control	(Def: 100)

HC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- H control	(Def: 100)
JC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- J control	(Def: 100)
CCF	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- CUF control	(Def: 100)
SC0	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- SP0 control	(Def: 100)
SC1	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- SP1 control	(Def: 100)
SC2	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- SP2 control	(Def: 100)
SC3	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- SP3 control	(Def: 100)
SC4	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- SP4 control	(Def: 100)
KYC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- KY control	(Def: 100)
ARC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- AR control	(Def: 100)
BRC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- BR control	(Def: 100)
CRC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- CR control	(Def: 100)
DRC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- DR control	(Def: 100)
KXC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- KX control	(Def: 100)
APC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- AP control	(Def: 100)
BPC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- BP control	(Def: 100)
CPC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- CP control	(Def: 100)
DPC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- DP control	(Def: 100)
CX1	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- HX1 control	(Def: 100)
CY1	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- HY1 control	(Def: 100)
CZ1	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- HZ1 control	(Def: 100)
CX2	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- HX2 control	(Def: 100)
CY2	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- HY2 control	(Def: 100)
CZ2	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- HZ2 control	(Def: 100)
FLC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- MFL control	(Def: 100)
RDC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- MRD control	(Def: 100)
FFC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- MFF control	(Def: 100)
BFC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- MBF control	(Def: 100)
EPC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- MEN control	(Def: 100)
FDC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- MFD control	(Def: 100)
EDC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- MED control	(Def: 100)
MCC	Sk|Si..j Cj 0|100|num_of_coupling_grp[....z]	- MCO control	(Def: 100)
SCC	Sk|Si..j Cj 0|100|num_of_coupling_grp[....z]	- SCO control	(Def: 100)
SCC	Sk|Si..j coef_alias 0|100|num_of_coupling_grp[....z]	- SCO control	(Def: 100)
XDC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- XDE control	(Def: 100)
YDC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- YDE control	(Def: 100)
ZDC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- ZDE control	(Def: 100)
XOC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- XOD control	(Def: 100)
YOC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- YOD control	(Def: 100)
ZOC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- ZOD control	(Def: 100)
ADC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- ADE control	(Def: 100)
BDC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- BDE control	(Def: 100)
CDC	Sk|Si..j 0|100|num_of_coupling_grp[....z]	- CDE control	(Def: 100)
UMC	UD1|UD3|USP|HO2 Cj 0|100|num_of_coupling_grp[....z]	- UMO UD1|UD3|USP|HO2 Cj control	(Def: 100)

Variable Increments

DER	[Ik|Im..n] CLR	- Clear all user-specified settings for the selected range of increments.	
DER	[Ik|Im..n] DEF	- Recompute the selected increments using the default algorithm.	
DER	[Ik|Im..n] DRC [cycle_interval|No]	- Specify how frequently to recompute the selected increments using the currently specified algorithm, where cycle_interval = the number of cycles between computations.	(Def: No)
DER	[Ik|Im..n] FDF	- Set the selected increment values to zero and configure CODE V to recompute the selected increments using the finite-differences algorithm the next time AUT is run.	
DER	[Ik|Im..n] FRZ [Yes|No]	- Freeze the derivative increment values to prevent the computation of scale factors for those derivatives.	(Def: No)
DER	[Ik|Im..n] UPD [Yes|No]	- Update the derivative increment values (multiplied by the current scale factor) at the end of each major cycle and set the scale factor back to one.	(Def: Yes)
DER	[Ik|Im..n] LIS	- List the selected increments.	
DER	[Ik|Im..n] [SCA] scale_factor	- Scale selected increments by the specified scale factor.	(Def: DER SCA enabled)
DER	[Ik|Im..n] VAL new_value	- Set the values of selected increments to the specified value.	
CVP	Yes|No	- Disable default curvature couplings during optimization. CVP No specifies using curvature variables and bending variables. CVP Yes specifies using curvature variables only and turns off the bendings (which are automatic couplings of individual curvature variables), and is useful for well-corrected systems, especially when many elements are packed close together such as lithographic lenses.	(Def: No)

Deleting Data

(Sk|Si..j, Fk|Fi..j, Zk|Zi..j required where shown):

	DEL CWL		- Delete CWL (use default: reference wavelength)
	DEL CRA	[Wi] [Zk|Zi..j] Fk|Fi..j	- Delete specified CRA (use default: iterate chief ray from program-determined aim points)
	DEL PRV	ALL|'glass_label'(8)	- Delete ALL or selected glasses from private catalog
	DEL TRN	Sk|Si..j	- Delete TRN data (use default: catalog or 1.0)
	DEL SPG	Sk|Si..j	- Delete SPG (use default: catalog or n,V formula)
	DEL PRC	Sk|Si..j	- Delete PRC (use default: catalog or 0.0)
	DEL Sk|Si..j		- Delete one or more surfaces (Sk|Si..j required)
	DEL Fk|Fi..j		- Delete one or more fields (Fk|Fi..j required)
	DEL Zk|Zi..j		- Delete one or more zoom positions (Zk|Zi..j required)
	DEL SOL	[THI|CUX|CUY] Sk|Si..j	- Delete specified solves on designated surface(s): DEL SOL Sk|Si..j - all solves DEL SOL THI Sk|Si..j - all THI solves DEL SOL CUX Sk|Si..j - all CUX solves DEL SOL CUY Sk|Si..j - all CUY solves
	DEL RED		- Leaves object distances unsolved
	DEL PIM		- Leaves image distances unsolved
	DEL GLB	Sk|Si..j	- Remove global interpretation of surface coordinates; revert to local decentered surfaces
	DEL DDA	Sk|Si..j	- Delete all decenter data on designated surface(s)
	DEL DAR	Sk|Si..j	- Convert decenter-and-return to decentered surface
	DEL BEN	Sk|Si..j	- Convert decenter-and-bend to decentered surface
	DEL REV	Sk|Si..j	- Convert reversed decenter to decentered surface
	DEL APE	Sk|Si..j [CLR|EDG|OBS|HOL] [L'label'(3)]	- Delete all or specific apertures - designated surface
	DEL CUM|THM|GLM	Sk|Si..j	- Mirror substrate: Any of CUM, THM, GLM deletes all three
	DEL CEM	Sk|Si..j	- Delete CEM (use default: 1.5585)
	DEL COA	Sk|Si..j	- Delete (CIN, CTH) or MLT - uncoated
	DEL TOL	Sk|Si..j [Zk] [L'label'(3)|ALL]	- Delete tolerances on designated surface(s)
or	**DEL**	tol_code Sk|Si..j [Zk] [C] [R] [L'label'(3)|ALL]	- Delete specified tolerance on designated surface(s)
	DEL CMP	Sk|Si..j [Zk]	- Delete all compensators on designated surface(s)
or	**DEL CMP**	[tol_code] Sk|Si..j [Zk] [C] [R] [L'label'(3)|ALL]	- Delete specified compensators on designated surface(s). Use tol_code to identify 1 compensator type
	DEL NSS	Si..j	- Remove non-sequential surface attribute
	DEL RMC	Sk|Si..j	- Delete multiple hit mode change
	DEL POP	Sk|Si..j	- Delete all polarizers/retarders on designated surface(s)
	DEL NEO	Sk|Si..j	- Delete all pseudo-birefringent data on designated surface(s)
	DEL INT	Sk|Si..j [L'label'(3)|ALL]	- Remove interferometric deformation/intensity apodization; ALL - all subsets

or	**DEL INT**	ENP|EXP [Fk] [Zn] [L'label'(3)|ALL]	- Remove interferogram from entrance or exit pupil
	DEL PIK	XXX [Sk|Si..j] [Zk|Zi..j] [Ck|Ci..j]	- Delete all pickups or those for specified parameter in the specified surface, zoom, and coefficient ranges
	DEL SLB	Sk|Si..j	- Delete the surface labels from the specified surfaces
	DEL SGP	Si..j	- Ungroup all surface groupings of any type matching the range

Transforming and Calculating Lens Data

End-for-End Flips

(Does not alter Specification data; if [Si..j] is omitted, uses S1..I-1)

	FLX	[Si..j]	- Flip, rotating about X axis
	FLY	[Si..j]	- Flip, rotating about Y axis

Scaling

(Inclusion of SPC scales specification data, too; otherwise, scale all other data only.)

	SCA FAC	[Si..j] [SPC] factor_scaled_by	- Scale lens [segment] by factor
	SCA OAL	[Si..j] [SPC] oal_scaled_to	- Scale lens [segment] to OAL value
	SCA TT	[SPC] tot_track_scaled_to	- Scale lens to total track (TT) value
	SCA EFX	[Si..j] [SPC] x_efl_scaled_to	- Scale lens [segment] to give x-z plane EFL value
	SCA EFY	[Si..j] [SPC] y_efl_scaled_to	- Scale lens [segment] to give y-z plane EFL value
or	**SCA EFL**	[Si..j] [SPC] efl_scaled_to	- Scale lens [segment] to give y-z plane EFL value
	SCA DIM	[Si..j] I|C|M	- Scale lens [segment] AND specification data to lens units
	SCA SPC		- Scale specification data by last factor (In case you forgot, but wanted, to include SPC.)

Setting of Data, Based upon Ray Tracing

(The following SET commands generate clear apertures or edge apertures on surfaces in the specified range which do not already have clear or edge apertures)

SET APE [Sk|Si..j] - Generate CIRs on specified surfaces without clear apertures, based on existing vignetting and pupil definition

SET CAP [Sk|Si..j] [EDG] [L'label'(3)] [CIR|REC|ELL [oversize_incr [rot_angle_degr]]]

- Generate centered clear aperture with the specified label based on FOO type analysis. Default for oversize increment on the half-aperture dimension is 0.0; default for rotation angle is 0.0.

  EDG - generate EDG apertures rather than clear apertures

  CIR - generate circular apertures (default)

  REC - generate rectangular apertures

  ELL - generate elliptical apertures

SET AAP [Sk|Si..j] [EDG] [L'label'(3)] [CIR|REC|ELL [oversize_incr [rot_angle_degr]]]

- Generate decentered clear aperture with the specified label based on FOO type analysis. Default for oversize increment on the half-aperture dimension is 0.0; default for rotation angle is 0.0.

  EDG - generate EDG apertures rather than clear apertures

  CIR - generate circular apertures (default)

  REC - Generate rectangular apertures (default if aspect ratio < 0.75)

  ELL - generate elliptical apertures

SET SAP [Sk|Si..j] [EDG] [L'label'(3)] [CIR|REC|ELL [oversize_incr]]

- Generate Y-decentered clear aperture with the specified label based on FOO type analysis, assuming X symmetry. Default for oversize increment on the half-aperture dimension is 0.0.

  EDG - generate EDG apertures rather than clear apertures

  CIR - generate circular apertures (default)

  REC - generate rectangular apertures (default if aspect ratio < 0.75)

  ELL - generate elliptical apertures

SET VIX [Yes|No....z] - Set X vignetting, based on apertures and pupil definition

SET VIY [Yes|No....z] - Set Y vignetting, based on apertures and pupil definition

SET VIG [Yes|No....z] - Set X and Y vignetting, based on apertures and pupil definition

SET EPD [Yes|No....z] - Set pupil definition in EPD form, based on apertures

SET FNO [Yes|No....z] - Set pupil definition in FNO form, based on apertures

SET NAO [Yes|No....z] - Set pupil definition in NAO form, based on apertures

SET NA [Yes|No....z] - Set pupil definition in NA form, based on apertures

V3D - Interactive 3D Viewing

Model Controls

SUR	[Sk|Si..j] [Zk|Zi..j] Yes|No	- Select surface range and zoom position range; cumulative. Only active zoom positions (POS Zk = Yes) will be included.	(Def: Finite: SO..I Infinite: S1..I)
RVS	[Sk|Si..j] [Zk|Zi..j] Yes|No	- Enables rendering of connective edge surfaces (generated by CODE V between actual surfaces), to make the surface model appear as a solid model.	(Def: RVS SA ZA Yes)
DUM	[Sk|Si..j] [Zk|Zi..j] APE|Yes|No	- Include dummy surfaces within range; cumulative.	(Def: DUM APE)
OVE	[Sk]	- Overlays rendering of all active zoom positions in a single graphical output window. If Sk is greater than the focal surface (FOC) in some zoom position, CODE V will use surface 1.	(Def: S1)

Rendering Controls

RND	SLD|TRA|WIR|HID	- Defines rendering style: solid (SLD), translucent (TRA), wireframe (WIR), or wireframe with hidden lines (HID).	(Def: SLD)
AXE	[Yes|No]	- Adds coordinate axes to the rendering.	(Def: AXE Yes)
VPT	[AZ] [EL]	- Defines the initial viewing angle when the system is rendered. The default azimuth and elevation are with respect to the global coordinate system. If OVE is also used, VPT applies to the first active zoom position.	(Def: VPT -37.8 26.6)
SAM	[grid_value]	- User-defined sampling grid.	(Def: 17)

Ray Definition

CAB	OBS|Yes|No	- Defines how rays are traced: CAB OBS: rays are traced up to the surface where they are obscured, outside the clear aperture, or miss the surface. CAB Yes: rays that are obscured, outside the clear aperture, or miss the surface, are not drawn. CAB No: all rays are drawn through the system.	(Def: CAB OBS)
RFR	[Fk|Fi..j] [Zk|Zi..j] Yes|No	- Renders reference rays from designated fields and zoom positions.	(Def: RFR FA ZA Yes)
RSI	[Fk|Fi..j] [Zk|Zi..j] [Wi] [VIG] x_pupil_fract y_pupil_fract	- Renders single ray at Fk, Zk, Wi, for x, y pupil fraction coordinates.	(Def: No single rays are rendered)
FAN	[Fk|Fi..j] [Zk|Zi..j] [Wi] [VIG] [YZ|XZ|pupil_angle_degr] [num_of_rays_across_diameter]	- Specifies a fan of rays to be rendered for specified fields, zoom positions, and wavelengths.	(Def: No fans)

GRD	[REC|POL] [Fk|Fi..j] [Zk|Zi..j] [Wi] [VIG] [#_x_rays|#_rings] [#_y_rays|#_spokes]		
		- Renders rectangular or polar grid of rays.	(Def: No grids)
RAT THI	1|2|3|4|5	- Designates thickness, in pixels, for ray drawing requests.	(Def: 1)
RAT COL	color|No...z	- Designates color for ray drawing requests.	(Def: FLD color)
RAT DEF		- Resets all ray drawing attributes (RAT commands) to their default values.	

VIE - Lens System View and Plot

Plotting Parameters

	LNG	[max_paper_length_inches|No....z]	- Change mode from 8 1/2 x 11 inch bordered, scaled plot to use long paper on continuous plotter; default max_paper_length = 42.5 inches	(Def: No)
	WID	max_paper_width_inches	- Define width of plotting area (7 to 48 inches)	(Def: 10)
	SF	fraction_of_full_scale....z	- Relative scale when printed or plotted	(Def: SSI)
or	**SSI**	lens_units_per_scale_bar....z	- Set scale size in X and Y	(Def: Automatic scaling)
	SSX	lens_units_per_scale_bar....z	- Override SSI and SF in X	(Def: SSI)
	SSY	lens_units_per_scale_bar....z	- Override SSI and SF in Y	(Def: SSI)
	LAB	[VAX] [PRE] Yes|No|color.....z	- Include labeling, designate color VAX - include box with view axes PRE - presentation quality font, instead of draft	(Def: Yes, in POC color)
	SUR	[Sk|Si..j] Yes|No....z	- Include these surfaces in the plot; cumulative	(Def: Finite: SO..I Infinite: S1..I)
	TIT	'temporary title'(40)....z	- Temporary title	(Def: 1st 40 char. of lens title)
	TTO	Yes|No....z	- Put title at top of plot	(Def: No)
	RET	[Zk|Zi..j] Yes|No....z	- Return to original origin to overlay next plot	(Def: No)
	OFS	[Zk|Zi..j] [DIM|NOR] x_offset y_offset [rotation_angle_degr]	- Offsets from default centering in printer/plotter paper inches DIM - lens units NOR - fraction (0 to 1) of plot size	(Def: Automatic centering)
or	**OFS**	[Zk|Zi..j] [Sk] POS x_pos y_pos [rotation_angle_degr]	- Position the vertex of surface Sk at the x,y position in printer/plotter unit	
or	**OFS**	[Sk] OVE [x_offset y_offset [rotation_angle_degr]]	- Used together with RET in zoomed system to overlay zoom positions at surface Sk. The integrated picture will be scaled to size and centered	

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Lens Drawing Controls (Defaults: Sk|Si..j - Range of all SUR commands)

HAT	Yes|No....z	- Hatch back of mirrors around the edge	(Def: No)
LNS	[Sk|Si..j] Yes|No|color....z	- Draw specified surface(s) in designated color; cumulative	(Def: SUR ranges in POC color)
EDG	[Sk|Si..j] Yes|No|color....z	- Draw edge-surface boundaries, designate color; cumulative	(Def: Yes)
EDL	[Sk|Si..j] Yes|No|color....z	- Draw edge line in cross-sections, designate color; cumulative	(Def: Yes)
NBR SUR	[Sk|Si..j] Yes|No|color....z	- Number surfaces in designated color; cumulative	(Def: No)
NBR ELE	[Sk|Si..j] Yes|No|color....z	- Number elements in designated color; cumulative	(Def: No)
LCO	[Sk|Si..j] Yes|No|color....z	- Draw local XY orientation of element, designate color; cumulative	(Def: No)
ID	Yes|No....z	- Remove small added aperture increment on concave surfaces with active apertures	(Def: No)
AAP	Yes|No....z	- Draw used area-asymmetric apertures	(Def: No)
DUM	[Sk|Si..j] Yes|No|Color....z	- Include dummy surface indicators	(Def: No)
LRS	[Sk|Si..j] resolution_factor	- Set line resolution for drawing a surface or a range of surfaces	(Def: S1..l;1.0)

Ray Drawing Controls

FLD	Yes|No|color....f,z	- Draw rays at designated fields and zoom positions in designated colors	(Def: CLS FLD colors)
CAB	Yes|No....z	- Drop CA blocked and obstructed rays	(Def: No)
RIE	Yes|No....z	- Draw rays inside elements	(Def: Yes)
ERI	value_in_lens_units....z	- Extend rays on input to surface range	(Def: 0.0)
ERO	value_in_lens_units....z	- Extend rays on output from surface range	(Def: 0.0)

Ray Drawing Attributes (for rays requested/defined to follow)

(Defaults: Sk|Si..j - Range of all SUR commands)

RAT COL	color|No....z	- Designate color for ray drawing requests that follow	(Def: FLD color)
RAT STL	[style_number|No....z]	- Designate linestyles for ray drawing requests that follow	(Def: STL styles)
RAT HIT	[Sk|Si..j] Yes|No....z]	- Draw symbol at ray-surface intersection on designated surfaces for ray drawing requests that follow	(Def: No)
RAT DOT	[num_symbol|No]	- Specify symbol number (1-17)	(Def: DTL symbols)
RAT DSI	[symbol_size|No]	- Specify symbol_size in scale bars	(Def: DSI size)
RAT SUR	[Si..j] Yes|No....z	- Draw rays only between designated surfaces for ray drawing requests that follow	(Def: Yes, over SUR range, subject to RIE)
RAT DEF		- Resets all RAT values to their respective defaults.	

Ray Definition

(Defaults: Fk - FA; Wi - REF wavelength)

RFR [YZ|XZ] Yes|No....f - Draw reference rays

YZ - in Y-Z pupil plane (default)

XZ - in X-Z pupil plane

(Def: For PLC, draw XZ or YZ; for VPT, draw YZ for sym., for asym., XZ and YZ)

RSI [Fk] [Wi] x_pupil_fract y_pupil_fract - Specify single ray; specify up to 200 total extra rays (Def: No single rays are drawn)

FAN [Fk] [Wi] [YZ|XZ|pupil_angle_degr [num_of_rays_across_diameter]]

		- Specify fan of rays, up to 200 total extra rays YZ - in Y-Z pupil plane (default, = 0 pupil_angle) XZ - in X-Z pupil plane Default rays_across_diameter: 11	(Def: No fans)
GRD REC	[Fk] [Wi] x_num_of_rays_across_diameter y_num_of_rays_across_diameter	- Specify rectangular ray grid, up to 200 total extra rays	(Def: No grids)
GRD POL	[Fk] [Wi] num_of_rings angle_between_spokes_degr	- Specify polar ray grid, up to 200 total extra rays	(Def: No grids)
DEL RSI	[Fk Wi x_pupil_fract y_pupil_fract]	- Delete a single ray. With omitted data, delete last ray	
DEL FAN	[Fk Wi YZ|XZ|pupil_angle_degr]	- Delete a fan of rays. With omitted data, delete last fan	
DEL GRD	[Fk Wi]	- Delete ray grid. With omitted data, delete last grid	

Viewing Controls (Choose one of: PLC, VPT, or SLC)

(Definition: Sr means first surface of SUR range.)

PLC	[YZ|XZ] [Sk]	- Local cross-sections projected with respect to global coordinates of Sk (def: Sr) YZ - projection of YZ cross-sections (default) XZ - projection of XZ cross-sections	(Def: PLC YZ Sr)
or **VPT**	[Sk] [azimuth_degr [elevation_degr [perspective_distance]]]	- Perspective view; designate view direction and projection with respect to global coordinates of Sk Defaults: Sr -37.8 26.6 perspective_distance = infinity (i.e. parallel projection)	(Def: PLC)
MOD	[Si..j] [FUL|HAL|QUA] [angle_of_rotation_around_local_Z]	- Specify element modeling for VPT FUL - complete element (no cut) HAL - half-cut QUA - quarter-cut angle-of_rot.... - rotate cut to face desired direction	(Def: FUL)
HID	Yes|No	- Draw VPT with hidden lines removed	(Def: No)
or **SLC**	[Sk] [azimuth_degr elevation_degr offset]	- Sliced view; single slice through system projected with respect to global coordinates of Sk Default: Sr 0.0 0.0 0.0	(Def: PLC)

Special Diagnostic Analysis

IOR	[Sk|Si..j] Yes|No|color	- Draw marks for image orientation at specified surface(s) - default surface: SI; cumulative	(Def: No)

Interactive Controls

DO	- Do drawing immediately and retain all previous inputs

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ELE - Element and Component Drawing

Plotting Parameters

	SUR	Sk|Si..j	- Limit to designated surface(s)	(Def: S1..I-1)
	SSI	lens_units_per_scale_bar	- Set scale size	(Def: automatic scaling)
or	**SF**	fraction_of_full_scale	- Scale of drawing when printed or plotted	(Def: SSI)
	TIT	'temporary_title'(20+20)	- Temporary title (Def: 1st 40 char. lens_system_title)	
	REN	num_1st_drawn_element	- Renumber spanned elements, starting at num_	(Def: 1)

Control of Lens Drawing

COM	Yes|No	- Draw as components, not elements	(Def: No)
AAP	Yes|No	- Draw used area - asymmetric apertures	(Def: No)
LNS	Yes|No|color	- Draw lenses, designate color	(Def: Yes)
EDG	Yes|No	- Include edges of elements	(Def: Yes)
ID	Yes|No	- Removes normal small added aperture increment on active apertures	(Def: No)
XZ	Yes|No	- Draw X-Z section instead of Y-Z	(Def: No)

User Notes

NOT num_first_note_replaced
'1st_line'(48)
'2nd_line'(48)
:
:
'last_line'(48)
END

- User-defined notes, replacing standard ones starting at the number of note given as num_first.... (Approximately 30 total lines can be fitted into the format, with the last 8 shortened to 40 characters.)
- Ends user-defined notes

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SLD - Solids Modeling

Two processes are needed to generate solids displays:
BLD - Build representation of solid shapes without regard to viewing conditions.
DIS - Display the solids with given viewing conditions.

Each process can be run separately, the default is to run both.

Build Solids Representation

FIL	[filespec]	- Create and save all intermediate SLD files with specified filename	(Def: Not given)
BLD	Yes|No	- Build new model Yes - build new model No - display will use a file specified by FIL	(Def: Yes)
DIS	Yes|No	- Display model. If Yes is given, uses file specified by FIL	(Def: Yes)
SHA	512|1024|Yes|No	- Shaded display instead of line drawing (.RAS file type) 512 - 512 x 512 pixel display 1024 - 1024 x 1024 pixel display Yes - equivalent to 512 No - do not display shaded solid	(Def: No)
SUR	Si..j	- Span of displayed surfaces	(Def: S1..I-1)
SEC	360|270|180	- Select sectioning	(Def: 360)
RAY	Yes|No....f	- Include rays at designated fields	(Def: No)

Display Parameters

BAC	r_value g_value b_value	- Background color in RGB unit cube	(Def: 1.0 0.83 .31)
RTX	angle_pict_rot_degr	- Rotate about screen X	(Def: 20)
RTY	angle_pict_rot_degr	- Rotate about screen Y	(Def: 45)
RTZ	angle_pict_rot_degr	- Rotate about screen Z	(Def: Line, 90; Shaded, 0)
RTO	1st_axis (X|Y|Z) 2nd_axis (X|Y|Z) 3rd_axis (X|Y|Z)	- Select order of execution - rotation angles	(Def: RTO Y X Z)
FAC	factor_increase	- Scale factor for picture relative to default	(Def: 1.0)

Queries

Placing ? before or after any command descriptor for data entry displays the value currently in memory

Ex: ?CUY S3 or CUY S3?

Sk|Si..j? - Lists CUY,THI,GLA for surface(s)

or

?Sk|S..ji..j - Lists CUY,THI,GLA for surface(s)

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List Data

LIS		- All data (SUR, SPC, APE, NSL, PVC, IND, SOL, ZLI, FIR)
SUR	Sk|Si..j [F] [Zk]	- Surface data
		F - include SPG,PRC,CUM,THM and control codes
		Omit F - do not include
SPC	[WL|APE|FLD|VIG|OTH]	- Specification data; WL,APE,...limits list
APE	Sk|Si..j [CLR|EDG|OBS|HOL]	- Apertures data:
		CLR - clear apertures only
		EDG - edges only
		OBS - obscurations only
		HOL - holes only
		omitted - clear apertures, edges, obscurations, and holes
NSL		- Non-sequential data table
PVC	[MLT]	- Private catalog
		MLT - include data on any melt fits
IND		- Index table at used wavelengths
SOL	Sk|Si..j	- Solve data
ZLI	Sk|Si..j [SPC|zoomed_parameter]	- Zoom data; zoomed_parameter is any zoomable mnemonic
TLI	Sk|Si..j [Zk] [CMP|FUL] [tol_code|C|V|F] [L'label'(3)|ALL]	
		- Tolerance data; restrict listing to:
		Zk - tolerances active in this zoom position only
		CMP - compensator(s) only
		FUL - both tolerance(s) and compensator(s)
		tol_code - this tolerance type only
		C - coupled group(s) only
		V - varied tolerances only
		F - frozen tolerances only
		L'label'(3)|ALL - a specific or all subset(s) of tolerances and compensators; if omitted, the subset having a blank label only

Draw lens

TTA		- Table of lens data with tolerances
CLI	[Sk|Si..j]	- List apertures for designated surface(s) and their effect on clipping
GSC	[Sk|Si..j] [COS] Yes|No....z	- List surface positions relative to the GLO coordinate system COS - express local Z axis in direction cosines Omit COS - express local Z axis in tilt angles
PKL	[XXX] [Sk|Si..j] [Zk|Zi..j] [Ck|Ci..j]	- List all pickups or those for specified parameter in the specified surface, zoom, and coefficient ranges

---

Draw lens

DRA	[XZ] [Si..j] [Zk]	- Draw YZ section of lens for spanned surfaces, scaled to screen, for first active zoom position; XZ - draw XZ section

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Performing Quick LDM Evaluations

For quick testing of optical properties of the data:

Evaluate

EVA	macro_expression	- Evaluate any valid Macro-PLUS expression
Examples:	EVA (EFY S1..5)	- Calculates EFL for part of system (surfaces 1 through 5)
	EVA 2 * (NA)/(WL WL)	- Calculates MTF cutoff frequency

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AUT- Automatic Design

Variable Designation

– At least one parameter of the lens must be variable, as designated through the LDM; see the commands VAR, FRZ, DEF VAR, and commands for individual variables/couplings under “Defining Variables and Control Codes” on page 53.

Specific Constraints

Notes:

1. Only the General Constraints:
   Center and Edge Thickness (MXT, MNT, MNA, MNE, MAE)
   Glass Map Boundaries (GLA)
   are imposed by default; the Specific Constraints have no defaults and are not potentially active unless included by the user. Exceptions are noted with the constraint.
2. Effect of omitting qualifiers:

Qualifier Omitted	Default
[Zn]	Z1
[Sk]	SI
[Si..j]	S1..I-1
[Fk]	FL (Last field)
[Wm]	Reference wavelength
[Rn]	R1 (chief ray)
[Gj]	Referenced to own surface

3. Special Syntax for Specific Constraints and User-defined Constraints (UDC):
   Interpretation of >|=|<
   EFL [Zn] >|=|< efl_tar
   means that any of the following are valid:
   EFL [Zn] = efl_tar
   EFL [Zn] > lower_efl_tar
   EFL [Zn] > lower_efl_tar < upper_efl_tar
   EFL [Zn] < upper_efl_tar
   EFL [Zn] < upper_efl_tar > lower_efl_tar
   The "...._tar" means that the data to be supplied is the target value of the constraint. Interpret other Specific Constraints and UDCs similarly.
4. Since there is no mechanism for deleting or modifying constraints once they have been entered, it may be helpful to generate a sequence file, where editing can be done, to be used in supplying constraints to AUT.
5. Whether active or not, the current value of each user entered Specific Constraint or User-defined Constraint (UDC) is always displayed in a table with the data for each cycle. To include a constraint for display ONLY (can never be active), use the **DSP** command.
6. Occasionally it is desirable to put an equality (=) constraint temporarily into the error function (instead of being solved exactly) by supplying its weight in the error function, using the **WTC** command.

DSP	constraint_name|udc_variable [Yes|No]	- (DSP prefix) Display only the constraint or user-defined variable; it will not be entered as a constraint
WTC	wt_on_prior_constraint	- Weight on prior constraint; choose smallest value that achieves control

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Variables

All variables (those parameters for which there is an LDM control code) are directly constrainable by using the parameter mnemonic in the general form:

xxx Sk [Zn] >|=|< parameter_tar

For HCO, MCO, SCO, UCO, use:

xxx Sk [Zn] Cj >|=|< coeff_tar

For GRN use:

GRN Sk [Wm] [Zn] Cj >|=|< coeff_tar

Optical Definitions

	EFL	[Zn] >|=|< efl_tar	- Effective focal length of total system (Y-Z plane)
	EFX	[Si..j] [Wk] [Zn] >|=|< x_efl_tar	- EFL of surface group - X-Z plane
	EFY	[Si..j] [Wk] [Zn] >|=|< y_efl_tar	- EFL of surface group - Y-Z plane
	FPX	[Si..j] [Wk] [Zn] >|=|< x_efl_tar	- EFL of surface group - X-Z plane. Calculates the effective focal length as positive (+) for converging lenses, and negative (-) for diverging lenses, regardless of light direction.
	FPY	[Si..j] [Wk] [Zn] >|=|< y_efl_tar	- EFL of surface group - Y-Z plane. Calculates the effective focal length as positive (+) for converging lenses, and negative (-) for diverging lenses, regardless of light direction.
	RED	[Wk] [Zn] >|=|< reduction_ratio_tar	- Reduction ratio - Do not use with RED solve
	TT	[Zn] >|=|< tot_track_tar	- Total track - object to image (finite conjugate only)
	IMD	[Zn] >|=|< image_dist_tar	- Image distance plus defocus
or	**IMC**	[Zn] >|=|< image_clearance_tar	- Image surface clearance (edge or center) - cancels MXT, MNT, MNA, MNE, MAE on SI-1, all Zn
	ENP	[Fk] [Zn] >|=|< entr_pup_dist_tar	- Distance from S1 to entrance pupil. No Fk: use paraxial value
	EXP	[Fk] [Zn] >|=|< exit_pup_dist_tar	- Distance from SI-1 to exit pupil. No Fk: use paraxial value
	DIX	[Fk] [Zn] >|=|< x_distortion_fraction_tar	- Distortion fraction - X coordinate (Ex: 0.05 is 5%)
	DIY	[Fk] [Zn] >|=|< y_distortion_fraction_tar	- Distortion fraction - Y coordinate (Ex: 0.05 is 5%)
	XFO	[Fk] [Zn] >|=|< x_focal_shift_tar	- X-fan close skew ray focal shift (with defocus)
	YFO	[Fk] [Zn] >|=|< y_focal_shift_tar	- Y-fan close skew ray focal shift (with defocus)
	XCN	[Fk] [Zn] >|=|< x_image_centroid_tar	- Image centroid - X coordinate
	YCN	[Fk] [Zn] >|=|< y_image_centroid_tar	- Image centroid - Y coordinate
	YNI	Sk [Zn] >|=|< y_times_ni_tar	- Narcissus control
	AFN	Si..j [Zn] >|=|< ansi_fno_tar	- ANSI f/no of surface group

Manufacturing and Packaging

	CT	Sk [Zn] >|=|< center_thickness_tar	- CT (Cancels MXT,MNT,MNA,MNE,MAE on Sk for all Zn)
	ET	Sk [Zn] >|=|< edge_thickness_tar	- ET (Cancels MXT,MNT,MNA,MNE,MAE on Sk for all Zn)
	OAL	[Si..j] [Zn] >|=|< overall_length_tar	- Overall length from Si to Sj
	SD	Sk [Zn] >|=|< semi_diam_tar	- Maximum semi-diameter of Sk needed by reference rays (near stops/images, use ray controls instead)
	BLO	Sk [Zn] >|=|< blocking_ratio_tar	- Blocking ratio (semi-diameter/radius) of Sk; + targets only
	XSC	Sk Gj [Zn] >|=|< x_rel_to_glo_surf_tar	- Pole of Sk at X coordinate of Gj
	YSC	Sk Gj [Zn] >|=|< y_rel_to_glo_surf_tar	- Pole of Sk at Y coordinate of Gj
	ZSC	Sk Gj [Zn] >|=|< z_rel_to_glo_surf_tar	- Pole of Sk at Z coordinate of Gj

LSC	Sk Gj [Zn] >|=|< l_rel_to_glo_surf_tar	- Local Z axis of Sk relative to L direction cosine of Gj
MSC	Sk Gj [Zn] >|=|< m_rel_to_glo_surf_tar	- Local Z axis of Sk relative to M direction cosine of Gj
NSC	Sk Gj [Zn] >|=|< n_rel_to_glo_surf_tar	- Local Z axis of Sk relative to N direction cosine of Gj
SNS	Sk [Zn] >|=|< sens_tar	- Sensitivity to tilts and decentering

Paraxial Ray Trace Data

UMX	[Sk] [Wm] [Zn] >|=|< x_mar_angle_tar	- X-Z paraxial marginal ray exit angle
UMY	[Sk] [Wm] [Zn] >|=|< y_mar_angle_tar	- Y-Z paraxial marginal ray exit angle
HMX	[Sk] [Wm] [Zn] >|=|< x_mar_ht_tar	- X-Z paraxial marginal ray height
HMY	[Sk] [Wm] [Zn] >|=|< y_mar_ht_tar	- Y-Z paraxial marginal ray height
IMX	[Sk] [Wm] [Zn] >|=|< x_mar_incidence_tar	- X-Z paraxial marginal ray incidence angle (index*i)
IMY	[Sk] [Wm] [Zn] >|=|< y_mar_incidence_tar	- Y-Z paraxial marginal ray incidence angle (index*i)
UCX	[Sk] [Wm] [Zn] >|=|< x_chief_angle_tar	- X-Z paraxial chief ray exit angle
UCY	[Sk] [Wm] [Zn] >|=|< y_chief_angle_tar	- Y-Z paraxial chief ray exit angle
HCX	[Sk] [Wm] [Zn] >|=|< x_chief_ht_tar	- X-Z paraxial chief ray height
HCY	[Sk] [Wm] [Zn] >|=|< y_chief_ht_tar	- Y-Z paraxial chief ray height
ICX	[Sk] [Wm] [Zn] >|=|< x_chief_incidence_tar	- X-Z paraxial chief ray incidence angle (index*i)
ICY	[Sk] [Wm] [Zn] >|=|< y_chief_incidence_tar	- Y-Z paraxial chief ray incidence angle (index*i)

First and Third Order Aberrations

Note: If Sk is used, the contribution on that surface is constrained; if Si..j is used, the sum over those surfaces is constrained; if Sk|Si..j is omitted, the sum is over all surfaces.

Transverse:

AX	[Sk|Si..j] [Wj..m] [Zn] >|=|< axial_color_tar	- Axial color - Wj and Wm (def: W1 and Wlast)
LAT	[Sk|Si..j] [Wj..m] [Zn] >|=|< lateral_color_tar	- Lateral color - Wj and Wm (def: W1 and Wlast)
SA	[Sk|Si..j] [Wm] [Zn] >|=|< sph_aber_tar	- 3rd order spherical aberration
TCO	[Sk|Si..j] [Wm] [Zn] >|=|< tan_coma_tar	- 3rd order tangential coma
SAS	[Sk|Si..j] [Wm] [Zn] >|=|< sag_ast_tar	- 3rd order sagittal astigmatic blur
TAS	[Sk|Si..j] [Wm] [Zn] >|=|< tan_ast_tar	- 3rd order tangential astigmatic blur
PTB	[Sk|Si..j] [Wm] [Zn] >|=|< petz_blur_tar	- 3rd order Petzval blur
DST	[Sk|Si..j] [Wm] [Zn] >|=|< distortion_tar	- 3rd order distortion

Curvature:

PTZ	[Sk|Si..j] [Wm] [Zn] >|=|< petz_curv_tar	- Petzval surface curvature

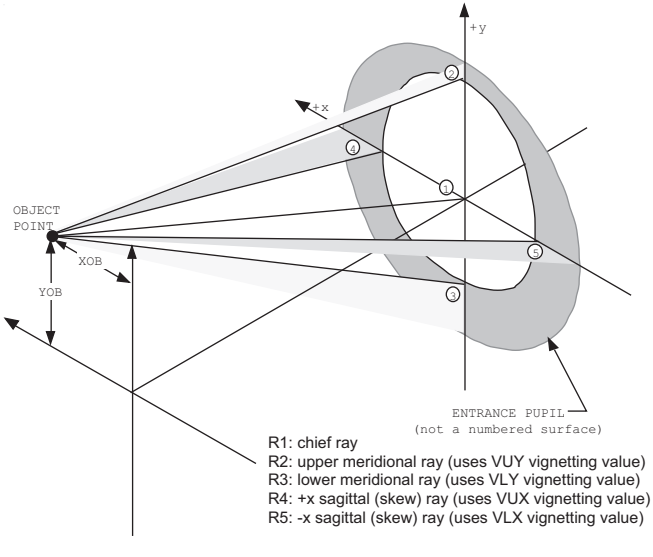
Real Ray Trace Data - Reference Rays and User-defined Constrainable Rays

Pre-defined rays at each field are (see figure on page 74 for description of the reference rays R1 to R5):

Rotationally symmetric systems on-axis:	R2
Rotationally symmetric systems off-axis:	R1,R2,R3 (with VUX,VLX also R4,R5)
Non-rotationally symmetric systems:	R1,R2,R3,R4,R5

If non-existent rays are referenced they will be included; these will be included also in any general thickness constraints.
To define special rays R6, R7, R8, R9 (up to 4 at any field angle and zoom position):

RAY	Ri Fk|Fi..j [Zk|Zi..j] x_pupil_fract y_pupil_fract	- Define ray Ri (must be R6,R7,R8, or R9) for specified fields/ zooms; x, y are pupil coordinates (fractions of radius)
X	[Ri] [Sk] [Wm] [Gj] [Fk] [Zn] >|=|< x_coord_tar	- X surface coordinate - ray Ri, Fk, Zn, for Wm
Y	[Ri] [Sk] [Wm] [Gj] [Fk] [Zn] >|=|< y_coord_tar	- Y surface coordinate - ray Ri, Fk, Zn, for Wm
Z	[Ri] [Sk] [Wm] [Gj] [Fk] [Zn] >|=|< z_coord_tar	- Z surface coordinate - ray Ri, Fk, Zn, for Wm
L	[Ri] [Sk] [Wm] [Gj] [Fk] [Zn] >|=|< l_opt_dir_cos_tar	- L optical direction cosine following Sk - ray Ri,Fk,Zn, for Wm
M	[Ri] [Sk] [Wm] [Gj] [Fk] [Zn] >|=|< m_opt_dir_cos_tar	- M optical direction cosine following Sk - ray Ri,Fk,Zn, for Wm
N	[Ri] [Sk] [Wm] [Gj] [Fk] [Zn] >|=|< n_opt_dir_cos_tar	- N optical direction cosine following Sk - ray Ri,Fk,Zn, for Wm
AOI	[Ri] [Sk] [Wm] [Gj] [Fk] [Zn] >|=|< angle_of_inc_tar	- Angle of incidence at surface Sk - ray Ri, Fk, Zn, for Wm
AOR	[Ri] [Sk] [Wm] [Gj] [Fk] [Zn] >|=|< angle_of_ref_tar	- Angle of refraction following surface Sk - ray Ri,Fk,Zn, for Wm
SRL	[Ri] [Sk] [Wm] [Gj] [Fk] [Zn] >|=|< l_sur_nor_tar	- L direction cosine of surface normal - ray Ri,Fk,Zn, for Wm
SRM	[Ri] [Sk] [Wm] [Gj] [Fk] [Zn] >|=|< m_sur_nor_tar	- M direction cosine of surface normal - ray Ri,Fk,Zn, for Wm
SRN	[Ri] [Sk] [Wm] [Gj] [Fk] [Zn] >|=|< n_sur_nor_tar	- N direction cosine of surface normal - ray Ri,Fk,Zn, for Wm
OP	[Ri] [Si..j] [Wm] [Fk] [Zn] >|=|< optical_path_tar	- Optical path between Si and Sj - ray Ri, Fk, Zn, for Wm
OPD	[Ri] [Wm] [Fk] [Zn] >|=|< opd_tar	- Optical path difference - ray Ri, Fk, Zn, for Wm



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Holographic Optical Elements (HOEs)

DEP	[Ri] Sk [Fm] [Zn] >|=|< diff_eff_param_tar	- Diffraction efficiency parameter (Value =0 at maximum efficiency, =1 at 1st zero)
HFR	[Ri] Sk [Fm] [Zn] >|=|< tot_grating_freq_tar_lines_per_mm	- Total spatial frequency (2 points plus aspheric phase terms)
HFA	[Ri] Sk [Fm] [Zn] >|=|< phase_terms_freq_tar_lines_per_mm	- Spatial frequency for aspheric phase terms only

User-defined

(See “Adding a User-Defined Constraint from the Command Line” on page 17-28 of the *CODE V Reference Manual* for more detail)

@xxx == macro_expression

where

@xxx	user-defined constraint name. It must begin with the @ character; any references (e.g., in other expressions or constraint entry) must include the @ character. xxx can be any 1 to 31 character alphanumeric code.
==	functional assignment operator. Spaces are not permitted between ==.
macro_expression	see Macro-PLUS description. Follows rules for user-defined functions.

General Constraints

Center and Edge Thicknesses

Note: These apply to all surfaces with variable center thickness as a class. The worst case (along axis and reference rays) in all zoom positions is controlled when violated; only one of these is applied to a given thickness, depending upon shape and material. Defaults are supplied by the program which are reasonable except in systems with a wide range of diameters. A CT or ET constraint (or IMD, IMC) on a given surface removes the action of MXT, MNT, MNA, MNE, and MAE on that surface for all zoom positions.

MXT	max_ele_center_thi	- Largest CT on elements	(Def: 1/2 max diam)
MNT	min_ele_center_thi	- Smallest CT on elements	(Def: 1/10 min diam)
MNE	min_ele_edge_thi	- Smallest ET on elements	(Def: = MNT)
MNA	min_air_center_thi	- Smallest CT, air spaces	(Def: 0.005,0.01,0.1)
MAE	min_air_edge_thi	- Smallest ET, air spaces	(Def: 0.0001,0.00025,0.0025)

Angle of Incidence Controls

MXA	[Sk|Si..j] Yes|No|max_angle_inc_degr	- Maximum angle of incidence of reference rays (default for Yes is 60°, default surface range is S1..I-1)	(Def: No)

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Glass Map Boundaries

Note: This applies to all variable, fictitious glasses as a class. Glasses are constrained only when violations occur; they are otherwise free to move within the area of the map.

GLA [Sk|Si..j] map_corner1 map_corner2 map_corner3....5
- Glass map convex polygon defined in N_d, N_F - N_C space by straight lines joining 3 to 5 corner points
(Def: GLA SA NFK5 NSK16 NLAF2 SF4)

Optimization Controls

Global Synthesis

GS	[Yes|No|discrimination_factor]	- Enable Global Synthesis. Discrimination factor distinguishes between distinct and equivalent solutions (default: 1.0)	(Def: No)

Run-time Controls

INT	Yes|No	- Interactive - interrupt at each cycle	(Def: No)
MXC	num_of_cycles_max	- Maximum number of permitted cycles	(Def: 25)
MNC	num_of_cycles_min	- Minimum number of required cycles	(Def: 2)
TIM	max_cpu_minutes	- CPU time limit (minutes)	(Def: No time limit)
TAR	lower_lim_err_fun [upper_lim_err_fun]	- Exit when err_fun below lower limit. Global Synthesis will not save lenses if err_fun above upper limit	(Def: 0.0 1.0E15)
IMP	min_impr_factor	- Continue unless improvement percentage remains below this level for several cycles. For example, the default value of 0.05 indicates a 5% decrease in the error function value.	(Def: 0.05)

Output - Listing/Drawing/Save Lens

VLI [Ik|Ii..j] [Yes|No|cycle] - List variables and derivative increments
- Yes - list variables only at cycle 0
- No - do not list either
- cycle - list variables and derivative increments at each multiple of cycle

(Def: Batch: Yes; Interactive: No)

	RSP		- Immediate listing - reference ray table	
or	**RSP**	Yes|No	- Reference ray table when calculation starts	(Def: Yes)
	SUR	[Sk|Si..j] Yes|No	- List only designated surface(s) at each cycle; cumulative	(Def: SO..I Yes)
	CHG	[Sk|Si..j] Yes|No	- List variable changes at each cycle for designated surface(s); cumulative	(Def: SO..I No)
	DRA	[Si..j] [XZ] Yes|No	- Draw YZ section of lens for Si..j at end of each cycle, for first active zoom position XZ - draw XZ section instead	(Def: No)

Convergence

ROU	Yes|No	- Rough-in to satisfy constraints first	(Def: No)
DIF	Yes|No	- Use wavefront differentials (Def: For OPD optimization: DIF N; for MTF optimization: DIF Y)	
CNV	Yes|No|convergence_factor	- Use convergence factor	(Def: No)
EXT	Yes|No	- Use extended optimization	(Def: No)

Error Function Construction

Aberrations

Note: The default error function is composed of X and Y ray aberrations in the nominal focus position for a grid pattern of rays, traced in all wavelengths with non-zero weights, referenced to the chief ray of the reference wavelength. Alter these assumptions with:

ASB	Yes|No	- Uses ray grid traced in AUT for AS_BUILT_VAR	(Def: Yes)
DMD	Yes|No....z-Use D	- d for color instead of tracing	(Def: No)
CEN	Yes|No....z	- Use centroid instead of chief ray	(Def: No)
WFR	Yes|No	- Minimize wavefront variance instead of ray aberrations	(Def: No)
WVB	wavefront_balance_ratio	- Balance between variance derived only from OPD (0) and derived from full ray integration (1)	(Def: 1.0)
ERR	CDV|USR|BTH|CON	- Select standard or user-defined error function, both, or constraints only	(Def: CDV)

Weights

WTA	aperture_weight....z	- Weight on aperture center	(Def: 0.5; with OPD, 0.0)
WTF	field-zoom_weight....f,z	- Weight on X and Y image components	(Def: System weights)
WTX	x_field-zoom_weight....f,z	- Weight on X image components only	(Def: see WTF)
WTY	y_field-zoom_weight....f,z	- Weight on Y image components only	(Def: see WTF
WTW	local_wl_weight....w,z	- Local wavelength weights	(Def: System weights)

Through-Focus Optimization

TFO	No|defocus_amount....t,z	- Turn through-focus optimization on/off and set defocus for up to seven focus positions (affects values of WTF, WTX, WTY)	(Def: TFO T1 0.0)
WTT	defocus_weight....t,z	- Weight on through-focus positions	(Def: 1.0)
WTF	[Tk|Ti..j] field-zoom-focus_weight....f,z	- Weight on X and Y image components	(Def: System weights)
WTX	[Tk|Ti..j] x_field-zoom-focus_weight....f,z	- Weight on X image components only	(Def: see WTF)
WTY	[Tk|Ti..j] y_field-zoom-focus_weight....f,z	- Weight on Y image components only	(Def: see WTF)

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Ray Grid

	CPA	Yes|No	- Chromatic pupil aiming Yes - iterate in all wavelengths No - iterate only in reference wavelength, use same aim points for all other wavelengths	(Def: No)
	FAP	Sk	- Fill aperture control	(Def: Stop surface)
	DEL	ray_interval_pup_fract....z	- Pupil grid increment	(Def: 0.385 / 12 rays, half pupil; 0.22 for systems with non-spherical surfaces / 34 rays, half pupil)
	OBS	obscured_pup_fract....z	- Fraction of pupil approximately obscured	(Def: 0.0)
	SAP	Yes|No....z	- Square aperture ray pattern	(Def: No)
or	**MER**	Yes|No....z	- Meridional ray fan optimization only	(Def: No)
or	**SAG**	Yes|No....z	- Sagittal ray fan optimization only	(Def: No)
	NRR	num_rings....z	- Number of rings in the Gaussian quadrature grid (up to 40 rings)	(Def: 3)
	NSP	num_spokes....z	- Number of spokes in the Gaussian quadrature grid in the half-pupil.	(Def: 3)

MTF Optimization (replaces standard error function)

FRE	[Fk|Fi..j] [Zk|Zi..j] frequency1 [frequency2 [frequency3 [frequency4 [frequency5 [frequency6]]]]]	- Frequency for MTFs in lp/mm	(Def: Use standard CODE V error function)
AZI	[Fk|Fi..j] [Zk|Zi..j] azimuth1|RAD|TAN [azimuth2|RAD|TAN [azimuth3|RAD|TAN [azimuth4|RAD|TAN [azimuth5|RAD|TAN [azimuth6|RAD|TAN]]]]]	- Azimuths for MTFs in degrees (0=RAD, 90=TAN)	(Def: TAN)
TGM	[Fk|Fi..j] [Zk|Zi..j] [Tk|Ti..j] MTF_target1|No [MTF_target2|No [MTF_target3|No [MTF_target4|No [MTF_target5|No [MTF_target6|No]]]]]	- MTF targets	(Def: Diffraction limit)
WTM	[Fk|Fi..j] [Zk|Zi..j] [Tk|Ti..j] MTF_weight1|No [MTF_weight2|No [MTF_weight3|No [MTF_weight4|No [MTF_weight5|No [MTF_weight6|No]]]]]	- Weight on MTFs	(Def: 1.0)
WTP	weight_on_phase	- Weight on phase vs. MTF from no weight (0) to heavy weight (large number)	(Def: 0.0)
NRD	num_rays_across_diameter	- Number of rays across pupil grid	(Def: 15)
DEL	ray_interval_pup_fract....z	- Pupil grid interval for MTF integration	(Def: 0.15)

CEF Optimization

MPR	mode_radius....z,w	- Specifies the mode radius (in lens units) for the CEF error function and turns on CEF optimization.	(Def: Use standard CODE V error function)

CED [BEA|BPR] - Specifies CEF calculation method. BEA qualifier selects method that combines the geometrical pupil function with a Gaussian beam trace. BPR qualifier selects method that accounts for beam spreading by diffraction and clipping using the BPR option. Default is geometric pupil function method. (Def: CED)

The following commands allow you to define additional parameters for the CED BPR and CED BEA calculations:

DBP [NFP|FFP|SSP] Si..j [Yes|No|sphere_radius]....z - Specifies diffraction-based propagation between surfaces i and j. Optional NFP (near field propagator), FFP (far field propagator), and SSP (sphere to sphere propagator) specify the type of propagator to be used for diffraction-based propagation. (Def: Si-1..i Yes)

TGR [Sk|Si..j] num_grid_points....z - Number of grid points across the data grid. num_grid_points must be a power of 2. If no surface qualifier is specified, the TGR applies to all surfaces. (Def: S0..i 128)

GRI [Sk|Si..j] grid_spacing....z - Defines the grid increment. If no surface qualifier is specified, the GRI applies to all surfaces. (Def: None)

WRX x_beam_half_width....z - Specifies initial beam-width radius (at the object plane) at the $1/e^2$ intensity point in the X meridian. (Def: PUX, PUY, and PUI for Gaussian apodization).

WRY y_beam_half_width....z - Specifies initial beam-width radius (at the object plane) at the $1/e^2$ intensity point in the Y meridian. (Def: PUX, PUY, and PUI for Gaussian apodization).

RCX x_wave_radius....z - For CED BPR, specifies radius of curvature of input wavefront (at object plane) in X meridian. Value of 0 is interpreted as infinity. Not available for CED BEA. (Def: Infinity)

RCY y_wave_radius....z - For CED BPR, specifies radius of curvature of input wavefront (at object plane) in Y meridian. Value of 0 is interpreted as infinity. Not available for CED BEA. (Def: Infinity)

AZI starting_orientation_degr....z - For CED BPR, specifies orientation (in degrees) of input beam definition about the optical (z) axis. Allows rotation of beam definition from x,y orientation. Not available for CED BEA. (Def: 0.0)

Note: The AZI command can also be used with MTF Optimization to specify azimuths in degrees that correspond to the frequencies.

User-defined Error Function

	ERR	CDV|USR|BTH|CON	- Turns on user-defined error function(Def: CDV)	
	ENT	[Ei] VIG x_ent_pup_fract y_ent_pup_fract	- Pupil coordinates (fractions of vignetted pupil radius)	
or	**ENT**	[Ei] Sk x_target y_target	- Ray coordinates on selected surface	
or	**ENT**	[Ei] x_ent_pup_fract y_ent_pup_fract	- Pupil coordinates (fractions of pupil radius)	
	ENT	[Ek|Ei..j] LIS	- List defined pupil points	
	ABR	Fk|Fi..j Rk|Ri..j|Ek|Ei..j [Wk|Wi..j] [Zk|Zi..j] [Sk|Si..j] [Gk] [Hk] X|Y|Z|L|M|N|SRL|SRM|SRN|AOI|AOR|LEN|OPL|DX|DY|OPD|DMD [aber_weight [aber_target]]	- Define one or more aberration database items	
or	**ABR**	@XXX [(argument1 {,argument2})] [aber_weight [aber_target]]	- Defines aberration database item using user-defined constraints or user-defined Macro_PLUS functions	
	ABL	[Ak|Ai..j] [Fk|Fi..j] [Wk|Wi..j] [Zk|Zi..j] [Rk|Ri..j|Ek|Ei..j] [Sk|Si..j] [Gk|Gi..j] [Hk|Hi..j] [X|Y|Z|L|M|N|SRL|SRM|SRN|AOI|AOR|LEN|OPL|DX|DY|OPD|DMD|UDF|ALL] [No|cycle_interval]	- List selected aberration items at AUTO cycle intervals	(Def: No)
	APL	Fk|Fi..j|Rk|Ri..j|Ek|Ei..j [Ak|Ai..j] [Zk|Zi..j] [Wk|Wi..j] [Sk|Si..j] [Gk|Gi..j] [Hk|Hi..j] [X|Y|Z|L|M|N|SRL|SRM|SRN|AOI|AOR|LEN|OPL|DX|DY|OPD|DMD]	- Plots the pupil or field coordinates	
	ABC	[Ak|Ai..j] [Fk|Fi..j] [Rk|Ri..j|Ek|Ei..j] [Wk|Wi..j] [Zk|Zi..j] [Sk|Si..j] [Gk|Gi..j] [Hk|Hi..j] X|Y|Z|L|M|N|SRL|SRM|SRN|AOI|AOR|LEN|OPL|DX|DY|OPD|DMD|UDF|ALL new_aber_weight|No [new_aber_target]	- Change weights or targets	
	AWF	field_zoom_weight....f,z	- Weights on field/zoom (cascaded with ABR weights)	(Def: 1.0)
	AWW	wavelength_zoom_weight....w,z	- Weights on wavelengths/zoom (cascaded with ABR weights)	(Def: 1.0)

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Diagnostic Analyses

ANA - First/Third Order Analysis

(Def: Includes THI and RAY)

THI	[F|P|N....w,z]	- Third order analysis F - all surfaces P - focal plane N - no list	(Def: F - reference wl; P - other wls)
RAY	[Yes|No....w,z]	- Trace pattern	(Def: Yes)
DEL	ray_interval_pupil_fraction....z	- Real ray interval for pattern rays	(Def: 0.2000001)
HIG	Yes|No	- Do higher order analysis of pattern rays	(Def: No)
SSP	[P|F|N....f,z]	- Override RAY command - single surface pattern trace Lists ray coordinates relative to GLO coordinates given in the LDM P - surface-by-surface output for chief rays and extreme rays F - all rays listed surface-by-surface N - no rays listed More than one SSP command can be given	(Def: not done)

BEA - Gaussian Beam Trace

Note: The system must have a finite object thickness ($<10^8$).

Input Beam Controls

At the object surface:
One of WRX or WRY is REQUIRED. If one is omitted it is set equal to the other.

WRX	x_beam_half_width....z	- REQUIRED. Beam half-width in X at the object surface	
WRY	y_beam_half_width....z	- REQUIRED. Beam half-width in Y at the object surface	
RCX	x_wave_radius....z	- Wave front radius of curvature in X-Z	(Def: Infinity)
RCY	y_wave_radius....z	- Wave front radius of curvature in Y-Z	(Def: Infinity)
AZI	starting_orientation_degr....z	- Rotate beam defining coordinates about chief ray	(Def: 0.0)

CAT

Color Display Controls

DIS	[LOG|UNI] [Yes|No] [threshold]	- Generates a Gaussian beam plot, for points above a defined threshold. Intensity plot is generated, unless one of the following is specified: LOG - Log intensity plot UNI - Uniform beam plot	(Def: No plot)
RGB	[r_value g_value b_value]	- Specifies color scale used for Gaussian beam. Result is monochromatic color ramp from white to the specified red, green, and blue values.	(Def: RGB 1 0 0)
XZ	Yes|No	- Draws Gaussian beam plot in the X-Z plane.	(Def: No)
SSI	lens_units_per_scale_bar....z	- Sets lens size per scale bar length in X and Y.	(Def: Auto scaling)
SSX	lens_units_per_scale_bar....z	- Override SSI in X direction for anamorphic scaling.	(Def: Auto scaling)
SSY	lens_units_per_scale_bar....z	- Override SSI in Y direction for anamorphic scaling.	(Def: Auto scaling)
OFS	[Sk] OVE [x_offset y_offset [rotation_angle_degr]]	- Overlays zoom positions at surface Sk. The integrated picture is scaled to size and centered.	(Def: Overlays at first surface defined by SUR)

Output Controls

SUR	[Sk|Si..j] Yes|No	- Include these surfaces in text and plotted output.	(Def: S1..i)

CAT - Catseye Plot

(Draw clear apertures and obscurations as projected on entrance pupil plane)

SUR	Sk	- REQUIRED. Designate drawn surfaces. (up to 10 commands allowed)	
TIT	'temporary_title'(40)	- Temporary title	(Def: 1st 40 char. lens_system_title)
SF	fraction_of_full_scale....z	- Factor relative to full scale	(Def: full scale or scaled down to fit)
or **EPD**	epd_in_scale_bars....z	- Scale EPD to multiple/fraction of scale bar	(Def: full scale or scaled down to fit)

FIE - Field Curves

DIO	Yes|No	- Afocal systems: Use diopters instead of focus shift	(Def: No)
PLO	Yes|No....z	- Plot astigmatism and distortion	(Def: Yes)
AST	[CHR] max_plotted_astigmatism....z	- Maximum focal shift CHR - compute for all wavelengths	(Def: scaled to fit)
DST	[CHR] max_plotted_distortion_%....z	- Maximum percent distortion CHR - compute for all wavelengths	(Def: scaled to fit)
ZFO	Yes|No	- Shift field curves to zero focus. Use with Plot setting(PLO). Sets origin of field curves at the axial focus instead of the current image plane position.	(Def: No)
TIT	'temporary_title'(40)....z	- Temporary title	(Def: 1st 40 ch. lens_system_title)
LSA	[Yes|No|max_plotted_long_spherical_aber....z]	- Include LSA output; max_plotted_... for PLO	(Def: No)
LIN	Yes|No....z	- List scanning linearity vs. $f * \theta$	(Def: No)
LIS	Yes|No....z	- Set listings on/off	(Def: Yes)
FFD	Yes|No	- Change output to full field display	(Def: No)

FIO - Paraxial Ray Trace

FIO [Sk|Si..j] [Zk] - Marginal, chief rays listed for surface(s), zoom position

FIR - First Order System Parameters

FIR - Table of first order parameters, all zoom positions

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FMA - Field Map

Object space grid definition:

MXE	max_elevation_degr	- Most + elevation	(Def: from +last YAN)
MNE	min_elevation_degr	- Most - elevation	(Def: from -last YAN)
NEL	num_elevations	- Number of elevations from MNE to MXE	(Def: 21)
AZI	azimuth_degr....7	- Azimuth angle(s)	(Def: 0.0)
OFS	offset_elevation_degr	- Elevation angle of lens optical axis	(Def: 0.0)
RAC	Yes|No	- Include surface number where ray is clipped or failed	(Def: No)
TIT	'temporary_title'(20+20)	- Temporary title	(Def: 1st 40 char. lens_system_title)

Non-Uniform Reference Grid:

Allows input of table 21 elevations high by 7 azimuths wide, using both ELC and AZC to describe each point; input is normally in decimal degrees; if DMS is included, use degrees, minutes, seconds as dd.mmssss where ssss is implied to be ss.ss

XLE	'replaced_azimuth_label'(30)	- Change "A Z I M U T H (DEGREES)"
YLE	'replaced_elevation_label'(15+15)	- Change "ELEVATION (DEGREES)"
ELC	[DMS] elevation_coordinates_degr....7	- (up to 21 commands)
AZC	[DMS] azimuth_coordinates_degr....7	- (up to 21 commands)

Field Display:

SLC [BDE|AST|DST|DSC|RWE|RSD|WPO|CTD|CCD] Yes|No

- Displays the value of the selected performance metric as a function of field in a 1D line plot. The plot displays a cross-sectional slice along a user-defined plane. Default metric is DST. (Def: No)
  - BDE - System diffraction efficiency
  - AST - astigmatism
  - DST - distortion
  - DSC - calibrated distortion
  - RWE - RMS wavefront error
  - RSD - RMS spot diameter
  - WPO - wavefront polynomial coefficient
  - CTD - PSF centroid-based distortion
  - CCD - calibrated PSF centroid-based distortion

or **SLC** [MTF|MTQ|GMT|GMQ] frequency [azimuth_degr]

- Displays value of selected MTF performance metric as a function of field in a 1D line plot. (Def: SLC No)
  - MTF - Diffraction sine wave MTF
  - MTQ - Diffraction square wave MTF
  - GMT - Geometrical sine wave MTF
  - GMQ - Geometrical square wave MTF
  - frequency - spatial frequency
  - azimuth_degr - azimuth (target orientation), in degrees. Defaults to 90 and 0 degrees.

FFD [BDE|AST|DST|DSC|RWE|RSD|WPO|CTD|CCD] Yes|No
- Displays value of selected performance metric as a function of field in a 2D plot. Default metric is DST. (Def: No)
  - BDE - System diffraction efficiency
  - AST - astigmatism
  - DST - distortion
  - DSC - calibrated distortion
  - RWE - RMS wavefront error
  - RSD - RMS spot diameter
  - WPO - wavefront polynomial coefficient
  - CTD - PSF centroid-based distortion
  - CCD - calibrated PSF centroid-based distortion

or **FFD** [MTF|MTQ|GMT|GMQ] frequency [azimuth_degr]
- Displays value of selected MTF performance metric as a function of field in a 2D plot. (Def: FFD No)
  - MTF - Diffraction sine wave MTF
  - MTQ - Diffraction square wave MTF
  - GMT - Geometrical sine wave MTF
  - GMQ - Geometrical square wave MTF
  - frequency - spatial frequency
  - azimuth_degr - azimuth (target orientation), in degrees. Defaults to 90 and 0 degrees.

TGR num_fft_grid_pow_of_2 - Transform grid; range: 16 or more (needed for WPO, CTD, CCD) (Def: 64 for WPO; 128 for CTD, CCD)

NRD num_rays_across_diameter - Number of rays across pupil diameter (needed for RWE, RSD, WPO, CTD, CCD) (Def: 20 for RWE, RSD; 58 for WPO; 60 for MTF, MTQ, GMT, and GMQ; 64 for CTD, CCD)

WCN [ONL] coef_number - Zernike coefficient number (for WPO only) (Def: 2)
- ONL - only plot specified term of paired terms

WPT [ZRN|ZFR] num_polynomial_terms - Zernike polynomial type (for WPO only) (Def: ZFR 21)
- ZRN - standard
- ZFR - FRINGE

PCS ENP|EXP|EXS - Pupil coordinate system (for WPO only) (Def: ENP)
- ENP - entrance pupil plane (normal to z-axis)
- EXP - exit pupil plane (normal to chief ray)
- EXS - exit pupil sphere

SSI distance_per_scale_bar....z - Scale size per scale bar (Def: Automatic scaling)

LIS Yes|No - Generates listing of full field data, corresponding to the type of performance data selected (distortion, astigmatism, etc.). (Def: Yes)

WBF Bk - Writes FMA output to the specified buffer (except B0). You must first enter an FFD or SLC command to use this feature. (Def: Not done.)

FOO

Field Description:

FCO	[CIR] [OBJ|IMG|RIH|ANG|AZE] ['field_coordinate_description'(27)]	- Field coordinate type and description OBJ - object height IMG - image height RIH - real image height ANG - field angle in degrees AZE - azimuth/elevation angle in degrees CIR - circular field display format	(Def: Object specification type in lens)
XMI	minimum_x_field....z	- Lowest X field plotted	(Def: see YMA)
XMA	maximum_x_field....z	- Highest X field plotted	(Def: see YMA)
YMI	minimum_y_field....z	- Lowest Y field plotted	(Def: see YMA)
YMA	maximum_y_field....z	- Highest Y field plotted (Def: For symmetric lenses, 0.7* (max absolute Y field value); for asymmetric lenses, field limit in lens)	
NFX	num_points_x....z	- Number of plotted points across X	(Def: 11)
NFY	num_points_y....z	- Number of plotted points across Y	(Def: 11)
ASC	Yes|No....z	- Adjust plot dimensions anamorphically to fit specified (XMI, XMA, YMI, YMA	Def: No)

FOO - Footprint Plot

Computation Controls

SUR	Sk|Si..j	- Plot footprints on designated surface(s)	(Def: SI)
ORI	Sk|Si..j [x_origin [y_origin]]	- Specify origin of plot on designated surfaces	(Def: 0 0)
BOU	Yes|No	- Beam boundary Yes - plot only the boundary of each beam No - plot full grid of rays for each beam; helpful for obscured systems	(Def: No, for obscured systems and/or those with ORed apertures; Yes, for boundary mode)
NRD	num_rays_across_diameter....z	- For BOU No; determines grid detail	(Def: 11)
SSI	lens_units_per_scale_bar	- Set scale size	(Def: 25 for mm, cm; 1 for inches)
or **SF**	fraction_of_full_scale	- Scale of drawing in X and Y when printed or plotted	(Def: 1.0)
SFX	x_fraction_of_full_scale	- Separate X scale factor	(Def: SF)
SFY	y_fraction_of_full_scale	- Separate Y scale factor	(Def: SF)

Computation Controls - Clearance

CLE	Yes|No|gap_size	- Include grid of rays and clearance check of all surfaces gap_size - threshold for display; def: 0	(Def: Yes, for decentered systems)
OBS	Yes|No	- Exclude obscured rays	(Def: No)
SKI	Yes|No	- Skip dummy surface clearance	(Def: No)
FUL	Yes|No	- List all minimum clearances, plot surfaces in conflict	(Def: No)

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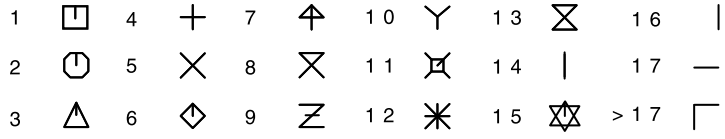
Plot Controls

LST	[Zk] Fj [line_style [color]]	- BOU Yes only. Draw single field in designated linestyle and color; range: 1 to 11; >11 is solid	(Def: STL styles; CLS FLD colors)
LEG	[[Zk] Fj 'linestyle_legend_label'(16)]	- BOU Yes only. Add legend for linestyle	(Def: no legend)
DOT	No|num_of_symbol	- For BOU No only. Plot points as symbols; range of symbols: 1 to 17; No - use the default	(Def: DTL symbols)



DSI	dot_size_fraction_of_scale_bar	- Change symbol size	(Def: DTS size)

Graphics Controls

LAB	Yes|No	- Displays the plot with border, scale factor, date for that zoom, surface number, and surface name or text label.	(Def: Yes)
DAP	Yes|No|Color [line_style]	- Draw limiting aperture. Default for line style is STL styles	(Def: No)
TIT	'temporary_title'(40)	- Enter up to 40 characters to display under the plot, left-aligned.	(Def: Uses first 40 characters of system title)
FLD	Yes|No|color....f	- Field: Designates field position where rays/boundaries will be drawn. - Color: Designates color of drawn rays at each field position.	(Def: Colors set by CLS FLD)
SNB	Yes|No	- Displays the surface number (e.g., Surface 1).	(Def: Yes)
SLB	Yes|No	- Displays the surface name (e.g., MySurface1)	(Def: Yes)
LLA	Yes|No 'local_plot_label'(28)	- Text of up to 28 characters to display in lower left corner inside plot.	(Def: No)
RET	Yes|No	- Returns to original origin when plot is finished; allows over-laying by later plots.	(Def: No

Special Controls

LIS	Yes|No....z	- List ray coordinates	(Def: No)

Controls on Search for Boundary

AZI	min_search_degr max_search_degr incr_search_degr	- BOU Yes only. Alter search angles for every beam (Def: -90. 90. 3. for x-symmetric systems; -90. 270. 3. for no symmetry systems)	
RAR	search_resolution_fraction....z	- BOU Yes only. Alter radial resolution in pupil fraction	(Def: 0.001)

Special Wedge Aperture for Multi-module Display

SAP	Si Sj wedge_aperture_distance	- Aperture on Si, defined by azimuth wedge at given distance from Sj	(Def: N/A)
WED	wedge_aperture_degr....z	- Azimuth angle of wedge aperture - required with SAP	

FOV - Biocular FOV Plot

Note: Object and stop surface must be changed before entering FOV (see “FOV - Biocular Field of View Plot” on page 18-113 of the *CODE V Reference Manual* for details).

Scaling

SSI	degrees_per_scale_bar	- Scale size X and Y	(Def: 1)
SSX	degrees_per_scale_bar	- Override SSI in X	(Def: SSI)
SSY	degrees_per_scale_bar	- Override SSI in Y	(Def: SSI)

Plotting Controls

LAB	Yes|No	- Label plot	(Def: Yes)
TIT	'temporary_title'(40)	- Temporary title	(Def: 1st 40 char. lens_system_title)
RET	Yes|No	- Return to original origin to overlay next plot	(Def: No)
FLD	Yes|No|color....f	- Draw boundaries at designated fields in designated colors	(Def: CLS FLD colors)
LLA	'local_plot_label'(28)	- Replace labeling	(Def: AZIMUTH/ELEVATION)
LST	[Zk] Fj [line_style [color]]	- Draw single field in designated linestyle and color; range: 1 to 11; >11 is solid	(Def: STL styles, CLS FLD colors)
LEG	[[Zk] Fj 'linestyle_legend_label'(16)]	- Add legend for linestyles	(Def: no legend)

Special Controls

LIS	Yes|No....z	- List ray coordinates	(Def: No)

Controls on Search for Boundary

AZI	min_search_degr max_search_degr incr_search_degr	- Alter search angles for every beam Def: -90. 90. 3. for x-symmetric systems; -90. 270. 3. for no symmetry systems)	
RAR	search_resolution_fraction....z	- Alter radial resolution in pupil fraction	(Def: 0.001)

Special Wedge Aperture for Multi-module Display

SAP	Si Sj wedge_aperture_distance	- Aperture on Si, defined by azimuth wedge at given distance from Sj	(Def: N/A)
WED	wedge_aperture_degr....z	- Azimuth angle of wedge aperture - required with SAP	

PMA - Pupil Map

Select Display (Def: Wave aberrations):

PIN [POL] Yes|No|norm_value....z - Display pupil intensity instead of wave aberrations (Def: No)
POL - polarization effects only
norm_value - maximum scale for full intensity; def: 100, range: 1 - 9999

or **RAC** Yes|No....z - Ray failure map; shows surface where ray failed (Def: No)

or **HFR** [ASP] Yes|No....z - Hoe spatial frequency map (Def: No)
ASP - from aspheric phase terms only

or **PPH** [YP1] [XP1] [YP2] [XP2] - Polarization phase shifts introduced by coatings, metallic reflectors, retarders. Exit pupil map through linear analyzer. (modulo ± half wave)
For light defined by PTP, POR, PRO:
YP1 - default; analyzer parallel to Y axis
XP1 - analyzer parallel to X axis
For light orthogonal to PTP, POR, PRO:
YP2 - analyzer parallel to Y axis
XP2 - analyzer parallel to X axis

Computation Controls:

TGR num_fft_grid_pow_of_two - Transform grid; range: 16 or more (power of 2) (Def: 128)

NRD num_rays_across_diameter....z - Determine grid from pupil diameter (Def: TGR/2 at short wl)

or **GRI** image_grid_spacing....z - Focal plane grid (Def: Airy disc diameter/4.88, short wl)

XSC scale_x_psf_by_factor....z - Scale X dimension of image - for anamorphic systems with highly unequal magnifications (Def: 1.0)

ADW x_tilt_waves [y_tilt_waves [focus_waves [piston_waves]]]
- Add tilt, focus, and piston, in waves at pupil edge (Def: not done)

or **ADW** TIL|FOC [x_tilt_waves [y_tilt_waves [focus_waves [piston_waves]]]]
- Add tilt, focus, and piston, in waves at pupil edge (Def: not done)
TIL - find best fit tilt first
FOC - find best focus and tilt first

Output Controls:

LIS Yes|No....z - Include listed output (No avoids listing with plots) (Def: Yes)

COM Yes|No....z - Compact listing; omits blank lines (Def: No)

WBF Bk - Writes PMA output to the specified buffer (except B0) (Def: No)

WIN int_filename - Write results to file int_filename.INT
Form is Zernike coefficients if ZRN or ZFR was used, grid otherwise.

Menu

Search

Plotting Controls:

CON	[SUP] Yes|No....z	- Contour map plot (aberration, intensity, or phase) SUP suppresses numbering	(Def: No)
LEV	[contour_level....30]	- Select contour levels to be plotted	(Def: LEV NUM 10)
or **LEV INC**	contour_increment	- Uniform levels, specified by increment	(Def: LEV NUM 10)
or **LEV NUM**	num_contour_levels	- Uniform levels, specified by total number	(Def: 10)
PLO	Yes|No....z	- Oblique projection plot (aberration, intensity, or phase)	(Def: Yes)
SSI	quantity_per_scale_bar....z	- Vertical scale size	(Def: largest error = 1 scale bar)
ROT	Yes|No....z	- Rotate oblique projection plot by 90°	(Def: No)
TIT	'temporary_title'(20+20)....z	- Temporary title	(Def: 1st 40 ch. lens_system_title)

Color Display:

DIS	[INT] Yes|No....z	- Color contour map display (aberration, intensity, or phase) INT displays as interferogram fringes	(Def: No)
RAN SCA	num_steps [min_value max_value]	- Set color scale range	(Def: 50)
RAN COL	SPE|RGB [r_value g_value b_value]	- Select type of color scale SPE - spectral color rainbow RGB - monochrome color ramp from black to r_value, g_value and b_value (values from 0 to 1)	(Def: SPE)
SIZ	max_pixels	- Set maximum dimension of display area in pixels	(Def: 512)
BAC	r_value g_value b_value	- Background color in RGB units	(Def: 0.30 0.49 0.49)

Fit aberration, intensity, or phase data to Zernike polynomials:

ZRN or	[EXP|EXS] num_terms [radius]	- Fit with standard Zernike (can use WIN)	(Def: No fit)
ZFR	[EXP|EXS] num_terms [radius]	- Fit with FRINGE Zernike (can use WIN) EXP - fit to exit pupil plane, normal to chief ray EXS - fit to exit pupil sphere no qualifier - fit to entrance pupil, normal to Z axis radius - fit to specified radius	(Def: Pupil radius)

Perturbed Wavefront:

ADD	Fn [Wm] [B|Q]	- Add perturbation to wavefront at Fn, for Wm B - bi-lateral symmetry about Y Q - quadrant symmetry neither - no symmetry	(Def: N/A)
Y	num_row perturbation_waves_x100....TGR	- Perturbation in waves x 100 in pupil grid cell defined by num_row; column defined by sequence of entries	
YC	perturbation_waves_x100....TGR	- Use YC to continue entries of Y command	

Menu

Search

RIM - Ray Aberration Curves/OPD Aberration Curves

WFR	Yes|No....z	- Plot wave aberration in waves instead of transverse ray aberration (Def: No)
SSI	aberration_for_plotted_inch....z	- Aberration scale size (Def: ray - 0.001,0.005,0.05; wave - 1)
EP	Yes|No....z	- Plot vs. entrance pupil instead of aperture stop (Def: No)
NRD	num_rays_across_diameter	- Number of real rays curve fitted for plot (Def: 100)
CAB	Yes | No	- Eliminates plotting of any rays which are clipped by active apertures or obscurations (Def: No)
LAB	Yes|No|color....z	- Label plot (Def: Yes)
TIT	'temporary_title'(20+20)....z	- Temporary title (Def: 1st 40 char. lens_system_title)
TYP	XY|XX|YY|YX....z	- Type of format: (Def: XY) XY - plot X coordinate of X-fans, Y coordinate of Y-fans XX - plot X coordinate of X-fans, Y-fans YY - plot Y coordinate of X-fans, Y-fans YX - plot Y coordinate of X-fans, X coordinate of Y-fans
WVL	Yes|No|color....w	- Plot this wavelength (Def: CLS WVL colors)

Menu

Search

RSI - Real Ray Trace

(If GLO is active, lists ray coordinates relative to GLO coordinates):

RSI [Sk|Si..j] [Zk] [Wn] x_fract_pupil y_fract_pupil x_fract_max_x_field y_fract_max_y_field
- Single trace, relative pupil coordinates, relative field

or **RSI** [Sk|Si..j] [Zk] [Wn] Fm x_fract_pupil y_fract_pupil - Single trace, numbered field, relative pupil coordinates

or **RSI** [Sk|Si..j] [Zk] [Wn] Fm Rs - Single trace, numbered field, numbered reference ray (see figure on page 93)

or **RSI** [Sk|Si..j] [Zk] [Wn] x_ref_surf y_ref_surf x_fract_max_x_field y_fract_max_y_field num_of_ref_surf
- Single trace, actual reference surface coordinates and relative field; num_of_ref_surf defines temporary reference surface for trace

or **RSI** [Sk|Si..j] [Zk] [Wn] Fm x_ref_surf y_ref_surf num_of_ref_surf
- Single trace, numbered field, actual reference surface coordinates, num_of_ref_surf defines temporary reference surface for trace

or **RSI** [Sk|Si..j] - Trace ray defined by last RSI command

SIN [Sk|Si..j] [Zk] [Wn] x_1st_surf_tan_plane y_1st_surf_tan_plane x_dir_tan y_dir_tan
- Single trace, input for 1st surface

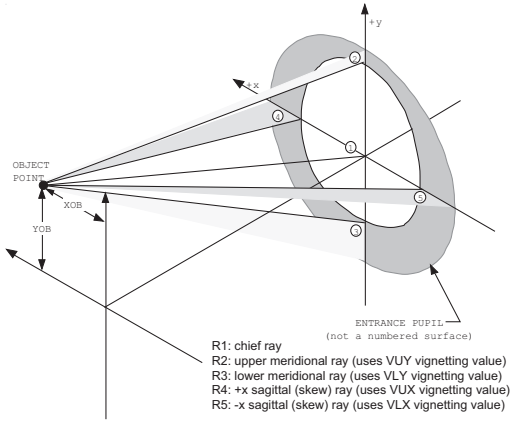
or **SIN** [Sk|Si..j] - Trace ray defined by last SIN command

ROF ['format'] [X|Y|Z|L|M|N|TNX|TNY|AOI|AOR|LEN
|SRL|SRM|SRN
|POL|PXI|PYI|PFR|PTP|POR|PRO
|JR1|JR2|JR3|JR4|JI1|JI2|JI3|JI4
|MGS|MGP|PHS|PHP|JNS...10]
- Ray output format; display up to 10 parameters:(Def: X Y Z TNX TNY LEN)

['format']	-	FORTRAN format for output (Def: 'F11.5')
X,Y,Z	-	coordinates of ray on surface
L,M,N	-	optical direction cosines of ray after surface
TNX,TNY	-	X,Y direction tangents
AOI	-	angle of incidence (degrees)
AOR	-	angle of refraction (degrees)
LEN	-	ray length from prior surface
SRL, SRM, SRN	-	direction cosines of surface normal
POL	-	equiv: ROF PXI PYI PFR PTP POR PRO
PXI, PYI	-	intensity through linear polarizer with transmission axis parallel to X,Y axis
PFR	-	fraction of light polarized
PTP	-	intensity ratio: minor axis to major
POR	-	orientation of major axis

PRO - right, left, or linear
JR1, JR2, JR3, JR4 - real components of Jones matrix
JI1, JI2, JI3, JI4 - imaginary components of Jones matrix
MGS, MGP - magnitude of S and P components of polarization
PHS, PHP - phase (in degrees) of S and P components of polarization
JNS - equiv: all 4 Jones matrix real and imaginary components, plus MGS MGP PHS PHP,output in two rows per surface

(Polarization output only available if POL command is activated).



THO - Third Order Aberrations

THO [Sk|Si..j] [Zk] - Aberration contributions for surface(s), zoom position

BIO - Biocular Analysis

(Geometrical)

Display Parameters

Object space grid definition

MXE	max_elevation_degr	- Most + elevation	(Def: from +last YAN)
MNE	min_elevation_degr	- Most - elevation	(Def: from -last YAN)
NEL	num_elevations	- Number of elevations from MNE to MXE	(Def: 21)
AZI	azimuth_degr....7	- Azimuth angle(s)	(Def: 0.0)
OFS	offset_elevation_degr	- Elevation angle of lens optical axis	(Def: 0.0)

Lens comparison

ZPO SIN	Zk	- Use single lens represented by Zk	
or **ZPO**	[DIF|AVE] Zk Zn|PAR|subs_lens	- Compare lens in Zk with:	(Def: ZPO DIF Z1 PAR)

Zn - lens in zoom position Zn
PAR - paraxial EFL or RED* of lens in position Zk
subs_lens - substitute value of EFL or RED*
DIF - Zk - second value (Zn|PAR|subs_lens)
AVE - average Zk with second value
neither - DIF
*Note: use RED if |RED|>1.0E-5

UNI	LNS|MIC|MIL|AMI|ASE|MLR|MCR	- Display units: Image: LNS - lens units; MIC - microns; MIL - mils Object: AMI - arc min; ASE - arc sec; MLR - milli-radians; MCR - microradians	(Def: LNS)
COR	a_coeff b_coeff c_coeff d_coeff	- Correction polynomial (odd order in tangent of object angle gives position on image surface) to be subtracted from chief rays before ZPO operation	
FTT	Yes|No	- Does f * tan (θ) conversion of image coordinates into object space for UNI with AMI, ASE, MLR, MCR **Note:** use only with object space selection with UNI	(Def: No

Plotting/Printing

PLO	[OVE] Yes|No	- Plot ZPO result; OVE plots only the curve - see RET	(Def: Yes)
SSI	vert_units_per_scale_bar	- Scale size of ZPO values	(Def: 10 UNI per scale bar)
RET	Yes|No	- Return to origin to overlay next plot	(Def: No)
RAC	Yes|No	- Ray failure map - surface where ray failed	(Def: No)
LAB	Yes|No	- Label plot	(Def: Yes)
TIT	'temporary_title'(20+20)	- Temporary title	(Def: 1st 40 char. lens_system_title)
XLA	'x_coord_label'(40)	- Label tables/plots of X coordinates	(Def: blank)
YLA	'y_coord_label'(40)	- Label tables/plots of Y coordinates	(Def: blank)

Non-Uniform Reference Grid

Allows input of table 21 elevations high by 7 azimuths wide, using both ELC and AZC to describe each point; input is normally in decimal degrees; if DMS is included, use degrees, minutes, seconds as dd.mmssss where ssss is implied to be ss.ss

XLE	'replace_azimuth_label'(30)	- Change "A Z I M U T H (DEGREES)"
YLE	'replace_elevation_label'(15+15)	- Change "ELEVATION (DEGREES)"
ELC	[DMS] elevation_coordinates_degr....7	- (up to 21 commands)
AZC	[DMS] azimuth_coordinates_degr....7	- (up to 21 commands)

Multi-Module Display

Allows comparison with the same optical system rotated in azimuth (or other zoom positions if ZCA is used); inputs describe the second (calibration) system(s) to be subtracted from the system(s) given in ZPO

XOF	azimuth_offset_degr....z	- Offset subtracted from second zoom position of pair specified in ZPO	(Def: 0.0)
ZCA	Zi [Zj]	- 1st and 2nd calibration positions; with ZPO, the results are for Zk - Zi, Zn - Zi or Zk - Zi, Zn - Zj	(Def: N/A)

Special Wedge Aperture for Multi-module Display

SAP	Si Sj wedge_aperture_distance	- Aperture on Si, defined by azimuth wedge at given distance from Sj	(Def: N/A)
SUR	Si....7	- Apply SAP wedge to up to 7 Si's	(Def: Si on SAP)
WED	wedge_aperture_degr....z	- Override XOF for azimuth angle of aperture only	(Def: use XOF)

BPR - Beam Propagation

(Diffraction)

Propagation Method

DBP	[NFP|FFP|SSP] [sphere_radius] Si..j Yes|No....z	- Use diffraction-based propagation between surfaces i and j. NFP (near field), FFP (far field), and SSP (sphere-to-sphere) specify type of propagator used. For SSP, use sphere_radius to specify radius of curvature of sphere.	(Def: Si-1..i Yes)

Input Beam

INB	Bi Im..n Jo..p grid_increment	- Specify input beam with complex values in buffer	
BIN	filename file_normalization_radius	- Specify input beam with intensity values in INT file	
BCM	filename	- Imports a data file (.dat extension) containing complex optical field data.	
BPH	filename file_normalization_radius	- Specify input beam with phase values in INT file	
WRX	x_beam_half_width....z	- REQUIRED. Beam half-width in X at the object surface	
WRY	y_beam_half_width....z	- REQUIRED. Beam half-width in Y at the object surface	
RCX	x_wave_radius....z	- Wave front radius of curvature in X-Z	(Def: Infinity)
RCY	y_wave_radius....z	- Wave front radius of curvature in Y-Z	(Def: Infinity)
AZI	starting_orientation_degr....z	- Rotate beam defining coordinates about chief ray	(Def: 0.0)

Computational Controls

NRD	num_rays_across_diameter....z	- Determine grid from pupil diameter	(Def: For Gaussian beams only: $NRD = INT\left[2 \times \sqrt{\frac{TGR}{\pi}} + 0.5\right]$ where INT is the largest integer less than or equal to the bracketed quantity. Minimum NRD = 15. For all other beams: TGR/2 for all wvls.)
TGR	[Sk|Si..j] num_fft_grid_pow_of_two....z	- Transform grid; range: 16 or more	(Def: S0..i 128)
GRI	[Sk|Si..j] grid_spacing....z	- Grid increment.	(Def: Computed)

Output Controls

WBF	INT|AMP|PHA|CMP SUR|REF Si|Si..j Bk Yes|No....z	- Specify type of output written to buffer	(Def: Sa No)
INT	NOR|DB|ListedPeakIntensity...z	- Specify normalization of output data	(Def: NOR)
THR	output_noise_threshold....z	- Specify output value threshold	(Def: -50 DB)
PGR	Sk|Si..j region_of_interest_size....z	- Specify subset of data grid relative to the center.	(Def: TGR - 1)
PRX	Sk|Si..j center_of_output_region_x_coord....z	- Specify X displacement of region of interest relative to center of data grid.	(Def: 0)
PRY	Sk|Si..j center_of_output_region_y_coord....z	- Specify Y displacement of region of interest relative to center of data grid.	(Def: 0)

Listing Controls

LIS	INT|AMP|PHA SUR|REF Si|Si..j Yes|No....z	- Specify type of output listed at specified surfaces	(Def: Sa No)

Plotting Controls

PLO	INT|AMP|PHA SUR|REF Si|Si..j Yes|No....z	- Oblique projection plot	(Def: Si Yes)
ROT	Yes|No....z	- Rotate oblique projection plot by 90°	(Def: No)
CON	INT|AMP|PHA SUR|REF Si|Si..j Yes|No....z	- Contour map plot	(Def: Sa No)
LEV	[contour_level....30]	- Select contour levels to be plotted	(Def: LEV NUM 10)
LEV INC	contour_increment	- Uniform levels, specified by increment	(Def: LEV NUM 10)
LEV NUM	num_contour_levels	- Uniform levels, specified by total number	(Def: LEV NUM 10)
TIT	'temporary_title'(20+20)....z	- Temporary title	(Def: 1st 40 char. lens_system_title)

Color Display

DIS	INT|AMP|PHA SUR| REF Si|Si..j Yes|No....z	- Color contour map display	(Def: Sa No)
RAN SCA	num_steps [min_value max_value]	- Set color scale range	(Def: 50)
RAN COL	SPE|RGB [r_value g_value b_value]	- Select type of color scale SPE - Spectral color rainbow RGB - Monochrome color ramp from black to r_value, g_value and b_value (values from 0 to 1)	(Def: SPE)
SIZ	max_pixels	- Set maximum dimension of display area in pixels	(Def: 512)
BAC	r_value g_value b_value	- Background color in RGB units	(Def: 0.30 0.49 0.49)

BSP - Beam Synthesis Propagation

(Diffraction)

Input Field and Location

	IFD	Fk [Zj]	- Specify LDM-defined field number for the initial optical field. (Def: FA)
or	**IFD**	[Zj] x_coord y_coord z_coord l_dir m_dir n_dir	- Specify coordinate and direction of the initial optical field.
	SPX	x_beam_half_width....z	- Designate a spherical wave. Half-width in X of the untruncated portion of the spherical wave.
	SPY	y_beam_half_width....z	- Designate a spherical wave. Half-width in Y of the untruncated portion of the spherical wave.
	WRX	x_beam_half_width....z	- Designate a Gaussian beam. Half-width of the $1/e^2$ intensity points for the Gaussian beam in the X-direction.
	WRY	y_beam_half_width....z	- Designate a Gaussian beam. Half-width of the $1/e^2$ intensity points for the Gaussian beam in the Y-direction.
	RCX	x_radius_of_curvature....z	- Specify radius of curvature of the wavefront in the X-direction. (Def: For spherical waves: center on the associated object point. For Gaussian beams: 0)
	RCY	y_radius_of_curvature....z	- Specify radius of curvature of the wavefront in the Y-direction. (Def: For spherical waves: center on the associated object point. For Gaussian beams: 0)
	AZI	starting_orientation_degr....z	- Specify orientation (in degrees) of the input optical field definition about the optical (z) axis. (Def: 0)
	WBS	Sk [Zi|Zi..j] [filename]	- Write the current beam state (at the input side of surface Sk) to a file for each zoom and wavelength. Default file name is *beam.bst*.
	RBS	Sk filename	- Read the beam data from the file and input it at surface Sk.
	INP	input_beam_power....z	- Specify power in the input optical field. The value is interpreted differently, depending on the input beam type: – Spherical wave: total power in 4π steradians emitted by the point source. – Plane wave: irradiance of the plane wave on a plane normal to the direction of propagation. – Gaussian: total power in the beam. (Def: 1.0)

Pre-Analysis

PRA	[RUN|TIM]	- Turn on pre-analysis and generate recommended BSP settings RUN - Execute BSP after pre-analysis using the recommended settings. TIM - Display only an estimated BSP computation time based on current settings.
IMA	[Sk|Si..j] number_of_airy_disks	- Specify the size of the patch near the focal region in which you are interested in modeling accurately. (Def: SA 2.0)

Input Field Sampling

NRI [NFR|FFR] number_of_rings....z - Number of rings to use in the initial fit.
(Def: FFR 10 for tightly focused Gaussian; NFR 10 otherwise)

Polychromatic Output

PCH [All] Yes|No - Specify polychromatic output: (Def: Yes)
No - Perform analysis at all defined wavelengths and generate separate output for each.
Yes - When either intensity of irradiance output is requested, incoherently sum the intensity or irradiance at the individual wavelengths and give result only for the sum.
All - Output is generated at the individual wavelengths as well as the incoherent sum.

Resampling Surfaces and Parameters

RSF [NFR|FFR] Sk|Si..j Yes|No....z - Resample the field (i.e., reconstruct field and perform new fit) (Def: NFR SA No)
NFR - Applied to resampling for the incident field in the near field.
FFR - Applied to resampling for the refracted/reflected field in the far field.

RPX [Fi] [NFR|FFR] Sk|Si..j resample_grid_size_x....z (Def: 21)
- Number of points in the resampling grid in the X-direction.
NFR - Applied to resampling the near field that is incident on the surface.
FFR - Applied to resampling the far field after interaction with the surface.

RPY [Fi] [NFR|FFR] Sk|Si..j resample_grid_size_y....z (Def: 21)
- Number of points in the resampling grid in the Y-direction. See RPX command for NFR and FFR keyword explanations.

ROX [Fi] [NFR|FFR] Sk|Si..j resample_grid_center_x....z
- X-coordinate of the position of the resampling grid. See RPX command for NFR and FFR keyword explanations.
(Def: See page 19-110 of the *CODE V Reference Manual*)

ROY [Fi] [NFR|FFR] Sk|Si..j resample_grid_center_y....z
- Y-coordinate of the position of the resampling grid. See RPX command for NFR and FFR keyword explanations.
(Def: See page 19-110 of the *CODE V Reference Manual*)

RWX [Fi] [NFR|FFR] Sk|Si..j resample_width_x....z
- Resample width in the X-direction. See RPX command for NFR and FFR keyword explanations.
(Def: See page 19-110 of the *CODE V Reference Manual*)

RWY [Fi] [NFR|FFR] Sk|Si..j resample_width_y....z
- Resample width in the Y-direction. See RPX command for NFR and FFR keyword explanations.
(Def: See page 19-110 of the *CODE V Reference Manual*)

RIX [Fi] [NFR|FFR] Sk|Si..j resample_grid_incr_x....z
- Resample grid increment in the X-direction. See RPX command for NFR and FFR keyword explanations.
(Def: See page 19-111 of the *CODE V Reference Manual*)

RIY [Fi] [NFR|FFR] Sk|Si..j resample_grid_incr_y....z
- Resample grid increment in the Y-direction. See RPX command for NFR and FFR keyword explanations.
(Def: See page 19-111 of the *CODE V Reference Manual*)

Clip Checking Surfaces

CLC Sk|Si..j Yes|No....z - Check beam clipping at designated surface(s). (Def: SA No)

Transmission Variation Checking

TVC Sk|Si..j Yes|No....z - Check individual beamlets for excessive transmission variations across the beamlet at designated surface(s). (Def: SA No)

BSP Termination Surface

ESN [Zi|Zi..j] Sk - Define surface at which BSP is to terminate. (Def: SI)

Output Grid Extent and Sampling

GOX [Fi] [NFR|FFR] Sk|Si..j center_of_output_region_x....z
- X-coordinate at which the output grid is centered.
NFR - Near field that is incident on the surface
FFR - Far field after interaction with the surface
(Def: See page 19-105 of the *CODE V Reference Manual*)

GOY [Fi] [NFR|FFR] Sk|Si..j center_of_output_region_y....z
- Y-coordinate at which the output grid is centered. See GOX command for NFR and FFR keyword explanations.
(Def: See page 19-105 of the *CODE V Reference Manual*)

GPX [Fi] [NFR|FFR] Sk|Si..j region_of_interest_size....z (Def: FA NFR SA 101)
- Size of output field grid in X dimension. See GOX command for NFR and FFR keyword explanations.

GPY [Fi] [NFR|FFR] Sk|Si..j region_of_interest_size....z (Def: FA NFR SA 101)
- Size of output field grid in Y dimension. See GOX command for NFR and FFR keyword explanations.

GWX [Fi] [NFR|FFR] Sk|Si..j grid_width_x....z
- Total grid width in the X-direction for the reconstructed field. See GOX command for NFR and FFR keyword explanations.
(Def: See page 19-105 of the *CODE V Reference Manual*)

GWY [Fi] [NFR|FFR] Sk|Si..j grid_width_y....z
- Total grid width in the Y-direction for the reconstructed field. See GOX command for NFR and FFR keyword explanations.
(Def: See page 19-105 of the *CODE V Reference Manual*)

GIX [Fi] [NFR|FFR] Sk|Si..j grid_increment_x....z
- Grid increment in the X-direction for the reconstructed field. See GOX command for NFR and FFR keyword explanations.
(Def: See page 19-105 of the *CODE V Reference Manual*)

GIY [Fi] [NFR|FFR] Sk|Si..j grid_increment_y....z
- Grid increment in the Y-direction for the reconstructed field. See GOX command for NFR and FFR keyword explanations.
(Def: See page 19-105 of the *CODE V Reference Manual*)

Output Controls

WBF INT|IRR|AMP|PHA|CMP|XAM|YAM|ZAM|RAM|AAM|XPH|YPH|ZPH|RPH|APH|CMX|CMY|CMZ|VEC|VFD [NFR|FFR] Sk|Si..j Bk [Zk|Zi..j] [SXO|SYO|SXY] [x_num_pts [y_num_pts]] [Yes | No]
- Specify type of output written to buffer (Def: NFR SA No)

INT [Sk|Si..j] NOR|DB|UNN|DBU|ListedPeakIntensity....z
- Specify normalization of output data (Def: SA NOR)

THR output_noise_threshold_db....z - Specify output value threshold (Def: -50 DB)

or **THR** PHA phase_threshold|No....z - Specify phase threshold for plotting

GFT Sk|Si..j [NFR | FFR] [Yes | No | threshold]....z
- Enable a least-squares fit of intensity data for the reconstructed field to an elliptical Gaussian beam at the specified surface(s). (Def: No)

Plotting Controls

PLO PHA|AMP|INT|IRR|XAM|YAM|ZAM|RAM|AAM|XPH|YPH|ZPH|RPH|APH [NFR|FFR] Sk|Si..j Yes|No....z
- Oblique projection plot (Def: NFR SA No)

ROT Yes|No....z - Rotate oblique projection plot by 90° (Def: No)

CON PHA|AMP|INT|IRR|XAM|YAM|ZAM|RAM|AAM|XPH|YPH|ZPH|RPH|APH [NFR|FFR] Sk|Si..j Yes|No....z
- Contour map plot (Def: NFR SA No)

LEV [contour_level....30] - Select contour levels to be plotted (Def: LEV NUM 10)

or **LEV INC** contour_increment - Uniform levels, specified by increment (Def: LEV NUM 10)

or **LEV NUM** num_contour_levels - Uniform levels, specified by total number (Def: LEV NUM 10)

GSL PHA|AMP|INT|IRR|FRI|XAM|YAM|ZAM|RAM|AAM|XPH|YPH|ZPH|RPH|APH [NFR|FFR] Sk|Si..j [Zk|Zi..j] [SXO|SYO|SXY] [GRD] [x_num_pts [y_num_pts]] [Yes|No]
- 1D slice plot (Def: No)

BFP Sk | Si..j [NFR | FFR] [Yes | No | energy_fraction....z]
- Beam footprint plot (Def: No)
  NFR - Plots the footprint in the near field
  FFR - Plots the footprint in the far field
  energy_fraction - Fraction of the total beamlet energy enclosed within each ellipse
(Def: See page 19-100 of the *CODE V Reference Manual*)

TIT 'temporary_title'(20+20)....z - Temporary title (Def: 1st 40 char. lens_system_title)

Color Display Controls

DIS PHA|AMP|INT|IRR|FRI|XAM|YAM|ZAM|RAM|AAM|XPH|YPH|ZPH|RPH|APH [NFR|FFR] Sk|Si..j Yes|No....z
- Color contour map display (Def: INT NFR Si Yes)

RAN SCA PHA|AMP|INT|IRR|FRI|XAM|YAM|ZAM|RAM|AAM|XPH|YPH|ZPH|RPH|APH [NFR|FFR] Sk|Si..j [Zk|Zi..j] [Fk|Fi..j] num_steps [lower_limit upper_limit]
- Use only with DIS; set color scale range. (Def: 50)

RAN COL SPE|RGB [r_value g_value b_value]
- Use only with DIS; select type of color scale (Def: SPE)

SPE - Spectral color rainbow
RGB - Monochrome color ramp from black to the specified red, green, and blue values.

BAC	r_value g_value b_value	- Use only with DIS; background color in RGB units	(Def: 0.30 0.49 0.49)

Advanced Propagation Controls

ACP	STD|ENH|HIG	- Sets values of BWE, BDT, and AET to one of three levels: standard (STD), enhanced (ENH), or high (HIG)	(Def: STD)
BWE	beamlet_wavefront_error_rms|DEF....z	- Maximum RMS wavefront error allowed to accumulate at a single surface.	(Def: ACP)
BMU	Sk|Si..j clipping_fidelity....z	- Fidelity with which clipping apertures are modeled.	(Def: 3)
CBD	clipped_beamlet_depth	- Number of beamlet sets used to model clipping.	(Def: 1)
BDT	beamlet_delta_transmission|DEF....z	- Maximum allowed RMS error in transmission across a beamlet.	(Def: ACP)
AET	apodization_edge_threshold|DEF....z	- Accuracy to which points on the edge of an apodizer are determined when TVC is active.	(Def: ACP)

CEF - Fiber Coupling Efficiency

(Diffraction)

Field Specification

MPR	STE core_radius delta_n	- Mode profile (select one of three):	(Def: None. Input is required.)
or **MPR**	GAU gaussian_radius	STE - Step index	
or **MPR**	FIL filename radius [angle]	GAU - Gaussian mode profile	
		FIL - User-defined profile (in filename.INT)	
CIN	index_of_fiber_core	- Refractive index of the fiber core	(Def: 1.4682)

Input Beam

WRX	x_beam_half_width...z	- X beam radius at the $1/e^2$ intensity point in the X meridian for specifying an incident Gaussian beam.	
WRY	x_beam_half_width...z	- Y beam radius at the $1/e^2$ intensity point in the Y meridian for specifying an incident Gaussian beam.	
RCX	x_wave_radius...z	- X radius of curvature of Gaussian wavefront in X meridian.	(Def: Infinity)
RCY	y_wave_radius...z	- Y radius of curvature of Gaussian wavefront in Y meridian.	(Def: Infinity)
AZI	starting_orientation_degr...z	- Orientation (in degrees) of amplitude function of Gaussian beam about the optical (z) axis.	(Def: 0.0)
AZP	orientation_of_phase_degr...z	- Orientation (in degrees) of phase function of Gaussian beam about the optical (z) axis.	(Def: 0.0)
BIN	filename normalization_radius...z	- Input INT file containing intensity data for the input beam.	
BPH	filename normalization_radius...z	- Input INT file containing phase data for the input beam.	
INB	Bi	- Use data in a worksheet buffer to define a grid of points that represents the input beam to the fiber.	

Fiber Alignment

WDX	x_wedge_angle_degr	- Wedge angle of the front face of the fiber in the X direction	(Def: 0.0)
WDY	y_wedge_angle_degr	- Wedge angle of the front face of the fiber in the Y direction	(Def: 0.0)

Computation Controls

TGR	num_fft_grid_pow_of_two	- Transform grid; range: 16 or more	(Def: 128)
NRD	num_rays_across_diameter....z	- Determine grid from pupil diameter	(Def: TGR/2 at short wl)
or **GRI**	image_surface_spacing....z	- Focal plane grid	(Def: Airy disc diameter/4.88, short wl)
XSC	scale_x_psf_by_factor....z	- Scale X dim of image - for anamorphic systems with highly unequal magnifications	(Def: 1.0)

Output Controls

LIS	Yes|No	- Provide tabular output	(Def: Yes)
PLO	Yes|No	- Provide plot of coupling efficiency versus the parameter entered with SN1 command for each value of the parameter entered with the SN2 command	(Def: Yes, if num_values >1 in SN1)
DB	Yes|No [threshold]	- Scale output to be in units of decibels subject to the threshold value. The default threshold is -50 decibels.	(Def: No)

Analysis Selection

SN1	XDE|YDE|ADE|BDE|WDX|WDY [max_value [min_value [num_values]]]	- Compute sensitivity of the coupling efficiency to changes in the specified alignment parameter	(Def: XDE 0.0 0.0 1)
SN2	XDE|YDE|ADE|BDE|WDX|WDY [max_value [min_value [num_values]]]	- Compute sensitivity of the coupling efficiency to changes in the specified alignment parameter	(Def: YDE 0.0 0.0 1)

GDE - Geometrical Detector Analysis

(Geometrical)

Counts rays passing through the system in each wavelength, field and zoom position; if DEX, or DEX, DEY is included, an array is generated, each point giving the number of rays passing through a detector of the total width specified when it is centered at the point.

NRD	num_rays_across_diameter...z	- Determine grid from pupil diameter for each wavelength	(Def: 20)
DEX	No|x_dim_of_detector....z	- Include detector; circular if DEX only; generate array of points representing 2-D convolution	(Def: No)
DEY	No|y_dim_of_detector....z	- Use with DEX for rectangular detector	(Def: No)
GRI	detector_incr....z	- Increment between array points	(Def: DEX/20)

GLS - Geometrical Line Spread Function

(Geometrical)

NRD	num_rays_across_diameter....z	- Determine grid from pupil diameter

		The number of rays for the wavelength with the largest weight. The default is that a total of approximately 316 rays are traced. The relative number of rays traced for each wavelength is determined by the wavelength weights. For a single wavelength, this corresponds to a value of 20 for the number of rays across the diameter.	
GAU	smoothing_spot_diam|No....z	- Smooth with a Gaussian distribution; for simulating Gaussian object (i.e, CRT spot); value is for the 50% intensity point	(Def: 1/200 of spot diameter)

IMS - 2D Image Simulation

(Diffraction)

Input Object Controls

OBJ	filename	- Defines the 2D object or “scene” file to use as input.	(Def: default.bmp)
FCO	OBJ|IMG|RIH|ANG	- Selects the field coordinate definition used by the OBH, YOF, and XOF commands: OBJ - Object Height IMG - Paraxial Image Height RIH - Real Image Height ANG - Field Angle in Object Space	(Def: Field specification type defined in the LDM)
OBH	object_ht....z	- Maps the half-diagonal of the input object file to the specified field size, as defined by FCO.	(Def: Maximum half-field specification)
XOF	object_offset_x....z	- Defines the offset of the center of the object in the X-direction.	(Def: 0)
YOF	object_offset_y....z	- Defines the offset of the center of the object in the Y-direction.	(Def: 0)
AZI	object_orientation_degrees....z	- Rotates the orientation of the digital object data.	(Def: 0)

Point Spread Function Controls

	TGR	num_fft_grid_pow_of_two	- Transform grid; range: 16 or more	(Def: 128)
	NRD	num_rays_across_diameter....z	- Determine grid from pupil diameter	(Def: TGR/2 at short wl)
or	**GRI**	image_grid_spacing....z	- Focal plane grid	(Def: Airy disc diameter/4.88, short wl)
	PMX	num_samples_x	- Number of samples in the X-direction in the field at which the PSF is computed.	(Def: 5)
	PMY	num_samples_y	- Number of samples in the Y-direction in the field at which the PSF is computed.	(Def: 5)
	SYM	ROT|NON	- System has rotational symmetry, regardless of actual symmetry.	(Def: Calculated from lens)
	DEX	detector_size_X	- X-dimension of rectangular detector to be convolved with the system PSF.	(Def: 0.0)
	DEY	detector_size_Y	- Y-dimension of rectangular detector to be convolved with the system PSF.	(Def: 0.0)

Color Controls

CME	PIS|RGB|COL	- Color computation method used to compute the output image. PIS - Polychromatic Intensity RGB - Separate PSF for red, green, blue contributions to the image COL - 3-Wavelength Color	(Def: CME PIS)
RWL	red_wavelength_nm....w	- Specifies one or more wavelengths to be used in computing the red PSF for CME RGB.	(Def: 650 nm)
RWT	red_wavelength_wt....w	- Associates a weight with the PSF computation at the RWL.	(Def: 1.0)
GWL	green_wavelength_nm....w	- Specifies one or more wavelengths to be used in computing the green PSF for CME RGB	(Def: 510 nm)
GWT	green_wavelength_wt....w	- Associates a weight with the PSF computation at the GWL.	(Def: 1.0)
BWL	blue_wavelength_nm....w	- Specifies one or more wavelengths to be used in computing the blue PSF for CME RGB	(Def: 440 nm)
BWT	blue_wavelength_wt....w	- Associates a weight with the PSF computation at the BWL.	(Def: 1.0)

Output Controls

ODP	[Yes|No]	- Display input object in the IMS file viewer.	(Def: Yes)
IDP	[Yes|No]	- Display image simulation in the IMS file viewer.	(Def: Yes)
PDP	[Yes|No]	- Display PSF map in the IMS file viewer.	(Def: No)
SVI	[BMP|JPG|PNG] [COL|GRY]	- Save image simulation to a file. BMP - Bitmap format JPG - JPEG format PNG - Portable Network Graphics format COL - For CME RGB or CME COL, generates a 24-bit color image file. GRY - For CME RGB or CME COL, generates an 8-bit grayscale image file.	(Def: No file generated)
SID	[Yes | No]	- Saves image data to a 16- or 48-bit PNG file (16 bits/pixel/color). Use this function if you would like to post-process the IMS result.	(Def: No)

LSF - Diffraction Line Spread Function

(Diffraction)

Plotting Controls

PLO	[LIS] Yes|No....z	- Plot line spread function LIS - List plotted points	(Def: Yes)
LAB	Yes|No....z	- Label plot	(Def: Yes)
TIT	'temporary_title'(20+20)....z	- Temporary title	(Def: 1st 40 char. lens_system_title)

Computation Controls:

TGR	num_fft_grid_pow_of_two	- Transform grid; range: 16 or more	(Def: 128)

PGR	num_integration_grid_width	- Limit integration grid size for PIX	(Def: TGR-1)
NRD	num_rays_across_diameter....z	- Determine grid from pupil diameter	(Def: TGR/2 at short wl)
or **GRI**	image_grid_spacing....z	- Focal plane grid	(Def: Airy disc diameter/4.88, short wl)
XSC	scale_x_psf_by_factor....z	- Scale X dim of image - for anamorphic systems with highly unequal magnifications	(Def: 1.0)
PIX	pixel_width|No....z	- Pixel detector function	(Def: No)
PRO	Yes|No	- Use propagate equations for out-of-focus image	(Def: No)

Perturbed wavefront:

ADD	[Wm] Fn [B|Q]	- Add perturbation to wavefront at Fn, for Wm; B - bi-lateral symmetry about Y; Q - quadrant symmetry; neither- no symmetry	(Def: N/A)
Y	num_row perturbation_waves_x100....TGR	- Perturbation (100 x waves) in pupil grid cell defined by num_row; column defined by sequence of entries	
YC	perturbation_waves_x100....TGR	- Use YC to continue entries of Y command	

MTF - Modulation Transfer Function, Geometrical and Diffraction

Spatial Frequency (See page 19-263 of the *CODE V Reference Manual* for interaction between MFR, IFR, NRD)

MFR	max_lines_per_mm....z	- Maximum spatial frequency	(Def: diffraction limit, shortest λ)
IFR	incr_lines_per_mm....z	- Increment in spatial frequency	(Def: diffraction limit, shortest λ / NRD)
NRD	num_rays_across_diameter|No....z	- Define range of valid grid sizes	(Def: 60)

Optional Forms of Computation

GEO	Yes|No....z	- Geometrical instead of diffraction MTF	(Def: No)
WFR	Yes|No....z	- Add diagnostic wavefront map	(Def: No)
DIA	Yes|No....z	- Include 45° diagonal target	(Def: No)
SQW	Yes|No....z	- Square wave instead of sine wave response	(Def: No)
PHA	Yes|No....z	- Add spatial phase shift (complete OTF)	(Def: No)

Plotting Controls

PLO FRE	Yes|No....z	- Plot MTF vs. frequency at designated FOC	(Def: Yes)
FOC	plotted_focus_shift....z	- Focus position for PLO FRE (Up to 10 commands allowed) (Def: center focus, or left of center defined by FFO,IFO,NFO in the LDM)	
SPA	max_frequency....z	- Maximum frequency plotted	(Def: MFR)
PLO FOC	Yes|No....z	- Plot MTF vs. focus at designated FRE	(Def: No)
FRE	plotted_frequency....z	- Frequency for PLO FOC (Up to 10 commands allowed)	(Def: 1st frequency = IFR)
LAB	Yes|No....z	- Label plot	(Def: Yes)
TIT	'temporary_title'(20+20)....z	- Temporary title	(Def: 1st 40 char. lens_system_title)
OVE	Yes|No....z	- Overlay field angles on same plot	(Def: Yes)
GRD	Yes|No....z	- Add grid lines to the plot. Applies to both PLO FRE and PLO FOC.	(Def: No)

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Vectorial Linear Image Motion/Lateral Color

IMX	x_mm_image_motion....w,z	- Image smear - X component	(Def: 0.0)
IMY	y_mm_image_motion....w,z	- Image smear - Y component	(Def: 0.0)

PAR - Partial Coherence, 1D and 2D

(Diffraction)

1D Partial Coherence (no 2D PAR commands allowed)

Source Parameters

RNA	fraction_of_fill....f,z	- Relative NA of condenser; range: 0.0 to 2.0 (Up to 5 commands)	(Def: 0.0 - full coherence)
RNX	x_shift_of_fill....f,z	- X decenter of fill - fraction of pupil	(Def: 0.0)
RNY	y_shift_of_fill....f,z	- Y decenter of fill - fraction of pupil	(Def: 0.0)
SRC	[Zi] [Fk] [ST1|ST2|ST3] filename [eff_src_radius [rot_angle_degr]]	- Define source distribution via .INT file	(Def: not done)
or **SRC**	[Zi] [Fk] ANN rna_min rna_max	- Define annular source	(Def: not done)
or **SRC**	[Zi] [Fk] CIR #_poles rna_min rna_max [rot_angle_degr]	- Define multi-pole intensity distribution with circular (CIR) poles	(Def: not done)
or **SRC**	[Zi] [Fk] SEC|BUN #_poles rna_min rna_max pole_subtense [rot_angle_degr]	- Define multi-pole intensity distribution with sector (SEC) or bun-shaped (BUN) poles	(Def: not done)
or **SRC**	POL [RAD|LIN|MIX|CIR|CIL] [fraction_pol]	- Defines the polarization that goes with the intensity pattern. The types of polarization are: – RAD is radial. This is the default. – LIN is linear in X. – MIX is linear in X for the first pole, but changes for each pole. – CIR is right circular. – CIL is left circular.	(Def: not done)

Object Description (Def: Image of zero-width line object):

BAR	num_of_bars width_of_one_bar....f,z	- Bar targets (1, 2, 3,...)	(Def: 1 bar, 0.0 width)
PER	distance_between_bar_centers....f,z	- Period of multi-bar pattern	(Def: 2 times BAR width)
DEP	min_fract_intensity....f,z	- Depth of spaces in bar patterns	(Def: 1.0)
BGI	background_fract_int....f,z	- Add background; range: 0.0 to 1.0	(Def: 0.0)
NEG	Yes|No	- Invert (negate) object profile	(Def: No)
AZI	object_azimuth_degr....z	- Object orientation	(Def: 0.0)
INN	intensity_transmittance....f,z	- Add intensity transmittance to bars in 1D object	(Def: 0.0)
PHN	bar_phase....f,z	- Add phase (in degrees) to bars in 1D object	(Def: 0.0)
BGP	background_phase....f,z	- Add background phase (in degrees) to bars to 1D object	(Def: 0.0)

RCN	width [location [intensity [phase_in_degrees]]]	- Define rectangular object of given x size (width) and x location, with a specified intensity (transmittance or reflectance) and phase (in degrees)	(Def: None entered)

Computation Controls

	PEA	Yes|No	- Normalize center to peak of 1.0	(Def: No, generally)
	TGR	num_fft_grid_pow_of_two	- Transform grid; range: 16 or more	(Def: 128)
	PGR	num_integration_grid_width	- Limit integration grid size	(Def: TGR-1)
	NRD	num_rays_across_diameter....z	- Determine grid from pupil diameter	(Def: TGR/2 at short wl)
or	**GRI**	image_grid_spacing....z	- Focal plane grid	(Def: Airy disc diameter/4.88, short wl)
	SLI	scan_slit_width|No....z	- Scan with slit	(Def: No)

Output Controls

LIS	Yes|No....z	- Use (with No) to turn off listed output when only plotting or output to the buffer is wanted	(Def: Yes)
WBF	Bk	- Write the PAR output to the specified buffer	(Def: Not done)

Plotting Controls

PLO	[LIS] Yes|No....z	- Plot intensity profile; LIS prints plotted points	(Def: Yes)
XMI	min_of_plot....z	- Lowest plotted scan position	(Def: -GRI*TGR/2)
XMA	max_of_plot....z	- Highest plotted scan position	(Def: +GRI*TGR/2)
XPR	Yes|No....z	- Plot X-profile	(Def: see YPR)
YPR	Yes|No....z	- Plot Y-profile	

(Def: if no XPR,YPR entered, both are plotted except on-axis in a rotationally symmetric system)

LAB	Yes|No....z	- Label plot	(Def: Yes)
TIT	'temporary_title'(20+20)....z	- Temporary title	(Def: 1st 40 char. lens_system_title)
MIC	Yes|No	- Label plot in microns instead of lens units	(Def: No)
SHA	Yes|No....z	- Plot geometrical "shadow" also	(Def: Yes)
OVE	Yes|No....z	- Overlay fields on one plot	(Def: Yes)
CRO	Yes|No	- Line up right hand 50% point of all curves	(Def: No)

Perturbed wavefront:

ADD	Fn [Wm] [B|Q]	- Add perturbation to wavefront at Fn, for Wm; B - bi-lateral symmetry about Y; Q - quadrant symmetry; neither - no symmetry	(Def: N/A)
Y	num_row perturbation_waves_x100....TGR	- Perturbation in waves x 100 in pupil grid cell defined by num_row; column defined by sequence of entries	
YC	perturbation_waves_x100....TGR	- Use YC to continue entries of Y command	

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Linewidth Computation Controls

	CDT	[LEF|RIG|CEN|DIF|AVG|ALL] [intensity_threshold|N]	- Computes width of image (Critical Dimension, or CD) of one bar of a bar object at a given intensity threshold. If there is more than one bar: – LEF: computes the linewidth of the leftmost bar. – RIG: computes the linewidth of the rightmost bar. – CEN: for odd values of N, computes the linewidth of the central bar; for even values of N, computes the average of the two bars surrounding the center of the pattern. – DIF: computes the difference in linewidth between the two outermost bars. – AVG: computes the average linewidth of all the bars. – ALL: computes the linewidths of all of the bars.	(Def: CEN)
	DOS	[linewidth|N]	- Exposure dose-to-size: Computes the exposure dose relative to the mask size.	(Def: The geometrical linewidth)
	BOS	[Bk] [LEF|RIG|CEN|DIF|AVG|ALL] [linewidth [min_percent max_percent num_percents]] | N	- Computes a focus exposure matrix for each field and places the results in an output buffer.	(Def: CEN)
or	**BOS**	[Bk] CDT [LEF|RIG|CEN|DIF|AVG|ALL] [CD_threshold [min_percent max_percent num_percents]] | N	- Computes a focus exposure matrix for each field and places the results in an output buffer. You can override the BOS command's dose-to-size calculation with the BOS CDT command form, in which you specify a CD threshold value (CD_threshold) that is used to calculate the dose-to-size. The CD threshold is a reciprocal of the desired dose-to-size value, and replaces the linewidth parameter in the BOS command syntax.	
	DKP	[GAU|DBG|LOR] width_param_1 [width_param_2 [width_param_3]] | N	- Performs a convolution of the image intensity with a specified diffusion kernel. Describes the resolution of the resist.	(Def: GAU is the default kernel; 0 for all parameters)
	LPM	contrast absorption resist_thickness min_develop_rate [refractive_index develop_time] | N	- Turns on the Lumped Parameter Model (LPM) for modeling the resist development process.	(Def: Not done)
	SCN	Yes|No	- For SCN Yes, the image is integrated over the field for each zoom position.	(Def: No)

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2D Partial Coherence (no 1D PAR commands allowed)

Source Parameters

RNA	fraction_of_fill....f,z	- Relative NA of condenser; range: 0.0 to 2.0 (up to 5 commands)	(Def: 0.0 - full coherence)
RNX	x_shift_of_fill....f,z	- X decenter of fill - fraction of pupil	(Def: 0.0)
RNY	y_shift_of_fill....f,z	- Y decenter of fill - fraction of pupil	(Def: 0.0)
SRC	[Zi] [Fk] [ST1|ST2|ST3] filename [eff_src_radius [rot_angle_degr]]	- Define source distribution via .INT file	(Def: not done)
or **SRC**	[Zi] [Fk] ANN rna_min rna_max	- Define annular (ANN) source	(Def: not done)
or **SRC**	[Zi] [Fk] CIR #_poles rna_min rna_max [rot_angle_degr]	- Define multi-pole intensity distribution with circular (CIR) poles	(Def: not done)
or **SRC**	[Zi] [Fk] SEC|BUN #_poles rna_min rna_max pole_subtense [rot_angle_degr]	- Define multi-pole intensity distribution with sector (SEC) or bun-shaped (BUN) poles	(Def: not done)
or **SRC**	POL [RAD|LIN|MIX|CIR|CIL] [fraction_pol]	- Defines the polarization that goes with the intensity pattern. The types of polarization are: – RAD is radial. This is the default. – LIN is linear in X. – MIX is linear in X for the first pole, but changes for each pole. – CIR is right circular. – CIL is left circular.	(Def: not done)

Object Parameters

BGI	background_fract_int....f,z	- Background intensity value	(Def: 0.0)
AZI	object_azimuth_degr....z	- Object orientation	(Def: 0.0)
RCT	x_width y_width [x_location y_location [intensity [phase_degr [rot_angle_degr]]]]	- Specify rectangular object. Up to 50 objects can be entered	(Def: not done)
INT	filename radius [rot_angle_degr]	- Specify .INT file for object intensity	(Def: not done)
PHA	filename radius [rot_angle_degr]	- Specify .INT file for object phase	(Def: not done)

Computation Controls

TGR	num_fft_grid_pow_of_two	- Transform grid; range: 16 or more	(Def: 128)
PGR	num_integration_grid_width	- Limit integration size	(Def: TGR-1)
NRD	num_rays_across_diameter....z	- Determine grid from pupil diameter	(Def: TGR/2 at short wl)
or **GRI**	image_grid_spacing....z	- Focal plane grid	(Def: Airy disc diameter/ 4.88, short wl)

Output Controls

COM	Yes|No....z	- Compact listing; omits blank lines	(Def: No)
LIS	Yes|No....z	- Include listed output (No kills listing with plots)	(Def: Yes)
WBF	Bk	- Write the PAR output to the specified buffer (not B0)	(Def: not done)
PLO	Yes|No....z	- Oblique projection plot	(Def: Yes)

ROT	Yes|No....z	- Rotate oblique projection plot by 90°	(Def: No)
CON	[SUP] Yes|No....z	- Contour map plot. SUP suppresses numbering	(Def: No)
LEV	[contour_level....30]	- Select contour levels to be plotted	(Def: LEV NUM 30)
LEV INC	contour_increment	- Uniform levels, specified by increment	(Def: LEV NUM 30)
LEV NUM	num_contour_levels	- Uniform levels, specified by total number	(Def: LEV NUM 30)
TIT	'temporary_title'(20+20)....z	- Temporary title	(Def: 1st 40 char. lens_system_title)

Color Display

DIS	[SRC] [Zi] [Fk] Yes|No	- Color contour map display. SRC specifies that the source intensity will be displayed in the color contour map.	(Def: No)
RAN SCA	num_steps [min_value max_value]	- Set color range	(Def: 50)
RAN COL	SPE|RGB [r_value g_value b_value]	- Select type of color scale SPE - spectral color rainbow RGB - monochrome color ramp from black to r_value, g_value, b_value (values from 0 to 1)	(Def: SPE)
BAC	r_value g_value b_value	- Background color in RGB units	(Def: 0.30 0.49 0.49)

PSF - Point Spread Function

(Diffraction)

Select Analysis (Def: INT NOR)

INT	[NOR|STR|DB|listed_peak_intensity|No....z]	- Include intensity display.(NOR - normalized to peak = 100 STR - normalized to perfect lens = 100 DB - dB falloff from peak = 0 listed_peak_intensity - enter normalization value No - skip computation and display for this zoom position	Def: NOR)
THR	output_noise_threshold_db....z	- For INT DB only. Set values below threshold to threshold value	(Def: -50)

Computation Controls

TGR	num_fft_grid_pow_of_two	- Transform grid; range: 16 or more	(Def: 128)
PGR	num_integration_grid_width	- Limit integration grid size for display, encircled energy and centroiding	(Def: TGR-1)
NRD	num_rays_across_diameter....z	- Determine grid from pupil diameter	(Def: TGR/2 at short wl)
or **GRI**	image_grid_spacing....z	- Focal plane grid	(Def: Airy disc diameter/4.88, short wl)
PRO	Yes|No	- Use propagate equations for out-of-focus image	(Def: No)
XSC	scale_x_psf_by_factor....z	- Scale X dim of image - for anamorphic systems with highly unequal magnifications	(Def: 1.0)

Write PSF to file

WIN	int_filename	- Write PSF grid(s) to file(s) in .INT format	
WBF	[CMP] Bk	- Write the PSF output to the specified buffer (not B0)	(Def: not done)

PSF

Listing Controls

COM	Yes|No....z	- Compact listing; omits blank lines	(Def: No)
LIS	Yes|No....z	- Include listed output (No kills listing with plots)	(Def: Yes)
PHA	Yes|No....z	- Change output to phase distribution in image	(Def: No)

Plotting Controls

	PLO	Yes|No....z	- Oblique projection plot	(Def: Yes)
	ROT	Yes|No....z	- Rotate oblique projection plot by 90°	(Def: No)
	CON	[SUP] Yes|No....z	- Contour map plot. SUP suppresses numbering	(Def: No)
	LEV	[contour_level....30]	- Select contour levels to be plotted	(Def: LEV NUM 10)
or	**LEV INC**	contour_increment	- Uniform levels, specified by increment	(Def: LEV NUM 10)
or	**LEV NUM**	num_contour_levels	- Uniform levels, specified by total number	(Def: 10)
	TIT	'temporary_title'(20+20)....z	- Temporary title	(Def: 1st 40 char. lens_system_title)

Color Display

DIS	Yes|No....z	- Color contour map display	(Def: No)
RAN SCA	num_steps [min_value max_value]	- Set color scale range	(Def: 50)
RAN COL	SPE|RGB [r_value g_value b_value]	- Select type of color scale SPE - Spectral color rainbow RGB - Monochrome color ramp from black to r_value, g_value and b_value (values from 0 to 1)	(Def: SPE)
SIZ	max_pixels	- Set maximum dimension of display area in pixels	(Def: 512)
BAC	r_value g_value b_value	- Background color in RGB units	(Def: 0.30 0.49 0.49)

Detector/Encircled Energy

DEX	No|full_x_dim_of_detector....z	- Change output for convolved detector; DEX only: circular	(Def: No)
DEY	No|full_y_dim_of_detector....z	- Use with DEX for rectangular detector	(Def: No)
ENC	[CHI|CEN] [PLO] Yes|No....z	- Change output to encircled energy; CHI - circles centered at chief ray CEN - circles centered at centroid neither (default) - circles shifted in Y to minimize diameters PLO - plot encircled energy	(Def: No)
PER	encircled_%....z	- Percentages enclosed by circles (Up to 10 commands allowed)	(Def: 10,20,..90)
XMA	horiz_axis_max...z	- Highest X values marked	(Def: 95% encircled energy diameter)
XDE	incr_between_horiz_axis_ticks....z	- X axis ticks increment	(Def: XMA/10)

Two Point Sources

PAI	[Zk|Zi..j] x_separation y_separation	- Change output to convolution with image of 2-point object; X and Y values are in image plane; can't be used with DEX, DEY	(Def: N/A)

Perturbed wavefront:

ADD	Fn [Wm] [B|Q]	- Add perturbation to wavefront at Fn, for Wm; B - bi-lateral symmetry about Y; Q - quadrant symmetry; neither - no symmetry	(Def: N/A)
Y	num_row perturbation_waves_x100....TGR	- Perturbation in waves x 100 in pupil grid cell defined by num_row; column defined by sequence of entries	
YC	perturbation_waves_x100....TGR	- Use YC to continue entries of Y command	

QUA - Quadrant Detector Analysis

(Geometrical)

NRD	num_rays_across_diameter....z	- Determine grid from pupil diameter The number of rays for the wavelength with the largest weight. The default is that a total of approximately 316 rays are traced. The relative number of rays traced for each wavelength is determined by the wavelength weights. For a single wavelength, this corresponds to a value of 20 for the number of rays across the diameter.	
STE	scan_step_size....z	- REQUIRED. Step size for scans in X and Y (up to 20 commands allowed)	
GAU	smoothing_spot_diam|No....z	- Smooth with a Gaussian distribution;for simulating Gaussian object (i.e, CRT spot); value is for the 50% intensity point	(Def: 1/200 of spot diameter)
QRE	selective_response_fraction|No....z	- Add output for the two scan positions where the response and its reciprocal are the designated value (up to 20 commands allowed)	(Def: No)

RAD - Radial Energy

(Geometrical)

NRD	num_rays_across_diameter....z	- Determine grid from pupil diameter for each wavelength	(Def: 20)
PER	encircled_%....z	- Percentages enclosed by circles Up to 10 commands allowed)	(Def: 10,20,..100)
XSC	Yes|No....z	- Scan centers in X only	(Def: see YSC)
YSC	Yes|No....z	- Scan centers in Y only	
		(Def: if no XSC,YSC entered, do both if no symmetry about Y-Z plane exists; otherwise, do Y only)	
COO	Yes|No....z	- List coordinates of circle centers	(Def: No)
PLO	Yes|No....z	- Plot encircled energy	(Def: Yes)
XMA	horiz_axis_max....z	- Highest X values marked	(Def: 100% encircled energy diameter)
XDE	incr_between_horiz_axis_ticks....z	- X axis ticks increment	(Def: XMA/10)

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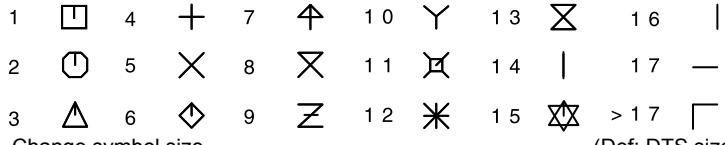
SPO - Spot Diagram

(Geometrical)

PLO	Yes|No....z	- Plot spot diagram	(Def: Yes)
SSI	image_size_per_scale_bar....z	- Aberration scale size in X and Y	(Def: automatic scaling)
SSX	image_size_per_scale_bar....z	- Override SSI in X	(Def: SSI)
SSY	image_size_per_scale_bar....z	- Override SSI in Y	(Def: SSI)
LAB	Yes|No|color....z	- Label plot	(Def: Yes)
TIT'	temporary_title'(40)....z	- Temporary title	(Def: 1st 40 ch. lens_system_title)
WVL	Yes|No|color....w	- Plot this wavelength	(Def: CLS WVL colors)

Plot Symbols

DOT	No|num_dot_symbol....w	- Plot points as symbols; range of symbols: 1 to 17; No - use the default	(Def: DTL symbols)



DSI	dot_size_fraction_of_scale_bar	- Change symbol size	(Def: DTS size)

Listing of Image Coordinates

LIS	Yes|No....z	- List ray coordinates	(Def: No)

Computation Controls

RTL	[NRD] n	- RMS spot size calculation: based on number of rays across diameter (RTL NRD), or fractional error for RMS defined by *n*.	(Def: RTL 0.01)
PAT	GRD|SOB|CIR	- Pattern of rays across the entrance pupil traced to the image surface: GRD - Rectangular grid of rays CIR - Circular ray pattern SOB - Quasi-random (Sobol) pattern	(Def: PAT GRD)
NRD	num_rays_across_diameter....z	- Number of rays used to generate the spot diagram. The number of rays for the wavelength with the largest weight. The default is that approximately 360 rays are started; those reaching the image plane are used to generate the spot diagram. The relative number of rays traced for each wavelength is determined by the wavelength weights. For a single wavelength, this corresponds to a value of 20 for the number of rays across the diameter.	

Annotations and Overlays

ANN	SPO Yes|No	- Displays text annotation specifying full spot diameter.	(Def: Yes)
ANN	RMS Yes|No	- Displays text annotation specifying RMS spot diameter.	(Def: Yes)

ANN	LEN Yes|No	- Displays text annotation listing lens file name.	(Def: No)
ANN	INI Yes|No	- Displays text annotation listing current date and initials.	(Def: Yes)
AIR	Yes|No	- Adds an ellipse to the spot diagram corresponding to the Airy disk diameter.	(Def: No)
DET	REC|CIR width height	- Superimposes a detector of specified size on the spot diagram.	(Def: Not drawn)
RL	CRA|CEN|USR user_defined_x user_defined_y	- Specifies reference location for center of detector or Airy disk: CRA - Chief ray CEN - Spot centroid USR - User-defined X and Y offsets from chief ray	(Def: RL CRA 0 0)

WAV - Wavefront Analysis

(Diffraction)

BES	Yes|No	- Focus selection-BES (best focus only)	(Def: BES)
NOM	Yes|No	- NOM (at nominal focus and BES)	(Def: BES)
THR	Yes|No	- THR (through-focus and BES)	(Def: BES)
RFO	Yes|No	- Replace focus; increment THI SI with best composite focus shift	(Def: No)
NRD	num_rays_across_diameter	- Determine grid from pupil diameter	(Def: 20)
WTF	field-zoom_weight....f,z	- Field weights to balance for best focus	(Def: System weights)
CPL	num_of_grouping....f,z	- Focus pattern; if num_of_grouping is the same for 2 or more members of the table, they are focused together	(Def: all = 1 - focus all together)

TOR - Wavefront Differential Tolerancing

Tolerance Database Input

Tolerances and compensators are designated through the LDM, and may be modified by inverse sensitivity (INV command). Compensator motions are limited to the entered value (or its default).

Performance Measures

For MTF only:

FRE	lines_per_mm|No....f,z	- Switches performance measure to MTF from RMS, value is frequency for which tolerances are evaluated/generated	(Def: No = RMS)
AZI	TAN|RAD|line_orientation_degr....f,z	- For MTF. Orientation of sine wave targets; RAD: 0; TAN: 90	(Def: TAN)

For RMS only:

CNS	DX | DY | DZ [Fk | Fi..j] [Zk | Zi..j] [Tk | Ti..j] max_absolute_shift	- Lagrange multiplier (hard) constraint on reference sphere shifts	(Def: No)
WTC	DX | DY | DZ [Fk | Fi..j] [Zk | Zi..j] [Tk | Ti..j] weight	- Weighted constraint on reference sphere shifts	(Def: No)

For MTF or RMS:

BOR	[Fi] [Zk] [XC|YC] [L'label'(3)] Yes|No	- Compensate Fi, Zk (def: 1,1) to have zero boresight error, using labeled compensator group. XC, YC- compensate for X or Y error only neither- compensate in X and Y	(Def: No)
MPR	[PDL] mode_radius....z,w	- Activates CEF or polarization dependent loss (PDL) tolerancing and specifies its mode radius (in lens units).	(Def: No)

Zernike Polynomial Controls

	ZRN	[ENP|EXP|EXS] [TIL] num_terms	- Fit with standard Zernikes; fit the entrance pupil (ENP), exit pupil (EXP), or exit sphere (EXS) for each field and wavelength to a Zernike polynomial. TIL specifies that the tilt terms in the Zernike representation of the wavefront are included in the error function.	(Def: No fit)
or	**ZFR**	[ENP|EXP|EXS] [TIL] num_terms	- Fit with fringe Zernikes	(Def: No fit)
or	**ZFE**	[ENP|EXP|EXS] [TIL] num_terms	- Fit with extended fringe Zernikes	(Def: No fit)
	ERF	Ej erf_name [erf_weight]	- Specifies an error function that is the weighted sum of squares of the specified Zernike coefficients and/or distortion.	
	COM	Ej Ck [component_weight]	- Defines specified coefficient number as a component of the Ej error function.	
	COM	Ej DIX|DIY [component_weight]	- Specifies distortion in the error function.	

UNI	LNS|MIC|MIL|AMI|ASE|MLR|MCR|NM|IN|MM|CM	- Specifies the units of the error function if it has linear units (e.g., critical dimension), as well as the units of distortion: LNS - Lens units MIC - Microns MIL - Mils AMI - Arc minutes ASE - Arc seconds MLR - Milliradians MCR - Microradians NM - Nanometers IN - Inches MM - Millimeters CM - Centimeters	(Def: Lens units)
LIS	[SEN] [PER] num_terms	- Lists components of Zernikes in sensitivity (SEN) and performance (PER) tables. Num_terms indicates how many terms to list.	(Def: No)

Computation Controls

INV	[DCP] [decrease_in_performance....f,z]	- Inverse sensitivity; generates values of tolerances subject to limits(LIM) and rounding(ROU) DCP-decouple the values of two-component tolerances	(Def: 0.01)
or **SNS**		- Sensitivity of current tolerances	(Def: INV)
NRD	num_rays_across_diameter	- Number used in each wavelength; use 10 for rough accuracy tolerancing	(Def: 32)
ROU	Yes|No	- For INV. Round tolerances to simple value	(Def: Yes)

Compensation Controls

WTF	field-zoom_weight....f,z	- Field weights to balance for compensation	(Def: System weights)
WTD	dist_wt_y [dist_wt_x]	- Weight on distortion compensation	(Def: 0.0 0.0)
WTS	linear-quadratic_ratio	- Relative weight on linear vs. quadratic terms	(Def: 1.0, equal)
SYM	Yes|No	- For compensation, force object points at both + and - Y	(Def: No)

Output Controls

FUL	Yes|No	- Lists tolerance descriptions and constant, linear, and quadratic coefficients	(Def: No)
SEL	[Yes|No|performance_threshold]	- Select outputs above threshold only Yes - select only outputs that are: for INV - above decrease_in_performance for SNS- above 0.01 No - list all tolerance effects performance_threshold - select only outputs that exceed value	(Def: No)

PLO [GRD|GRX|GRY] [SPL|LIN|PNT] [#_trials [min_errf [max_errf [delta_errf]]]] (Def: PLO)
or **PLO** No

- Produces plotted output showing the cumulative probability of the image quality versus the figure of merit, which is either RMS wavefront error, MTF, or coupling efficiency.
  - GRD - Draw grid lines in X and Y.
  - GRX - Draw grid lines in X.
  - GRY - Draw grid lines in Y.
  - SPL - Spline fit on data
  - LIN - Connect points with straight lines
  - PNT - Plot points only
  - #_trials -Number of Monte Carlo trials.
  - min_errf -Minimum value for X axis range.
  - max_errf -Maximum value for X axis range.
  - delta_errf -Increment for tick marks or grid lines on X axis.

DST [L'label'(3)] Yes|No|ALL - List x, y distortion summary only; ALL includes contributions from each tolerance; a label uses compensators with that label for distortion calibration. (Def: No)

WBF Bk|No SEN|DST|PER|ZRN|MC[APP] (Def: No)

- Writes TOR output to the specified buffer.
  - SEN - writes sensitivity tables
  - DST - writes distortion tables
  - PER - writes performance summary data
  - ZRN - writes Zernike sensitivity data of the compensators, if the Zernike error function has been specified.
  - MC - writes Monte-Carlo data to the buffer, whether plotted output is produced or not.

  You can write all types of data to the same buffer. The buffer will be cleared before new data is saved to it, unless it is the same buffer used in the current TOR run, or the APP qualifier has been entered.

For CEF tolerancing only:

DB Yes|No [threshold] - Convert coupling efficiency to units of decibels subject to the threshold value. The default threshold is -50 dB. (Def: No)

For RMS only:

XYZ Yes|No|ALL - List x,y,z reference sphere shifts; ALL includes shifts for each optimally compensated tolerance (Def: No)

Probability Density Functions

PDS UNI - For scalar (1D) tolerances: (Def: UNI)
or **PDS** GAU gaussian_truncation_value
or **PDS** END
or **PDS** MOM second_moment fourth_moment

- UNI - uniform in 1D
- GAU - 1D Gaussian with specified truncation value
- END - tolerances can only take on values at end points
- MOM- second and fourth moment of density function

	PDD	UNI	- For decentered (2D) tolerances:	(Def: GAU 0.135)
or	**PDD**	GAU gaussian_truncation_value	UNI - uniform in 2D	
or	**PDD**	END	GAU - 2D Gaussian with specified truncation value	
or	**PDD**	MOM second_moment fourth_moment	END - tolerances can only take on values at end points	
			MOM- second and fourth moment of density function	
	PDI	UNI	- For cylindrical irregularity tolerances:	(Def: UNI)
or	**PDI**	GAU gaussian_truncation_value	UNI - uniform in 2D	
or	**PDI**	END	GAU - 2D Gaussian with specified truncation value	
or	**PDI**	MOM second_moment fourth_moment	END - tolerances can only take on values at end points	
			MOM- second and fourth moment of density function	

Tolerance Limits

LIM tolerance_code min max increment - For INV.

Defaults (where 3 numbers appear, they correspond to inches, centimeters, millimeters):

tolerance_code		min	max	increment
Centered Tolerances				
LIM	**DLF**	2.0	12.0	2.0
LIM	**DLT**	.001/.002/.02	.025/.05/.5	.001/.002/.02
LIM	**DLN**	.0001	.002	.0001
LIM	**DLV**	.002	.008	.001
LIM	**DLR**	.001/.002/.02	1.E10	.001/.002/.02
LIM	**DLS**	.0001/.0002/.002	.002/.005/.05	.0001/.0002/.002
LIM	**DLC|DAK|DAA|DAB|DAC|DAD|DAE|DAF|DAG|DAH|DAJ**	1.E-10	1.E10	1.E-6
LIM	**HOM**	5.E-6	.001	5.E-6
LIM	**AXG|RAG**	.0001	.002	.0001
Irregularity Tolerances				
LIM	**IRR|CYD|CYN**	.5	3.0	.5
Single Surface Decenters and Displacements				
LIM	**DEC|DLX|DLY|DLZ**	.001/.002/.02	.025/.05/.5	.001/.002/.02
LIM	**TIL|DLA|DLB|DLG**	.0003	.005	.0005
LIM	**TIR|TRX|TRY**	.0001/.0002/.002	.005/.01/.1	.0001/.0002/.002
Group Decentering Tolerances				
LIM	**STI|STX|STY**	.0003	.005	.0005
LIM	**BTI|BTX|BTY**	.0003	.005	.0005
LIM	**BRL**	.0003	.005	.0005
LIM	**DIS|DSX|DSY|DSZ**	.001/.002/.02	.025/.05/.5	.001/.002/.02
LIM	**ROL|RLX|RLY**	.001/.002/.02	.025/.05/.5	.001/.002/.02
LIM	**DOL**	.001/.002/.02	.025/.05/.5	.001/.002/.02

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Polarization Tolerances

LIM	**PPA**	.001	.1	.005
LIM	**PPR**	.001	.05	.001
LIM	**PPO**	.0003	.005	.0005
LIM	**PPF**	.0003	.005	.0005
LIM	**BMN**	.000001	.001	.000005
LIM	**BMA|BMB|BMG**	.001	.05	.005

Zernike Tolerances

LIM	**ZRN**	0.01	1.0	0.001
LIM	**ZFR**	0.01	1.0	0.001

Linewidth Computation Controls for 1D Partial Coherence Tolerancing

CDT	threshold....z	- Computes width of image (Critical Dimension, or CD) of one bar of a bar object at a given intensity threshold.	
BAR	num_of_bars width_of_one_bar….f, z	- Specifies a bar object pattern.	(Def: 1 bar, 0.0 width. A zero-width line.)
PER	distance_between_bar_centers....f,z	- Use only with BAR setting, for more than 1 bar. Period of multi-bar pattern expressed as separation of bar centers in dimensions of its geometrical image.	(Def: Twice the BAR width. Equal bar and spaces.)
DEP	min_fract_intensity....f,z	- Use with multi-bar patterns. Defines fractional dip to the minimum intensity in the space(s) relative to the bars at 1.0.	(Def: 1.0)
BGI	background_fract_int....f,z	- Adds background intensity; compresses bar pattern to range above background.	(Def: 0.0)
INN	bar_fract_int....f,z	- Intensity of bar.	(Def: 1.0)
PHN	[ALT] bar_phase_deg....f,z	- Phase of bar in degrees.	(Def: 0.0)
BGP	background_phase_deg....f,z	- Phase of background in degrees.	(Def: 0.0)
NEG	Yes|No	- Inverts the object profile.	(Def: No)
AZI	orientation_degrees....z	- Specifies orientation of the bar; rotates the bar by the specified angle.	(Def: 0.0)
NRD	number_rays_across_diameter	- Determines ray trace grid for PAR calculation.	(Def: TGR/2)
GRI	image_grid_spacing	- Focal plane grid for PAR calculation.	(Def: Shortest wavelength * fnumber/2)
RNA	fraction_of_fill....f,z	- Relative NA of condenser; range: 0.0 to 2.0 (Up to 5 commands)	(Def: 0.0 - full coherence)
RNX	x_shift_of_fill....f,z	- X decenter of fill - fraction of pupil	(Def: 0.0)
RNY	y_shift_of_fill....f,z	- Y decenter of fill - fraction of pupil	(Def: 0.0)
TGR	num_fft_grid	- Transforms grid size.	(Def: 128)
ERF	Ej erf_name [erf_weight]	- Specifies an error function.	(Def: If CDT is specified, a single error function representing the vertical CD)

	COM	Ej CDH|CDV|HVB|LRH|LRV|OVH|OVB [weight]	- Defines the specified lithographic metric as a component of the Ej error function.	(Def: CDV)
	SCN	Yes|No	- For SCN Yes, the image is integrated over the field for each zoom position.	(Def: No)
	SRC	[Zi] [Fk] [ST1|ST2|ST3] filename [eff_src_radius [rot_angle_degr]]	- Define source distribution via .INT file	(Def: not done)
or	**SRC**	[Zi] [Fk] ANN rna_min rna_max	- Define annular source	(Def: not done)
or	**SRC**	[Zi] [Fk] CIR #_poles rna_min rna_max [rot_angle_degr]	- Define multi-pole intensity distribution with circular (CIR) poles	(Def: not done)
or	**SRC**	[Zi] [Fk] SEC|BUN #_poles rna_min rna_max pole_subtense [rot_angle_degr]	- Define multi-pole intensity distribution with sector (SEC) or bun-shaped (BUN) poles	(Def: not done)
or	**SRC**	POL [RAD|LIN|MIX|CIR|CIL] [fraction_pol]	- Defines the polarization that goes with the intensity pattern. The types of polarization are: – RAD is radial. This is the default. – LIN is linear in X. – MIX is linear in X for the first pole, but changes for each pole. – CIR is right circular. – CIL is left circular.	(Def: not done)

TOD - Distortion Tolerancing - Chief Ray Distortion

Performance Measure Construction

UNI	LNS|MIC|MIL|AMI|ASE|MLR|MCR	- Units of distortion: Image: LNS - lens units; MIC - microns; MIL - mils Object: AMI - arc min; ASE - arc sec; MLR - milli-radians; MCR - microradians	(Def: LNS)

Relation of Field Positions:

BRF	[Fk] Yes|No	- Subtract chief ray values at Fk from all others	(Def: No)

Relation of Zoom Positions (Use up to 7 ZPO commands to cover all needed zoom positions):

	ZPO SIN	Zk	- Use single lens represented by Zk	(Def: SIN, all pos)
or	**ZPO**	[DIF|AVE] Zk Zn	- Compare lens in Zk with lens in Zn; DIF: Zk - Zn AVE: average Zk with Zn neither= DIF	

Controls

WTF	field-zoom_weight....f,z	- Field weights to balance for compensation	(Def: System weights)
XSY	Yes|No-Assumes X	- symmetry regardless	(Def: No)

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TOL - Primary Aberration Based Tolerancing

Tolerance Database Input

Tolerances are designated through the LDM, and may be modified by inverse sensitivity (INV command).

Add-on Tolerance

ADD	[Zk|Zi..j] error_in_perf_meas gaussian_at_cutoff 'description'(50)		
		- User-defined degradation	(Def: None)

Output Table Selection (select 1 or more - default gives all tables applicable to performance measure)

FIR	Yes|No....z	- Lists only first order attribute table
THI	Yes|No....z	- Lists only third order and X, Y focus tables
THR	Yes|No....z	- Same as THI converted to RMS
CEN	Yes|No....z	- Lists FIR, THI, and THR tables
IRR	Yes|No....z	- Lists only sensitivities of CYL and HOM
DEC	Yes|No....z	- Lists only 0 and 2nd order decenter aberrations
DER	Yes|No....z	- Lists only 2nd order aberrations converted to RMS
DEF	Yes|No....z	- Lists full diagnostic development -DEC and DER tables

Functions and Output Commands - These act immediately to perform the required operation; there are no defaults:

TAB	Yes|No....z	- List table of data and tolerances developed in TOL
SNA	Yes|No....z	- Generate sensitivity tables of all performance measures
SNS	* Yes|No....z	- Generate sensitivity table of this performance measure
INV	* Yes|No....z	- Generate tolerances - inverse sensitivity of this performance measure
MON	* Yes|No....z	- Effect of Monte Carlo simulation on this performance measure
AVE	Yes|No....z	- Change lens to average of Monte Carlo systems
PER	Yes|No....z	- Change lens to last of Monte Carlo systems

* Performance Measures (See “TOL - Primary Aberration-Based Tolerancing” on page 20-81 of the *CODE V Reference Manual*):

IMA|EFL|EP|OBJ|TT|RED|	- First order
SA|COM|ASS|AST|DST|AX|LAT|XFO|YFO|	- Third order and astigmatic foci
RSA|RCO|RAS|RFC|RFI|RMA|RMF|	- Third order and astigmatism converted to RMS
DDI|DDT|DDR|DCO|DAS|DTI|DRC|DRA|DRN|DFT|DFN|	- Decentered aberrations and RMS equivalents
AXI|EDG|EDF	- Compound aberrations

Controls

TRI	num_of_trials....z	- Used for MON, AVE, PER; range:1 to 1000	(Def: 100)
TAR	change_in_perf_meas....z	- For INV; target for change	(Def: 0.01)

ALI - Alignment Optimization

(Assumes that interferogram files exist with filespec int_filename.INT - see "ALI - Alignment Optimization" on page 21-5 of the *CODE V Reference Manual* for details on creation and format. Deformations attached to surfaces are assigned in the LDM; specify compensators (CMP) and INC (independent compensation over field) in the LDM; compensator motions are limited to the entered value (or its default); measured system wavefronts to be optimized by realignment are assigned here).

Interferogram Field Data

INT	Fk [Zn] int_filename	- Assign system wavefront file data to Fk, Zn (at least 1 REQUIRED).	
ISF	Fk scale_factor....z	- Scale system wavefront deformation data at Fk by factor	(Def: 1.0)

Reference Interferograms to Exit Pupil

(Use FID or IMI, IRO, INR, INX, INY, not both)

FID	Fk [Zn] x_R2 y_R2 x_R3 y_R3 [x_R4 y_R4 [x_R5 y_R5]]	- Translate, rotate interferogram to pass rays R2, R3 (and mirror image with R4, R5 if needed) through the fractions of the unit circle specified in x_..., y_...	(Def: None. Uses IMI, IRO, INR, INX, INY)
or **IMI**	Fk XC | YC | No....z	- Mirror image: XC - reverse X lateral coordinate YC - reverse Y lateral coordinate No - remove mirror image reversal	(Def: No)
IRO	Fk ang_rot_degr....z	- Rotate interferogram	(Def: 0.0)
INR	Fk radius....z	- Assign unit radius of interferogram to this linear dimension on exit pupil, perpendicular to chief ray	(Def: semi-diameter of exit pupil)
INX	Fk x_dec....z	- X coordinate on exit pupil of interferogram center	(Def: Chief ray intersection)
INY	Fk y_dec....z	- Y coordinate on exit pupil of interferogram center	(Def: Chief ray intersection)

Convert Non-Normal Null Test Interferogram File to Surface Deformation File

(One, and only one, interferogram processed at a time; alignment operation is bypassed)

NUL	Sk [radius]	- Fit Zernike polynomial to surface deformations needed to explain difference between measured and traced wavefronts. Radius is the surface height converted to polynomial unit circle; default is clear aperture of Sk	
ZRN	num_terms	- Specify number of terms for standard Zernike polynomial	(Def: 36)
or **ZFR**	num_terms	- Specify number of terms for FRINGE Zernike polynomial	
WIN	int_filename	- Write interferogram (Zernike coefficients) to file int_filename.INT	

Ray Number, Weights

NRD	num_rays_across_diameter	- Number used at each field/zoom	(Def: 16)
WTF	field-zoom_weight....f,z	- Field weights to balance for solution of alignment parameters	(Def: System weights)

Focus Adjustments

FOC	focal_shift....f,z	- Specifies pattern of focal surface adjustments	(Def: 0.0)

CAM - CAM Calculation

A zoom system has been designed for which the in-between cam behavior is needed.

Mode 1 - Interpolate all zoomed data between positions - approximate, but fast

Enter CAM with lens system zoomed.

NCS	num_points_in_cam	- Number of total cam steps; max = 200	(Def: 200)
LIN	value....z	- Values for any parameter to be stepped linearly	(Def: 1st zoomed thickness)
LLA	'linear_parameter_label'(7)	- Label for column of LIN command values	(Def: 'THI n')

Mode 2 - Step and optimize - accurate, but slow

Note: This is a front end to AUT; besides these inputs, the program expects to accept AUT inputs defining the rest of the optimization, before GO is given.

Enter CAM with lens system dezoomed to either extreme position of the cam. Freeze all but the zoomed spaces. Recognize that the same conditions (vignetting, f/no or EPD, etc.), will apply throughout run; if this is not valid, break up cam run into multiple runs where it is valid or write macro.

STE	Sk	- Step THI Sk as linear parameter	(Def: 1st AUT constraint)
INC	step_size	- REQUIRED. Increment in linear parameter	
LIM	max_value_of_stepped_parameter	- REQUIRED. Largest value of linear parameter	
LIS	Sk....7	- REQUIRED. Separations (THI) to be listed for cams	
BAS	constant_added_to_listed_sep....7	- Add constant(s) to listed separations	(Def: 0.0)

(Follow Mode 2 commands with AUT commands that apply to this run.)

COS - Cost Analysis

(Defaults: For lens units in inches, centimeters, millimeters)

BLD	block_diameter	- Block diameter in lens units	(Def: 12, 30, 300)
SEP	gap_between_blocked_elements	- Edge-to-edge gap in lens units	(Def: 0.03, 0.08, 0.8)
STE	max_blocker_angle_degr	- Maximum "steepness"	(Def: 160)
MAX	num_max_elements_on_blocker	- Limit on number, not otherwise limited	(Def: 100)
EDG	incr_for_edging	- Diameter allowance for edging	(Def: 0.04, 0.1, 1.0)
DTH	extra_center_thickness	- Thickness allowance for grinding	(Def: 0.06,0.15,1.5)

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CXP - CAD Export

Note:
The command GLO in LDM can be used to set the reference surface. If no global origin is defined, S1 is used.

Export Controls

TYP	IGE|SAT|STE	- Defines the output file format: IGES, SAT, or STEP.	(Def: IGES)
FIL	[filename]	- Filename, extension based on selected file type (IGES, STEP, of SAT).	(Def: lens_name.IGS)
LYR	[Sk|Si..j] [Zk|Zi..j] layer_number	- Defines the CAD layer number for the export model. Supported only by the IGES format.	(Def: LYR SA ZA 1)
REN	Yes|No	- When the file export is run, automatically creates a 3D Viewing (V3D) window containing a rendering of the model.	(Def: Yes)

Model Controls

SUR	[Sk|Si..j] [Zk|Zi..j] Yes|No	- Select surface range and zoom position range; cumulative. Only active zoom positions (POS Zk = Yes) will be included.	(Def: SUR SA ZA Yes)
RVS	[Sk|Si..j] [Zk|Zi..j] Yes|No	- Enables rendering of connective edge surfaces (generated by CODE V between actual surfaces), to make the surface model appear as a solid model.	(Def: RVS SA ZA Yes)
DUM	[Sk|Si..j] [Zk|Zi..j] APE|Yes|No	- Include dummy surfaces within range; cumulative.	(Def: DUM APE)
OVE	[Sk]	- Overlays active zoom positions in the export file. Also overlays zoom positions in a single graphical output window, if a rendering is requested (REN Yes).	(Def: S1)

Ray Definition

CAB	OBS|Yes|No	- Defines how rays are traced: CAB OBS: rays are traced up to the surface where they are obscured, outside the clear aperture, or miss the surface. CAB Yes: rays that are obscured, outside the clear aperture, or miss the surface, are not drawn. CAB No: all rays are drawn through the system.	(Def: CAB OBS)
RFR	[Fk|Fi..j] [Zk|Zi..j] Yes|No	- Renders/exports reference rays from designated fields and zoom positions.	(Def: RFR FA ZA Yes)
RSI	[Fk|Fi..j] [Zk|Zi..j] [Wi] [VIG] x_pupil_fract y_pupil_fract	- Renders/exports single ray at Fk, Zk, Wi, for x, y pupil fraction coordinates.	(Def: No single rays are rendered)
FAN	[Fk|Fi..j] [Zk|Zi..j] [Wi] [VIG] [YZ|XZ|pupil_angle_degr] [num_of_rays_across_diameter]	- Specifies a fan of rays to be rendered/exported for specified fields, zoom positions, and wavelengths.	(Def: No fans)
GRD	[REC|POL] [Fk|Fi..j] [Zk|Zi..j] [Wi] [VIG] [#_x_rays|#_rings] [#_y_rays|#_spokes]	- Renders/exports rectangular or polar grid of rays.	(Def: No grids)

RAT THI	1|2|3|4|5	- Designates thickness, in pixels, for ray drawing requests.	(Def: 1)
RAT COL	color|No...z	- Designates color for ray drawing requests. Applies only to renderings in CODE V; not supported in export file.	(Def: FLD color)
RAT LYR	layer_number	- Designates CAD layer for all ray requests that follow. Only supported in the IGES format.	(Def: 1)
RAT DEF		- Resets all ray drawing attributes (RAT commands) to their default values.	

FAB - Fabrication Data

Output Controls

SUR	Yes|No	- Surface listing instead of element listing	(Def: No, unless asymm.)
IND	Yes|No	- Include refractive index table	(Def: No)
SPA	Yes|No	- Include spacer table	(Def: No)
ZLI	Yes|No....z	- List as non-zoom system in each position	(Def: No)
GSC	[Sk|Si..j] Yes|No....z	- List surface positions relative to GLO coordinates given in the LDM	(Def: No)

Aspheric Sag Data

SAG [Sk] [max_ht|No incr_ht|No ref_curv|No delta_excess|No min_ht|No]

- Add sag table for each designated aspheric surface; if Sk is omitted, do all. (Def: No table)

Defaults (use No):

max_ht	clear aperture
incr_ht	rounded - 20 to 40 steps
ref_curve	CUY for surface
delta_excess	0.0
min_ht	obscuration (if active), 0.0 otherwise

BES	Yes|No	- Make ref_curve = best fitting sphere	(Def: No)
FRI	Yes|No	- Include fringe departure from sphere	(Def: No)
SLO	Yes|No	- Include surface slope	(Def: No)

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Interferogram Contour Plots

	CON	[SUP] interf_filename	- Contour map plot of interferogram file, instead of FAB data table. SUP suppresses numbering	(Def: No)
or	**CON**	[SUP] Si|ENP|EXP	- Contour map plot of the interferogram data assigned to the specified surface, exit pupil, or entrance pupil, instead of FAB data table. SUP suppresses numbering.	(Def: No)
	LEV	[contour_level_waves....30]	- Select contour levels to be plotted	(Def: LEV NUM 10)
or	**LEV INC**	contour_increment_waves	- Uniform levels, specified by increment	(Def: LEV NUM 10)
or	**LEV NUM**	num_contour_levels	- Uniform levels, specified by total number	(Def: 10)
	ADW	x_tilt_waves [y_tilt_waves [focus_waves [piston_waves]]]	- Add tilt, focus, and piston, in waves at unit circle	(Def: 0 0 0 0)

Color Display:

	DIS	[INT] interf_filename	- Color contour map display of interferogram file instead of FAB data table	(Def: No)
or	**DIS**	[INT] Si|ENP|EXP	- Color contour map display of the interferogram data assigned to the specified surface, exit pupil, or entrance pupil, instead of FAB data table.	(Def: No)
	RAN SCA	num_steps [min_value max_value]	- Set color scale range	(Def: 50)
	RAN COL	SPE|RGB [r_value g_value b_value]	- Select type of color scale SPE - spectral color rainbow RGB - monochrome color ramp from black to r_value, g_value and b_value (values from 0 to 1)	(Def: SPE)
	SIZ	max_pixels	- Set maximum dimension of display area in pixels	(Def: 512)
	BAC	r_value g_value b_value	- Background color in RGB units	(Def: 0.30 0.49 0.49)

LTE - *LightTools* Export

Export to *LightTools*

FIL	[filespec]	- Filename, with default extender .sys, for the name of the output file	(Def: lens_name.sys)
IMP	Yes|No	- Specify system as an image path in *LightTools*	(Def: No)
ORI	x_rotation_in_degrees y_rotation_in_degrees z_rotation_in_degrees	- Specify the orientation of the optical axis to match the system in *LightTools*	(Def: 0.0 0.0 0.0)
OAR	[Fk]	- Use the chief ray (R1) of the specified field as the optical axis ray in the *LightTools* imaging path	(Def: F1)
SUR	Si..j	- Surface range to export	(Def: Finite: SO..I Infinite: S1..I)

TES - Test Plate Fitting

Note: TES is a front end to AUT; besides the TES inputs, the program expects to accept AUT inputs (e.g., constraints) defining the rest of the optimization, before GO is given.

(Recommendation: have plate list - PLA.....END - prepared in a filename.SEQ file; invoke with IN filename)

GAP|POW|STC|FUR|NEA - Fitting strategy: (Def: GAP)
- GAP - largest (gap in list)x(index difference) first
- POW - strongest surface power first
- STC - strongest curvature first
- FUR - curvature furthest from test plate first
- NEA - curvature nearest to test plate first

ERM reject_fit_above_erf_max - Error function above which fits are disallowed (Def: 5% larger than starting design error function)

ERI reject_fit_above_erf_increment - Maximum increase in error function allowed in one fit (Def: half of starting gap from ERM)

FUL Yes|No - Include output of all AUTO operations (Def: Yes)

SKI Sk|Si..j - Skip fitting these surface(s);enter as many SKI commands as needed (Def: try to fit all variable surfaces)

LIS Yes|No - Include sorted listing of test plates (Def: No)

PLAI|C|M 'plate_list_name'(80) - Start test plate list, defined in units = I|C|M; order of radius is unimportant - program will sort as needed; an unlimited number of plates

1st_plate_radius
2nd_plate_radius
:
may be entered.
last_plate_radius

END - Terminates the PLA entry

(Follow this set of commands with AUT commands that apply to this run.)

WEI - Weight Analysis

No input required. (Define SPG as needed in the LDM.)

Environmental Change

ENV - Environmental Change

(See also “NASTRAN-Generated Deformations” on page 10-37 of the *CODE V Reference Manual* for receiving deformation information from that program.)

Protection Against Running on Zoom System

(The complexity of zoom systems usually precludes getting meaningful results in ENV; however, the zoom feature is often used for other purposes - adding field angles, shift of reference wavelength, etc. - that don't invalidate ENV results.)

	ZOK	Yes|No	- Override exclusion of zoom systems	(Def: No)

Steady-State Conditions

	TEM	degrees_c	- Temperature of entire system	(Def: No change)
	TOK	Yes|No	- Allows temperatures outside the range 20°C to 40°C.	(Def: No)
	PRE	mm_hg	- Pressure of all spaces	(Def: No change)
or	**ALT**	feet_or_meters	- Pressure expressed as altitude	(Def: see PRE)
	ATT	Si Sj	- Designates surfaces that are separated but physically attached (Use as many as needed)	(Def: only recognizes cemented surfaces)

Pressure/Temperature Gradients

	GRR	Sk radius|M....8	- Radial temperature gradient zones for GRT M in last zone - use surface clear aperture	(Def: N/A)
	GRT	Sk degrees_c|M....8	- Radial temp gradient temperatures for GRR M in last zone - use mount temperature	(Def: N/A)
	PRE	[Sk|Si..j]	- Vacuum used in space(s)	(Def: No change)
or	**PRE**	[Sk|Si..j] mm_hg	- Current gas used in space(s) at mm_hg	
or	**PRE**	[Sk|Si..j] gas_type mm_hg	- gas_type used in space(s) at mm_hg	

where gas_type is:

AIR ARGON ETHANE HELIUM HYDROG MTHANE NITROG OXYGEN

Expansion/Refraction Constants

(Supply alpha values multiplied by E7. Ex: 236 = 23.6 x 10^{-6}.)

	EXP	metal|alpha	- Mount and all spacers	(Def: AL7075 or 236.)
or	**EXP**	Si..j metal|alpha	- Spacers in range	
or	**EXP**	glass_name alpha	- Value for all glasses of a type	(Def: catalog values or 0)
or	**EXP**	Si..j glass_name alpha	- Value for glasses of type in range	
or	**EXP**	Sk alpha	- Value for surface regardless	
or	**EXP**	Sk catalog_glass|metal	- Pre-stored value for surface regardless	
	EXM	[Sk|Si..j] alpha	- 1st surface mirror substrate(s)	(Def: 0.0)
or	**EXM**	[Sk|Si..j] catalog_glass|metal	- 1st surface mirror substrate(s) - prestored value	

where metal generically refers to the materials listed below:

ABS	ALUMINA	CERVIT	GRANITE	MMGRAL	SS316	T400
ABSG	BECU172	CORDIERITE	GREPOXY	MOLYLCG	SS416	TBB
AL356	BEI70A	CR39	INVAR35	MOLYTZM	SS430	TI
AL713	BEI220	CU101	INVAR36	NYLON	SS440	TI6AL4V
AL771	BEI400	CU102	KOVAR	PLEXI	STEEL1015	TSINVAR
AL1100	BEO	DUCTILE	LEXAN	SIC	STYRENE	TSTEEL
AL2024	BES200F	EPOXY	MEGE30	SINVAR	SXA20	ULE
AL6061	BRASSC	FS7940	MGAZ31BF	SS303	SXA30	ZERODUR
AL7075	BRASSF	FSAMERSIL	MGM1A	SS304	SXA40	

Index of Refraction Constants

(Supply dn/dT values multiplied by E6. Ex: 2.3 = 2.3 x 10^{-6}.)

(Use DN or DR, depending on which data is available, to override default data for glasses. Omission of range implies S0..I)

	WL	nanometers....21	- Wavelengths for following DN or DRs	(Def: lens system wavelengths)
	DN	Sk catalog_glass	- Get dn/dTs from designated glass	(Def: 20°C to 40°C cat data)
or	**DN**	Sk abs_dndt....21	- Absolute dn/dTs for wavelengths determined by preceding WL command	(Def: 20°C to 40°C cat data)
or	**DN**	[Si..j] glass_name abs_dndt....21	- Apply values to all of that glass type in range	
	DR	Sk rel_dndt....21	- Relative dn/dTs for wavelengths determined by preceding WL command	
or	**DR**	[Si..j] glass_name rel_dndt....21	- Apply values to all of that glass type in range	

Systems Analysis and Multilayer Design

GHO - Ghost Image Analysis

SUR	Si..j....z	- Limit to ghosts generated between these surfaces	(Def: S1..I-1)
SSP	Yes|No....z	- List first order traces	(Def: No)

LUM - Illumination Analysis

Analysis Controls

NRA	[num_rays]	- Number of rays to trace	(Def: 0)
CLR	Yes|No	- Clear the results of the previous LUM run before starting the current run.	(Def: No)
REV	Yes|No	- Specify the direction in which the lens is set up. Yes indicates the lens is set up in the reversed direction, where the object surface is the receiver, and the image surface is where sources are located. No indicates the sources are located at the object surface, and the receiver is located at the image surface.	(Def: No)
AIM	x_dimension [y_dimension [x_offset [y_offset [z_offset]]]]		
or **AIM**	SPH	- Specify the region for aiming the rays to be considered for the the ray trace. The defaults for the parameters are: x_dimension - calculated y_dimension - x_dimension x_offset - 0.0 y_offset - x_offset z_offset - the distance from the first surface tangent plane to the entrance pupil SPH - rays traced from source into whole sphere surrounding the source (only for finite object distance and REV N) (Def: Maximum aperture of first surface at sag of aperture)	
PHO	Yes|No	- Specify whether the response of the receiver is to be photometric or radiometric	(Def: No)
UNI	CGS|MKS|ENG	- Specify the system of units: CGS - CGS system of units (centimeter, gram, second) MKS - MKS system of units (meter, kilogram, second) ENG - English system of units (foot, pound, second)	(Def: CGS)

Output Controls

EPL	Yes|No	- Plot error estimate for all specified graphical forms	(Def: No)
PLO	Yes|No	- Plot illuminance distribution as an oblique projection plot	(Def: No)
ROT	Yes|No	- Rotate the oblique projection plot by 90° to reveal hidden features. Use only with PLO.	(Def: No)
CON	Yes|No	- Plot a contour plot of the illuminance data	(Def: No)

	LEV	[contour_levels....(30)]	- Select contour levels to be plotted	(Def: LEV NUM 30)
or	**LEV INC**	contour_increment	- Uniform levels, specified by increment	(Def: LEV NUM 30)
or	**LEV NUM**	num_contour_levels	- Uniform levels, specified by total number	(Def: 30)
	TIT	'temporary_title'(20+20)	- Temporary title	(Def: 1st 40 char. lens_system_title)
	SMO	[num_smoothing_passes]	- Specify that the output data are smoothed by a 3x3 smoothing kernel prior to graphical output	(Def: Not done)
	PRO	[Bk] [x [y [angle]]]	- Plot a profile cross-section of the illuminance output	(Def: Not done)
	WIN	int_filename	- Write the illuminance data to the specified .INT file for use in initializing the receiver data in future LUM runs	(Def: Not done)
	WBF	Bk	- Write the illuminance output to the specified buffer	(Def: Not done)
	REL	Yes|No	- Designates output as relative or absolute illuminance	(Def: No)
	NSO	Yes|No	- Designates simulation for single or multiple sets of sources	(Def: No)

Color Display

DIS	Yes|No	- Display illuminance as a colored contour map	(Def: No)
RAN SCA	[num_steps [min_value [max_value]]]	- Scaling of the data range as well as the number of color steps into which the range is divided	(Def: RAN SCA 30)
RAN COL	SPE|RGB [r_value [g_value [b_value]]]	- Type of color scale to be used in display	(Def: RAN COL SPE)
SIZ	[max_pixels]	- Maximum pixel dimension of the rectangular area into which the data are drawn	(Def: 512)
BAC	[r_value [g_value [b_value]]]	- Background region outside the data display area (default color is black)	(Def: 0.0 0.0 0.0)

Receiver Definition

RCV	width [height [x_center [y_center]]]	- Specify the full width and height of the receiver and its position relative to the vertex of the: Image surface - REV No Object surface - REV Yes	(Def: A square with width equal to the largest aperture in the lens)
RCG	num_grids_x [num_grids_y]	- The number of grid boxes in X and Y across the receiver surface	(Def: 21 21)
SYM	ROT|XZ|YZ|QUA|NON	- Specify the lens symmetry for graphics display ROT - system has rotational symmetry XZ - YZ plane about the X axis YZ - XZ plane about the Y axis QUA - four-fold symmetry (XZ and YZ) NON - system has no symmetry	(Def: Calculated from lens)
INT	int_filename....(32)	- Name of .INT file to initialize the receiver grid	(Def: None)

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Source Definition

RMX [Ek] [Zk|Zi..j] max_radiance - Maximum radiance (or intensity or exitance) of the specified source (default is all sources) (Def: 1.0)

SRC [Ek] [Zk|Zi..j] [x [y [z [alpha [beta [gamma]]]]]] - Source location and orientation of specified source facet relative to the origin of the object surface for REV No or relative to the origin of the image surface for REV Yes (Def: 0 0 0 0 0 0)

SHA [Ek] [Zk|Zi..j] REC|ELL|PNT|INF|SPH|CYL [x_width [y_width]] (Def: PNT for forward trace; INF for reverse trace)
- Source boundary shape and full width for the specified source
  - REC - rectangular shape
  - ELL - elliptical shape
  - PNT - point source (not allowed for REV Yes)
  - INF - infinite sheet (not allowed for REV No)
  - SPH - spherical source (diameter is x_width)
  - CYL - cylindrical source (diameter is x_width, length is y_width)

RAP [Ek] [Zk|Zi..j] GAU x_width [y_width [angle]] - Relative radiance spatial profile for the specified source over the surface of the source: (Def: UNI)

or **RAP** [Ek] [Zk|Zi..j] UNI
- GAU - Gaussian spatial distribution
- UNI - uniform spatial distribution of radiance

or **RAP** [Ek] [Zk|Zi..j] FIL filename scale [angle]
- FIL - radiance specified by .INT file

ANP [Ek] [Zk|Zi..j] GAU a_width_degr [b_width_degr [angle]]

or **ANP** [Ek] [Zk|Zi..j] UNI - Relative radiance angular profile for specified source
- GAU - Gaussian angular distribution

or **ANP** [Ek] [Zk|Zi..j] LAM
- UNI - uniform angular distribution of radiance

or **ANP** [Ek] [Zk|Zi..j] FIL filename scale [angle]
- LAM - lambertian distribution
- FIL - radiance is specified by .INT file

or **ANP** [Ek] [Zk|Zi..j] COS n
- COS - cosine^{n} distribution
  - n = 0same as UNI
  - n = 1same as LAM

(Def: UNI for SHA PNT; LAM for all others)

ANG [Ek] [Zk|Zi..j] SUR|LCL|GBL - Specify coordinate system for ANP (Def: SUR)
- SUR - measured relative to surface normal
- LCL - measured relative to source local
- GBL - measured relative to global coordinates of object surface

Menu

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MUL - Multilayer Coating Design and Analysis

MDATA - To input an initial coating stack and operating conditions

```
   MDA                                          - Call sub-option MDATA - for first entry
Operating Conditions
   PHT     Yes|No                               - Thicknesses are physical (nm)                    (Def: No)
                                                    No  -  fraction of waves at REF
   TIT     'multilayer_title'(80)               - Coating title                          (Def: Lens system title)
   WLG     min_wl_nm  max_wl_nm  incr_wl_nm     - Alternate to WL: Enter equally spaced wavelengths
   WL      wavelength_nm....7                   - Coating analysis wavelengths.  Up to 100 wave-
                                                  lengths :can be entered on additional WL records.
   REF     ref_wl_nm                            - Reference wavelength for defining thicknesses in waves
                                                                  (Def: central (or left of center) wavelength)
   ANG     inc_angle_degr....5                  - Define up to 5 incidence angles for computations (Def: 0.0)
Layer Description
   COA       'group_label'(1)                   - Add one coating group to stack
or COA       coating_thi  0|100|num_of_coupling_grp  refr_index  [ext_coef]
or COA       coating_thi  0|100|num_of_coupling_grp  'm_label'(6)
                                                - Define one coating layer in stack; up to 200 layers
                                                  entered in operating sequence
   GRO       'group_label'(1)                   - Start group definition
     COA     coating_thi  0|100|num_of_coupling_grp  refr_index  [ext_coef]
or   COA     coating_thi  0|100|num_of_coupling_grp  'm_label'(6)
     :
     :
     END                                        - Terminate group definition
   SUB       refr_index|'m_label'(6)            - REQUIRED as last layer.  Define substrate medium
   INC       refr_index|'m_label'(6)            - Define incident medium                           (Def: air)
Multilayer Index Catalog
   MIC                                          - Start multilayer index catalog entries
     MWL   wavelength_nm....21                  - Wavelengths for next indices
     'm_label'(6)  refr_index....2              - Indices for each user-defined material
     EXT   'm_label'(6)  ext_coef....21         - Extinction coefficient (optional) for material   (Def: 0.0)
       :
       :
     MWL   wavelength_nm....21                  - Different wavelengths for next indices
           'm_label'(6)  refr_index....21       - Indices for more user-defined materials
       :
       :
     END                                        - Terminates the MIC entry
```

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MCHANGE - To change the data for the coating definitions and operating conditions

	MCH		- Call sub-option MCHANGE - for changing entries	

Operating Conditions

	PHT	Yes|No	- Thicknesses are physical (nm) No - fraction of waves at REF	(Def: No)
	TIT	'multilayer_title'(80)	- Alter title	(Def: Lens system title)
	WL	wavelength_nm....7	- Alter coating analysis wavelengths. Up to 100 wavelengths on additional WL records	
	:			
	REF	ref_wl_nm	- Alter reference wavelength for thickness definition	
	ANG	inc_angle_degr....5	- Alter all incidence angles	
or	**ANG**	Fn inc_angle_degr	- Alter incidence angle for field Fn	

Layer Descriptions

	COA	Sn 'group_label'(1)		
or	**COA**	Sn coating_thi 0|100|num_of_coupling_grp refr_index [ext_coef]		
or	**COA**	Sn coating_thi 0|100|num_of_coupling_grp 'm_label'(6)		
			- Alter coating layer at Sn	
	THI	Sn coating_thickness	- Alter coating thickness on Sn	
	THC	Sn 0|100|num_of_coupling_grp	- Alter coating thickness control on Sn	
	IND	Sn refr_index|'m_label'(6)	- Alter coating index|material on Sn	
	EXT	Sn ext_coef	- Alter coating extinction coefficient for m_label	(Def: 0.0)
	INC	refr_index|'m_label'(6)	- Alter incident medium	(Def: 1.00)
	SUB	refr_index|'m_label'(6)	- Alter substrate medium	
	INS	Sn	- Insert layer ahead of Sn	
	DEL	Sn	- Delete layer Sn	

Multilayer Index Catalog Alteration

	DEL	'm_label'(6)	- Delete material m_label from MIC
	MIC		- Add to MIC; use MWL.....END commands as in MDATA

MANALYSIS - Analyze transmission and reflection of multilayer stack

	MAN		- Call sub-option MANALYSIS - for analyzing data

MAUTO - To optimize transmission of the multilayer stack, using coating thicknesses as variables

	MAU		- Call sub-option MAUTO	

Optimization Targets

	RPT	refl_p_pol_target....7	- Targets - P polarization reflection; up to 100 targets on additional RPT records corresponding to WL values in stack operating data	(Def: 0.0)
or	**RST**	refl_s_pol_target....7	- Targets - S polarization reflection; up to 100 targets on additional RST records corresponding to WL values in stack operating data	(Def: 0.0)
	TRT	trans_ave_target....7	- Targets - average (of S and P) transmittance; up to 100 targets on additional TRT records corresponding to WL values in stack operating data	(Def: 1.0)

WTW	wavelength_wt....7	- Weighting of individual targets; must immediately follow RST, RPT, or TRT target clusters to which they apply. Up to 100 weights on additional WTW records corresponding to WL values	(Def: 1.0)

Optimization Control and Angle Weights

WTA	angle_wt....5	- Relative weight on angle of incidence	(Def: 1.0)
MNT	min_thickness_waves	- Smallest layer thickness, in waves	(Def: 0.0)
MXT	max_thickness_waves	- Largest allowable thickness, in waves	(Def: 0.5)
MNC	num_of_cycles_min	- Minimum number of optimization cycles	(Def: 0)
MXC	num_of_cycles_max	- Maximum number of optimization cycles	(Def: 25)
IMP	min_impr_factor	- Smallest improvement fraction - start looking to exit	(Def: 0.05)

MTOLERANCE - To display changes in transmission and reflection caused by perturbations of coating thickness and index

MTO		- Call sub-option MTOLERANCE	
DLT	fract_thi_variation	- Thickness tolerance in fraction of thickness	(Def: 0.1)
DLN	fract_index_variation	- Index tolerance in fraction of index	(Def: N/A)

MPLOT - Plot transmission or reflection characteristics of the multilayer coating stack

MPL		- Call sub-option MPLOT	
TRN|**RFL**		- Plot transmission (TRN) or reflection (RFL)	(Def: TRN)
AVE|**SPL**|**PPL**|**ALL**		- Plot average polarization (AVE), S polarization (SPL), P polarization (PPL), or all (ALL)	(Def: AVE)
RAN	min_plotted_trans _or_refl max_plotted_trans _or_refl [incr_ticks]	- Range of plotted transmission values and increment for ticks	(Def: 0.0 1.0 0.2)
SPA	min_plotted_wl_nm max_plotted_wl_nm [incr_ticks_wl_nm]	- Span of plotted wavelengths and increment for ticks	(Def: all wavelengths, incr = 1/7 span)

MPRINT - Display data for coating stack and operating conditions

MPR		- Call sub-option MPRINT - for listing data

MLIBRARY - To examine, copy and delete coating files

MLI			- Call sub-option MLIBRARY
DIR			- List the .MUL filenames
DEL	coating_filename		- Delete the designated file
COP	coating_file1	coating_file2	- Copy coating_file1 to coating_file2
REN	coating_file1	coating_file2	- Rename coating_file1 to coating_file2

Immediate Commands - To save/restore a coating stack description

CSA	coating_filename [err_fun]	- Save stack in coating_filename.MUL if current err_fun is less than stored err_fun; if [err_fun] is supplied, it is used for stored value in test
RES	coating_filename	- Restore stack from coating_filename.MUL
SAV	coating_filename	- Save stack in coating_filename.MUL

GO - Triggers execution of any Multilayer option

GO

MEXIT - Triggers exit from Multilayer back to the rest of CODE V; must use MEX

MEX

NAR - Narcissus Analysis

Narcissus Parameters

POS	Yes|No....z	- Analyze zoom position	(Def: POS Z1 Yes; POS Z2..L No)
CLD	Sk....z	- Cold stop surface	(Def: SI-1)
SCN	Sk....z	- Scanner surface (< cold stop surface)	(Def: CLD-1)
TEM	BAC|HOU|DET temperature_degrees_c....z	- Temperatures BAC - scene background HOU - lens housing DET - detector	(Def: BAC 20.0; HOU 20.0; DET -195.86)
BAN	[Zk|Zi..j] wavelength_limit1_nm wavelength_limit2_nm	- Integrate over spectral band	(Def: high, low of WL)
RPS	Sk|Si..j reflectivity_per_surface....z	- Fraction of light reflected at each surface	(Def: 0.01)
NOT	Yes|No	- Include notes about calculation	(Def: Yes)

Real-ray/Scan

PVT	[Sk] ADE|BDE|CDE ending_angle_degr [starting_angle_degr [angle_incr_degr]]	- Enable scanned narcissus calculation and define pivot parameters. Default for pivot surface is scan surface. Default for starting angle = 0, default for angle increment = (ending_angle - starting_angle)/4.	(Def: No; do paraxial calculations)
XDE	x_detector_coord....z	- X coordinate of detector in image plane	(Def: 0.0)
YDE	y_detector_coord....z	- Y coordinate of detector in image plane	(Def: 0.0)
NRD	num_rays_across_cold_stop....z	- Number of rays across cold stop largest aperture dimension	(Def: 15)
SUR	Sk|Si..j Yes|No....z	- Select surfaces for narcissus computations	(Def: SUR SA Yes)

SPE - Spectral Analysis

Define Cascading of Responses (Up to 10 responses can be selected or defined; at least one RSP or BLA must be.)

(Note: In the response names below, the underscore must be typed.)

RSP P_1 | P_11 | P_16 | P_20 | P_24 | S_1 | S_20 | S_20EX |
RCA_I | RCA_II | RCA_III | RCA_IV | RCA V | RCA_VI | RCA_VII |
EARTH | EYE | PHOTOPIC | SCOTOPIC |
WRA_2A | WRA_2B | WRA_2C | WRA_2E | WRA_3 | WRA_4 | WRA_8 | WRA_9 |
WRA_12 | WRA_15 | WRA_16 | WRA_21 | WRA_22 | WRA_23A | WRA_24 | WRA_25 |
WRA_26 | WRA_29 | - Cascade selected responses((Def: None)

RSP 'user_supplied_response_name'(9) - Start user-defined response; cascade; (Def: None)
1st_wavelength_nm 1st_response label is for output; pairs of values define
2nd_wavelength_nm 2nd_responseresponse
:
:
(Up to 10 user-defined responses are allowed)

last_wavelength_nm last_response (Up to 45 entries/definition)
END - Terminates the user-defined RSP entry
BLA color_temp_degr_kelvin - Black body source cascaded with rest (Def: None)
SPA resp_cutoff_long resp_cutoff_short - Limits of integration, listing and plotting
or **SPA** wl_cutoff1 wl_cutoff2 (Def: 0.01 responses or 300 nm to 1000 nm)

Plotting/Listing Controls

PLO [ALL] [LOG] - Plot combined response curve (Def: combined curve)
ALL - plot component responses as well
LOG - use log response scale instead of linear
TIT 'temporary_title'(20+20) - Affects both plotting and listing (Def: 1st 40 char. lens_system_title)
RPL Yes|No - Plot pre-stored response curves, 12 per page (Def: No)

Determine System Weights and Wavelengths

NWL num_wl_bands - Weighting: Number of equal wavelength bands (Def: 5)
FIT [wl_band_nm....21] - Override NWL; specify wavelength band limit (Def: see NWL)
RWL Yes|No - Replace system wavelengths (Def: No)
RWT Yes|No - Replace system wavelengths and weights (Def: No)

SSS - Solar Simulator System

Commands are generally order independent except where noted; all input is read in first and computation starts when GO is received.

Labeling of Output

NOT '1st_label'(60) ['2nd_label'(60) ['3rd_label'(60) ['4th_label'(60)]]]
- Adds up to 4 labeling lines to the listing and plot (Def: All blanks)

Lamp Array

LAM x_center y_center - X,Y position in the object surface of the lamp center (one required) (Def: None)

Mixer Array

ARR Sk num_of_channel x_decenter y_decenter [Yes]
- X,Y position of the designated surface for the specified mixer channel (one required): (Def: None)
Sk - surface number
num_of_channel - assigned channel
x_decenter, y_decenter - coordinates of channel
[Yes] - use LDM clipping apertures on Sk

Perform Simulation

SIM poly_order [grid_increment] - REQUIRED. Compute all needed polynomials, in preparation for SCAn and CLM commands. Default for grid_increment is program generated. (Def: None)

Plotting

PLO Yes|No - Triggers plotting of two scans (Def: No)

Perform Irradiance Scans

ENS	energy_scale_factor	- Scales irradiance derived from apodization by PUI, PUX/PUY commands and/or .INT apodization files	(Def: 1.0)
SCA	beginning_x beginning_y ending_x ending_y num_of_scan_points	- Gives the beginning and ending points of the scan line in the test plane (focal surface) to be performed for irradiance calculations	(Def: None)

Perform Collimation Computation

CLM	x y sin_theta collimation_angle_step_degrees	- Gives the included irradiance for each step of angle for the specified point (x,y) in the test plane (focal surface)	(Def: None)

TRA - Transmission Analysis

FUL	Yes|No....z	- Give full listing on fields beyond the 1st	(Def: No)
NRD	num_rays_across_diameter....z	- Override automatic grid selection	(Def: 20)
PLI	[GEO|STP] Yes|No....z	- List average polarization data	(Def: No)

GEO - geometrical parameters (default for **PLI** Yes)
STP - Stokes parameters

Menu

Search

Defaults and Utilities

Command Processing

Applies to all commands.

\XYZ	- One line syntax HELP for command XYZ
\M*	- One line syntax HELP for all commands in option (or LDM) starting with M (for example)
*	- One line syntax HELP for all commands in option (or LDM)

Option Processing

GO	- Use at end of option input to trigger option operations	(command mode only)
CAN	- Cancel all input to this option	(command mode only)
Ctrl-**BREAK**	- Emergency keyboard intervention to exit computation in this option at the first available opportunity	

Exit from CODE V

EXI [Yes|No]	- Normal exit from CODE V to operating system. EXI Yes exits CODE V without any query to confirm the exit. EXI No is equivalent to EXI, and displays a prompt to confirm the exit.
ALT+F4 (PC)	- Keyboard intervention to exit CODE V immediately

Menu

Search

Immediate Commands/Defaults

Recognized whenever input is expected.

Query by putting a ? in front or behind.

Number of Processors for Parallel Processing

	MPP	num_of_processes	- Sets the maximum number of processors to be used by CODE V when computing a parallel-processing-enabled option	(Def:Number of processors in the computer)

User Helps

	HLN	num_lines	- Number of lines in Help listing (command mode only)	(Def: 20)
	HHE	Yes|No	- Include header and subheaders (command mode only)	(Def: Yes)
	HEL	[command [INDX]]	- Prompting Guide level of HELP	(command line only)
or	**HEL**	CONT	command - 3 letter mnemoic‘ INDX - show command in index list CONT - show table of contents	
	CPU		- Display cumulative CPU time in lens session	(command line only)
	SYS	['op_sys_command'(250)]	- Go to operating system to execute command(s)	(command line only)
	EDI	filespec	- Enter the editor, with the selected file; default extender is .SEQ	(command line only)

Mode Control

	SCR	[COM|NOC] [SAV|NOS]	- Convert to screen mode	(command line only)
or	**GUI**	[COM|NOC] [SAV|NOS]	COM - display command mnemonics (default) NOC - do not display command mnemonics SAV - save screen inputs (default) NOS - don’t save screen input	
	PTH	LEN|SEQ|INT [APP|DEL|PRE] [directory _name1....50]		
or	**PTH**	[LEN|SEQ|INT] Yes|No |?	- Define directory search list LEN - for .LEN and .MUL files SEQ - for .SEQ files INT - for .INT files APP - append to list (make last) DEL - delete from list PRE - prepend to list (make fiirst) Yes - turn on search list No - turn off search list ? - query path list	(Def: PTH Yes)
	SVL	Yes|No|ALL [filespec]	- Save lens when modified by option or user inputs in specified file (default CVRECOVR.LEN). The filename can be up to 256 characters long, including file extension. Yes - save when modified No - do not save when modified ALL - (AUT only) save results of each AUT cycle in successive versions	(Def: No)
	TAD	Yes|No	- Print time and date on printed graphical output	(Def: Yes)
	TOW;	commands	- Generate output in a tabbed output window	(command line only)

Menu

Search

Configuration - Optical

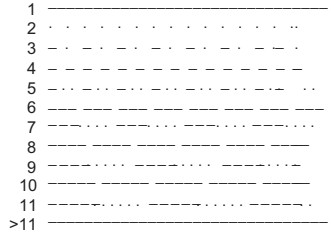
HEA	'heading_for_fabrication_data'(80)	- Company heading for FAB option output	(Def: blank)
DIN	'initials'(3)	- Default user's initials for plotting	(Def: 'ORA')
DDM	I|C|M	- Default dimensions: I - inches C - cm M - mm	(Def: I)
RDM	Yes|No	- Radius I/O mode instead of curvature	(Def: Yes)
CSO	[glass_catalog_name....10]	- Catalog search order; no list restores default order (Def: SCHOTT SPECIAL OHARA HOYA NSG CHANCE CORNFR KODAK CORNING CDGM HIKARI PILINGTON SUMITA CHINA)	

Configuration - Mathematical

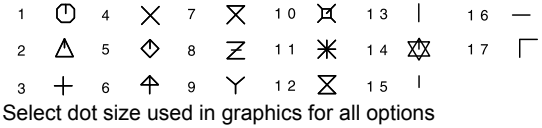
SEE	random_seed	- Seed for random number function RANDF	(Def: -1)

Configuration - Graphics

CLS	[color....25]	- Select colors used for data lists in graphics for all options (Def: See page 24-16 of the *CODE V Reference Manual*)	
CLS WVL	[color....w]	- Select colors used for wavelengths in graphics for all options (Def: See page 24-16 of the *CODE V Reference Manual*)	
CLS FLD	[color....f,z]	- Select colors used for fields in graphics for all options (Def: See page 24-16 of the *CODE V Reference Manual*)	
CLS ZOO	[color....z]	- Select colors used for zoom positions in graphics for all options	(Def: Black)
STL	Yes|No|line_style....25	- Select line styles used in graphics for all options	(Def: No=solid line)



DTL	dot_symbol....25	- Select dot symbols used in graphics for all options	(Def: 1-17)



DTS	dot_size....25	- Select dot size used in graphics for all options	(Def: 0.025)
POC	DEF|BW|color....z	- Select plot color used in graphics for all options DEF - default color BW - black and white (automatically turns on line styles)	(Def: DEF)

Configuration - I/O

BSB	backscroll_buffer_lines	- Number of lines in scrollable backscroll buffer (Def: 2000)
PPS	LTR|A4	- Select paper size for plotting (Def: LTR) LTR - 8.5x11 inch A4 - 210x297 mm
EJE	PAG|Yes|No	- Page eject (.LIS): (Def: Yes) PAG - now Yes - as programmed No - off
ECH	Yes|No	- Echo user terminal inputs to the screen display (Def: No)
CRT	Yes|No	- Use 80 column screen formats as available (Def: No)
COL PLT	color	- Designate default plotting color (Def: BLA)
COL TER	background|No color_1|No color_2|No color_3|No	- Designate the four colors on the display device (Def: BLAck GRAy WHIte CHArcoal)
COL SET		- Enter the interactive color display setup procedure
DEV	PRT|PLT|RAS device_name	- Designates active output device names for user's own installation:
DEV	PLT PROMPT|NOPROMPT|device_name	- Enables or disables Windows Print dialog, or specifies plot device (Def: PROMPT)
	The plot device types are:	
	CEPSFILE - Color Encapsulated PostScript file (.EPS file)	
	CPSFILE - Color PostScript file (.CPS file)	HP7475F - Hewlett Packard 7475
	DXFILE - AutoCAD DXF file (.DXF file)	HPLJF - Hewlett Packard Laser Jet
	EPSFILE - Encapsulated PostScript file (.EPS file)	HPLJ3F - Hewlett Packard Laser Jet III
	HP7470AF - Hewlett Packard 7470A	PSFILE - PostScript file (.PS file)
DEV	PRT PROMPT|NOPROMPT	- Enables or disables Windows Print dialog (Def: PROMPT)
DEV	RAS PROMPT|NOPROMPT|device_name	- Enables or disables Windows Print dialog, or specifies plot device (Def: PROMPT)
	The plot device types are:	
	CEPSFILE - Color Encapsulated PostScript file (.EPS file)	
	CPSFILE - Color PostScript file (.CPS file)	HP7475F - Hewlett Packard 7475
	DXFILE - AutoCAD DXF file (.DXF file)	HPLJF - Hewlett Packard Laser Jet
	EPSFILE - Encapsulated PostScript file (.EPS file)	HPLJ3F - Hewlett Packard Laser Jet III
	HP7470AF - Hewlett Packard 7470A	PSFILE - PostScript file (.PS file)
REC	[Yes|No]	- Enable/disable recording of data in the CODE V recovery file (Def: Yes)

I/O File Selection and Display

IN	filespec [replacement_field....9]	- Read in macro .SEQ file and use any specified replacement fields; use quotes around string entries (Def: command-line input)
OUT	[T] [*|filespec]	- Direct listed output to terminal (T) and/or to specified .LIS file * means last used OUT filespec (Def: OUT T)
OUT	Yes|No	- Turn listed output on or off (Def: Yes)

GRA	[T] [*|filespec]	- Direct graphics output to terminal (T) and/or to specified .PLT file * means last used GRA filespec	(Def: GRA T)
GRA	Yes|No	- Turn graphics output on or off	(Def: Yes)
RGR	[T] [*|filespec]	- Direct raster output to terminal (T) and/or to specified .RAS file * means last used RGR filespec	(Def: RGR T)
RGR	Yes|No	- Turn raster output on or off	(Def: Yes)
PRT	[filespec]	- Print current (or filespec) list file (.LIS) on PRT device	
PLT	[filespec]	- Plot current (or filespec) graphics file (.PLT) on PLT device	
DPL	[filespec]	- Plot current (or filespec) graphics file (.PLT) directly on TER device	
RAS	[filespec]	- Plot current (or filespec) raster file (.RAS) on RAS device	
DRS	[filespec]	- Plot current (or filespec) raster file (.RAS) directly on TER device	
GCV	BMP|DXF|EMF|EPS|GIF|JPG| PNG|PS|TIF|WMF filename	- Convert specified PLT, RAS, or V3D file to selected standard graphics type. (PS, EPS, & DXF types are not valid for V3D files. DXF is not valid for RAS files.)	

Control of Workstation Graphics Windows

The WND immediate command with qualifiers is used for control of various aspects of the workstation graphics windows. The GRA command is used to direct graphics between the screen and a file.

Unless otherwise noted, if Pk|Pi..j is omitted from the commands below, the command is applied to the last window to which graphics were directed. Pk can have a value of 1 to 100.

WND OPE	[#_of_windows]	- Allocate number of windows for graphics output; resets WND PLO to default # omitted - add one window to total	(Def: WND OPE 1)
WND PLO	[Pk|Pi..j]	- Directs graphics output to Pk or to cycle through Pi..j Pk|Pi..j omitted - reset to current WND OPE range	(Def: Use all windows opened by WND OPE)
WND CLO	[Pk|Pi..j]	- Close (clear) graphics window and contents	
WND SCA	[Pk|Pi..j] [relative_size]	- Subsequent plots to the specified window(s) are made the relative_size fraction of CODE V default workstation plot window size Pk|Pi..j omitted - applies to next window(s) relative_size omitted - returns to default size	(Def: 1.0)
WND ICO	[Pk|Pi..j]	- Shrink graphics window to an icon	(Def: No)
WND EXP	[Pk|Pi..j]	- Expand icon back to graphics window	
WND POS	[Pk] x_coord y_coord	- Position upper left corner of window in scaled X,Y coordinates of screen. Upper left corner of screen is 0,0; range of X (horizontal) and Y (vertical) is 0 to 100; lower right corner of screen is 100,100. Default Pk -current window	(Def: P1 - 0,5; P2 - 45,5; P3 - 0,45; P4 - 45,45; P5 - 10,10; P6 - 35,10; P7 - 10,30; P8 - 35,30; Sequence repeated for k > 8)
WND BAC	[Pk|Pi..j] background_color	- Define background color	(Def: WHI)

Restore Lens Filename

RFN	lens_filename	- For Macro-PLUS. Defines the current (e.g., original) lens filename (shown by the FIL database item) at the completion of the macro.

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Enable or Disable File Versioning

FVR	Yes|No	- Enables or disables versioning for CODE V files.	(Def: Yes)

Macro-PLUS Settings

NAB	Yes|No	- No abort command for Macro-PLUS users. NAB Yes causes CODE V to ignore any error conditions that would normally halt execution of the macro. The macro will continue to run until it encounters an exit condition not associated with an error. Use with caution

Default Configuration - DEFAULTS.SEQ File

Immediate Commands and LDM commands can be edited into DEFAULTS.SEQ, which will be read whenever CODE V is started, prior to accepting other inputs.

LIB - Library Maintenance

TYP	filetype|*	- Restrict operations to designated filetype (SEQ, etc.) only; * means "all filetypes."	(Def: *)
DIR	[filespec]	- List directory(s); filespec restricts action	
LIS	filespec	- List file (only possible with .SEQ, .LIS files)	
DEL	filespec	- Delete filespec	
COP	filespec1 filespec2	- Copy filespec1 to filespec2	
REN	filespec1 filespec2	- Rename filespec1 to filespec2	
PUR	filespec	- Removes (purges) all versions of filespec except the most recent.	

GLD - Glass Catalog Data

Note: Using the glass_catalog_name (CDGM, CHANCE, CHINA, CORNFR, CORNING, HIKARI, HOYA, KODAK, NSG, OHARA, PILKINGTON, SCHOTT, SPECIAL, SUMITA) restricts the action to only that catalog; otherwise, the action will apply to all catalogs.)

GLI	[glass_catalog_name]	- List glass catalog indices
TLI	[glass_catalog_name]	- List transmission data
MLI	[glass_catalog_name] [GOB]	- List all other glass data; GOB - lists gob prices instead of slab B; Note: Use the GOB qualifier when specifying the appropriate vendor price for lens pressings. This value will be used in the COSt option. Often, this price refers to the strip form of supply.
GPR	[glass_catalog_name [glass_name]]	- List all data for designated glass(es): GLI,TLI,MLI
REL	[glass_catalog_name] [glass_name] [wavelength_nm....4]	- Do relative partial dispersion analysis of catalog; use partial characteristics of glass_name

Menu

Search

UGR - User-defined Graphics

Note: X, Y axes refer to the abscissa(horizontal) and ordinate(vertical) axes, respectively. For plots of X,Y data sets, the X axis is 7 inches long and the Y axis is 5 inches high.

General (apply to all plot types)

TIT	'temporary_title'(32+32)	- Temporary title	(Def: blank)

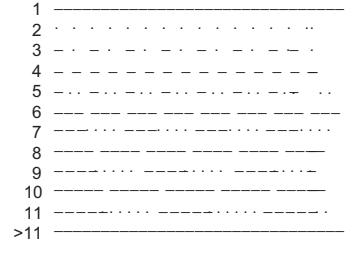
X-Y Data Sets

XLA	'horiz_axis_label'(40)	- Label for X axis	(Def: 'X-AXIS')
YLA	'vert_axis_label'(40)	- Label for Y axis	(Def: 'Y-AXIS')
XMI	horiz_axis_min	- Lowest X values marked	(Def: automatic selection)
XMA	horiz_axis_max	- Highest X values marked	(Def: automatic selection)
YMI	vert_axis_min	- Lowest Y values marked	(Def: automatic selection)
YMA	vert_axis_max	- Highest Y values marked	(Def: automatic selection)
XAX	y_value_for_horiz_axis	- Draw X axis at this Y	(Def: YMI)
YAX	x_value_for_vert_axis	- Draw Y axis at this X	(Def: XMI)
XDE	[GRD] [incr_between_horiz_axis_ticks]	- Draw grid lines; X axis ticks increment	(Def: automatic selection)
YDE	[GRD] [incr_between_vert_axis_ticks]	- Draw grid lines; Y axis ticks increment	(Def: automatic selection)
XFO	D|E|F|G num_digits_to_right_of_decimal_horiz	- FORTRAN type X axis format	(Def: E 3)
YFO	D|E|F|G num_digits_to_right_of_decimal_vert	- FORTRAN type Y axis format	(Def: E 3)

X-Y Data Point Entry

DPO 'label_for_following_dataset'(24) - REQUIRED. Starts data set;
'label_...' - label for legend block
(Up to 20 commands + data sets allowed)

LIN [PNT] [line_style] - Connect points with straight lines (default); PNT includes points.
or **LIN** [PNT] [line_style line_color]
line_style selects line pattern for that data set.
Range of values 1 - 11.
Default is to cycle through styles set by STL.



line_color selects color for that data set. Default is CLS colors.

or	**SPL**	[PNT] [line_style]	- Fit points with spline curve; PNT includes points.
or	**SPL**	[PNT] [line_style line_color]	line_style selects line pattern for that data set. Range of values 1 - 11. Default is to cycle through styles set by STL. line_color selects color for that data set. Default is CLS colors.
or	**PNT**	[NOT] [point_color]	- Draw points only; NOT includes string annotations (up to 6 chars.) specified with data set pairs; point_color selects color for that data set. Default is CLS colors.
	1st_horiz_value 1st_vert_value [1st_string]		- 1st X,Y pair (at least 1 required; no limit)
	2nd_horiz_value 2nd_vert_value [2nd_string]		- 2nd X,Y pair (at least 1 required; no limit)
	:		:
	last_horiz_value last_vert_value [last_string]		- Last X,Y pair
	END		- Terminates this data set

Interface with Worksheet Buffer

DTB [Bn] lj..k Jm..n [ROW|COL] [PNT|LIN|SPL] 'label_for_dataset'...(20)

- Data Table. Extract contiguous rows or columns (default COL) from specified buffer (default current buffer) for plotting. First row or column is X data, succeeding rows or columns are separate Y data, identified by 'label_...'. Up to 20 data sets can be plotted. Default plot type is LIN.

BIM [Bn] [CC|CR|RC|RR] x_row x_col y_row y_col num_points

- Buffer Import. Extract num_points for plotting from specified buffer (default current buffer), starting at x_row, x_col for X data and at y_row, y_col for Y data. Used after DPO command and before END.
  - CC - both data are columnar (default)
  - CR - X data in column, Y data in row
  - RC - X data in row, Y data in column
  - RR - both data in rows

Scalar Field Plot

SFP	[Bn] lj..k Jm..n PLO|CON|DIS	- Scalar field plot (default current buffer): PLO - isometric plot (oblique projection) CON - contour line plot DIS - shaded color contour plot	(Def: None)
ANN	line_number 'annotation string'(40)	- Annotation text strings displayed in text boxes at the bottom of the plot	(Def: None)
BAC	r_value g_value b_value	- Background color for the region outside the data display area (Use only with SFP DIS)	(Def: 0.30 0.49 0.49)
GRI	x_grid_spacing [y_grid_spacing]	- Grid spacing between grid values	(Def: Scale bar not computed)
CLR	SPE|RGB [r_value g_value b_value]	- Type of color scale to be used to display the intensity data (Use only with SFP DIS) SPE - spectral rainbow RGB - monochromatic ramp from black to specified color (default values are 1.0 1.0 0.0, which creates a yellow ramp)	(Def: CLR SPE)

	LEV	[Bn] lj..k Jm..n PLO|CON|DIS	- Select contour levels to be plotted	(Def: LEV NUM 30)
or	**LEV INC**	contour_increment_fraction	- Uniform levels, specified by increment	(Def: LEV NUM 30)
or	**LEV NUM**	num_contour_levels	- Uniform levels, specified by total number	(Def: 30)
	LTI	'legend_title'(8)	- Plot title text string (Use only with SFP DIS)	(Def: None)
	NDA	No|no_data_value	- Enable the "no data" value number (Use only with SFP CON and SFP DIS)	(Def: No)
	RAN SCA	num_steps [min_value max_value]	- Set color scale range	(Def: 50)
	RAN COL	SPE|RGB [r_value g_value b_value]	- Select type of color scale SPE - spectral color rainbow RGB - monochrome color ramp from black to to r_value, g_value and b_value (values from 0 to 1)	(Def: SPE)
	SIZ	max_pixels	- Maximum pixel dimension	(Def: 512)
	STI	'subtitle' ['subsubtitle'(20)]	- Up to 20 characters are plotted below the plot title	(Def: None)
	UNI	'x_axis_units'(2) ['y_axis_units'(2) ['z_axis_units'(2)]]	- Unit labels for each axis	(Def: None)

Vector Field Visualization

	VIS	[Bn] lj..k Jm PHA|ELL|LIN|ARO|CIR [ORI]	- Visualization plot (default current buffer): PHA - phase ellipse icon (with directional arrow) ELL - ellipse icon (no directional arrow) LIN - vector icon (line with no arrow) ARO - arrow icon (line with directional arrow) CIR - circle icon ORI - include origin on each icon	(Def: None)
	SSI	distance_per_scale_bar....z	- Specifies visualization plot scale size in X and Y per scale bar	(Def: Auto-scaling)

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Macro-PLUS

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Introduction

Notes:

1. Use of the Macro-PLUS programming language is optional - CODE V can be used very effectively without it. It is an extension of the sequence file concept (.SEQ files) that provides control statements, looping, formatting of text and graphics output, and decision making based on calculated results. Usage can be as simple as evaluating an expression with the EVA command (LDM - Section 2D), picking up another parameter for entry, or as complex as needed.
2. More often the statements will be part of a prepared .SEQ file, but some of the operations can also be run interactively. Prepare the .SEQ file in the normal manner by editing and run with the IN command. The .SEQ file can have other IN commands - nested sequences. The sequence runs until:
   - An RTN (return) statement is reached
   - The last statement of the file is executed
   - An error in macro statements is found. All of sequence and any it calls are skipped.
   - You type CTRL/C. Rest of all sequences are skipped.
3. Macro expressions can be used within CODE V commands to supply the values for commands. Macro variables may also be used to supply values for qualifiers such as S, W, F...., but can only be scalar variables, not arrays. If a macro string variable is used as a filename, use $ to strip off the enclosing quotes.

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Language Reference

Rules

Special added rules for interpreting macro command syntax:

{ }	NOT typed - repetitive contents - the contents of { } can be issued zero or more times
( )	Is typed - either an argument list for a function, array subscripts, use of a variable or parameter in a statement, or for database retrieval
,	Is typed and valid only for separating arguments in a function (definition or usage), or subscript expressions in user-defined array variables; otherwise, no commas are ever typed
^	Is typed - denotes a user-defined variable
@	Is typed - denotes a user-defined function
$	Is typed - denotes use of a user-defined string replacement

User-Defined Elements

User-Defined Variable

Implicit Definition:
By using it on the left hand side of an assignment statement. Whether it is a numeric or string variable is determined by the result of the right hand side expression

Explicit Definition:
May appear anywhere interactively, but must appear first, before any Macro-PLUS or CODE V statements, either within sequences, or within user-defined functions.

```
[ GBL|LCL ]  NUM|STR  ^user_var  { ^user_var }
```

where:

GBL	- Global variable (accessible in all used macros and functions)
LCL	- Local variable (accessible in only this macro, or function)
NUM	- Numeric variable
STR	- String variable (Up to 9999 characters)
^user_var	- May be: ^name- Scalar variable ^name (range [, range]) - Array variable (up to 2 dimensions allowed) where range is a range of integer values for the subscripts. The range is of the form: [lo..]hi - If the [lo..] is omitted, low subscript value is 1.

Usage:
As a parameter (or operand) in an expression, or on the left hand side of an assignment statement:

Scalar:	^name
Array:	^name (expression1 [, expression2]) where expression 1 and 2 are evaluated and truncated to the nearest whole number

User-Defined Function

Must be defined in a sequence (.SEQ file); must appear before the first reference to it; cannot appear in the span of a control statement; cannot be redefined in the same CODE V session. Good practice would put it first, before any Macro-PLUS or CODE V statements; even better as a separate sequence.

Definition:

```
FCT@name [ ( NUM|STR ^arg_var { , NUM|STR ^arg_var } ) ]
    { definition }
    { macro statement }
  END FCT expression
```

where:

@name	- User-defined scalar function name; arguments are optional
^arg_var	- Scalar variable or array variable inputs; only value returned to the calling statement is the changed value of @name. If desired, array variable inputs may also be changed within the function.
definition	- User-defined variable; all definitions must appear before any Macro statement
macro statement	- Macro assignment and control statements only (no macro I/O or debug statements or CODE V commands can appear here)
expression	- Value determined by expression is the function value returned to calling statement

Usage:
As a parameter (or operand) in an expression:
@name [(expression { , expression })]

User-Defined Subroutine

One user-defined subroutine can be generated in any available language (FORTRAN, etc), compiled to generate routine_name, then linked with CODE V, like user-defined surfaces and user-defined gradients. Regardless of language, use the "call by reference" method that is standard in FORTRAN.

Usage:
Include as a macro statement:

```
USR [routine_name] ^arg_var { ^arg_var }
```

where:

routine_name	- Name of subroutine to be called. If not specified, calls default: usersub.
^arg_var	- Scalar variable or numeric (NUM) array variable inputs or returned values

In the subroutine itself, the argument list variables must be defined as REAL*8 for numeric arguments and CHARACTER*(*) for string arguments.

User-Defined String Replacement

String variables may be used to replace pre-defined commands, qualifiers or values by using $ in place of the ^ on the variable name. The outermost quote marks enclosing the string are stripped off.

Example:

```
STR ^CV
^CV  ==  'CUY'
$CV  S3  .14159
```

Dropping a User-defined Element

Drop a local or global variable or user-defined function. The ^ or @ is optional in the name, but must match.

```
DRO  FCT|LCL|GBL name1 [name2...]
```

Functions

Pre-defined Function Operands

Math Functions

ABSF(expression)	- Absolute value	MODF(expr1, expr2)	- Returns remainder when expr1 is divided by expr2
ACOSF(expression)	- Arccosine (in radians)	RANDF	- Random number (0 to 1 range)
ASINF(expression)	- Arcsine (in radians	ROUNDF(expression)	- Round to nearest whole number
ATANF(expression)	- Arctangent (in radians)	SIGNF(expr1, expr2)	- ABSF(expr1)*SIGN(expr2)
COSF(expression_rad)	- Cosine	SINF(expression_rad)	- Sine
EXPF(expression)	- Exponential (e raised to power)	SQRTF(expression)	- Square root
LOGF(expression)	- Natural logarithm	TANF(expression_rad)	- Tangent
LOG10F(expression)	- Common logarithm	ZFRFIT(num_points, x, y, f, num_terms, coefs)	- Fits user data to Fringe Zernike polynomials
MAXF(expr1, expr2)	- Maximum value		
MINF(expr1, expr2)	- Minimum value	ZRNFIT(num_points, x, y, f, num_terms, coefs)	- Fits user data to standard Zernike polynomials

GAUSSWTS(num_input_pts, input_coord, input_wts, num_quad_pts, quad_coord, quad_wts)
- Compute Gaussian quadrature coordinates and weights

Optical Functions

BESTSPH(surface, zoom_pos, min_height, max_height) - Return the curvature of the best fitting sphere.

CNVTFIELD(field_type) - Converts system's field representation to the designated type: object height (OBJ), paraxial image height (IMG), real image height (RIH), or field angle in object space (ANG).

GAUSSBEAM(surface_num, zoom_pos, field_num, wave_num, ^input_array, "output_string") - Trace a "slow" Gaussian beam and calculate at the specified surface the beam radius, beam orientation, wavefront radius of curvature, waist position, and waist radius.

EVALZERN(wave_num, field_num, zoom_pos, x, y, pol_type, "output_string", zernike_type) - Evaluates a Zernike polynomial (generated with ZERNIKE or ZFRCOEF) and computes the value at a point X,Y.

FITERROR(wave_num, field_num, zoom_pos, pol_type, "output_string", zernike_type) - Returns the RMS fit error of a Zernike polynomial generated with ZERNIKE or ZFRCOEF.

INDEX(surface_num, zoom_pos, wave_num, glass_num, x, y, z) - Index of refraction at location (x,y,z) in a gradient index glass; glass_num is 1 or 2 (for GL1 or GL2)

MTF_1FLD(zoom_pos, field_pos, frequency, azimuth, nrd, ^output_array, dif_or_geo, sin_or_sqw) - Returns the MTF of the lens system including or excluding diffraction effects, assuming either a sine wave or a square wave object.

NORMRADIUS(wave_num, field_num, zoom_pos, pol_type, "output_string", zernike_type) - Returns the normalization radius of a Zernike polynomial with ZERNIKE or ZFRCOEF.

POLGRID(zoom_pos, wave_num, field_pos, aper_check, nrays, ^input_array, ^output_array) - Traces a grid of rays and returns the polarization properties of the rays at the image surface.

AS_BUILT_VAR(zoom, field, NRD, output-type) - If TOR has not been previously run on the lens, performs a sensitivity tolerance analysis based on wavefront variance using the current set of tolerances and compensators and returns the statistical as-built performance information for any zoom and field.
- If TOR has been previously run on the lens, returns the statistical as-built performance information generated by TOR.

RAYPOL(zoom_pos, wave_num, aper_check, input, ^output_array) - Fast ray trace to SI (results in array), with a greater number of output elements than RAYTRA.

RAYRSI(zoom_pos, wave_num, field_num, ref_surf, ^input_array) - Perform an RSI ray trace (results in database)

RAYSIN(zoom_pos, wave_num, x_tan, y_tan, x_dir_tan, y_dir_tan) - Perform a SIN ray trace (results in database)

RAYTRA(zoom_pos, wave_num, aper_check, ^input_array, ^output_array) - Perform a SIN ray trace to SI (results in array)

RMSSPOT(zoom_pos, field_num, defocus_num, RTL/NRD) - Calculates and returns the RMS spot size based on the parameters passed in the function.

RMSWE(zoom_pos, wave_num, NRD, ^output_array, focus) - Calculate RMS wavefront error information at a specified zoom position for all fields, with or without optimum focus.

RMS_1FLD(zoom_pos, field_pos, wave_num, NRD, ^output_array, focus) - Calculate RMS wavefront error information at a specified zoom position for a single field, with or without optimum focus.

SAGF(surface_num, zoom_pos, x_coord, y_coord) - Sag of the designated surface at x_coord, y_coord

SASF(surface, zoom_pos, xs, ys, ^out) - Compute surface astigmatism (results in array)

SPOTDATA (zoom_pos, field_num, defocus_num, RTL/NRD, Reference, x_shift, y_shift, ^output_array) - Performs spot size calculations and fills in the data in the supplied array.

SURFSAGD(surface, zoom_pos, curvature, ^x_array_input, ^y_array_input, ^output_array) - Returns the variance of the sag difference from the input curvature for the specified points (results in array)

SVD(A,rows,cols,U,V,S) - Applies singular value decomposition algorithm to arrays that have been declared global variables

TRA_1FLD(zoom_pos,x_fld,y_fld,nrd,geo_or_stokes,grid_scale_fact, ^pol_input, ^output_array) - Compute average transmission and projected solid angle at the object for a field point using TRA

TRANSFORM(surface, ref_surface, zoom_pos, ^trans_data) - Compute transformation of one surface to local coordinates of another surface

ZERNIKE(wave_num, field_num, zoom_pos, coef_num, num_rays_across_dia, num_terms, 'pupil_type', pol_type, int_or_phase, zernike_type) - Compute Zernike fit coefficients, either FRINGE or standard, for specified wavelength, field, and zoom position, with or without polarization ray tracing

ZERNIKEGQ(wave_num, field_num, zoom_pos, coef_num, num_terms, 'pupil_type',pol_type, int_or_phase, zernike_type) - Compute Zernike fit coefficients, either FRINGE or standard, for specified wavelength, field, and zoom position, with or without polarization ray tracing. Performs fit using a radial grid of rays based on Gaussian quadrature.

ZFRCOEF(wave_num, field_num, zoom_pos, coef_num, num_rays_across_dia, num_terms, 'pupil_coord_type') - FRINGE Zernike coefficient for specified wavelength, field, and zoom position

Image Simulation Functions

ImageAdd(^imageA, ^imageB, ^outputImage) - Adds ^imageA and ^imageB and stores the results in ^outputImage.

ImageAddConstantTo(^imageA, ^constVal) - Adds a constant to an image. Overwrites the starting image.

ImageChangeGamma(^image, ^gammaValue)	- Modifies the data in the image according to the formula: output = input$^{(\text{^startingGammaValue/GammaValue})}$
ImageClip(^image, ^maxValue, ^minValue, ^component)	- Clips the values in the image so that values less than ^minValue are set to ^minValue and values greater than ^maxValue are set to ^maxValue.
ImageCombineComponents(^redImage, ^grnImage, ^bluImage, ^colorImage)	- Combine three images (must be identical size) that represent the colors of an image into a single, color image.
ImageCopy(^inputImage, ^outputImage)	- Copies an image.
ImageDelete(^image)	- Deletes an image.
ImageDisplay(^image, ^scaling)	- Opens a display window containing the image.
ImageExtractComponent(^RGBImage, ^monochromeImage, ^channel)	- Extracts a monochrome image from a color image.
ImageFlipX(^image)	- Flips an image from left to right.
ImageFlipY(^image)	- Flips an image vertically.
ImageFromArray(^inputArray, ^monochromeImage)	- Writes data from a Macro-PLUS 2D array to an image.
ImageGetAverageValueColor(^image, ^aveArray)	- Returns the average of the values of the pixels in each color of a color image.
^result == ImageGetAverageValueMonochrome(^image)	- Returns the average value of the pixels of a monochrome image.
ImageGetMaxValueColor(^image, ^maxArray)	- Returns the maximum value for each channel of a color image.
^result == ImageGetMaxValueMonochrome(^image)	- Returns the maximum value of a monochrome image.
ImageGetMinValueColor(^image, ^minArray)	- Returns the minimum value for each channel of a color image.
^result == ImageGetMinValueMonochrome(^image)	- Returns the minimum value of a monochrome image.
^result == ImageGetPixelAt(^image, ^row, ^column,^component)	- Returns the value of the image at a particular location.
^status == ImageGetStatus	- Returns the status of the previous image function call.
ImageGetSumOfValuesColor(^image, ^sumArray(3))	- Returns the sum of the values of the pixels in each channel of a color image.
^result == ImageGetSumOfValuesMonochrome(^image)	- Returns the sum of the values of the pixels for a monochrome image.
ImageMDCopy(^fromImage, ^toImage)	- Copies all metadata from one image to another.
ImageMDCopyWavelengthsAndWeights(^sourceImage, ^destinationImage)	- Copies wavelengths and weights from one specified image to another specified image.

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^result == ImageMDGetCME(^image)	- Returns CME value.
^descriptorString == imageMDGetDescriptor(^image)	- Returns a string that you set in ImageMDSetDescriptor with (^descriptorString).
^result == ImageMDGetDEX(^image)	- Returns DEX value.
^result == ImageMDGetDEY(^image)	- Returns DEY value.
^result == ImageMDGetFieldOffsetX(^image)	- Returns the offset of the center of the object in the X-direction within the field of view of the lens.
^result == ImageMDGetFieldOffsetY(^image)	- Returns the offset of the center of the object in the Y-direction within the field of view of the lens.
^result == ImageMDGetFieldRotation(^image)	- Returns the field rotation.
^result == ImageMDGetFieldUnits(^image)	- Returns the field units.
^result == ImageMDGetGamma(^image)	- Returns the gamma parameter value.
^result == ImageMDGetGRI(^image)	- Returns the GRI value.
^result == ImageMDGetImagePixelSize(^image)	- Returns the pixel size.
^result == ImageMDGetImageSemiDiagonal(^image)	- Returns the image semi-diagonal measurement, i.e., radius of a circle circumscribed around the image.
^result == ImageMDGetLensName(^image)	- Returns the lens name.
^result == ImageMDGetNRD(^image)	- Returns the NRD value.
^result == ImageMDGetNumXPixels(^image)	- Returns the number of pixels in the X direction.
^result == ImageMDGetNumYPixels(^image)	- Returns the number of pixels in the Y direction.
^numwavelengths == ImageGetNumWavelengths(^image, ^colorStr)	- Returns the number of wavelengths used to represent the red, green, and blue components of a color image or the luminescense of a monochrome image.
^result == ImageMDGetObjectFileName(^image)	- Returns the object's file name.
^result == ImageMDGetObjectSemiDiagonal(^image)	- Returns the object's half diagonal measuement, i.e., radius of a circle circumscribed around the object.
^result == ImageMDGetOffsetValue(^image)	- An IMS simulation that is subsequently processed can produce a negative result. The offset value is the difference from 0 when an IMS simulation is subsequently processed and produces a negative result: TrueValue = (file value + offset) * scale.
^result == ImageMDGetPMX(^image)	- Returns the PMX value.
^result == ImageMDGetPMY(^image)	- Returns the PMY value.
^result == ImageMDGetScaleValue(^image)	- Returns the scale for fitting 16-bit data to the dynamic range: TrueValue = (file value + offset) * scale.
^result == ImageMDGetSimulationDate(^image)	Returns the date when the image simulation was made.
^result == ImageMDGetSym(^image)	- Returns the symmetry: rotation (ROT) or non-rotational (NON).

^result == ImageMDGetTGR(^image)	- Returns the TGR value.
^result == ImageMDGetTitle(^image)	- Returns the title set with ImageMDSetTitle with ^titleString.
ImageMDGetWavelengthsAndWeights(^image,^wvlAndWtArray, ^colorStr)	- Returns wavelengths and weights for one color at a time.
ImageMDListHeaderInfo(^image)	- Displays the header information in the output window.
ImageMDSetDescriptor(^image, ^descriptorString)	- Sets a string (^descriptorString) that can be used to describe the image. This function is primarily useful for image display using the imageDisplay function. When the image is displayed, the ^descriptorString will be used to label the image display.
ImageMDSetDEX(^image,^dexValue)	- Sets the DEX value.
ImageMDSetDEY(^image,^deyValue)	- Sets the DEY value.
ImageMDSetFieldOffsetX(^image,^fieldOffsetX)	- Sets the offset of the center of the object in the X-direction within the field of view of the lens.
ImageMDSetFieldOffsetY(^image,^fieldOffsetY)	- Sets the offset of the center of the object in the Y-direction within the field of view of the lens.
ImageMDSetFieldRotation(^image,^fieldRotation)	- Sets the field rotation.
ImageMDSetFieldUnits(^image,^fieldUnitsStr)	- Sets the field units.
ImageMDSetGRI(^image,^griValue)	- Sets the GRI value.
ImageMDSetImagePixelSize(^image,^pixelSize)	- Sets the pixel size.
ImageMDSetImageSemiDiagonal(^image,^semiDiagonal)	- Sets the image semi-diagonal measurement, i.e., the radius of a circle circumscribed around the image.
ImageMDSetLensName(^image,^lensNameString)	- Sets the lens name.
ImageMDSetNRD(^image,^nrdValue)	- Sets the NRD value.
ImageMDSetObjectFileName(^image,^objectFileNameString)	- Sets the object's file name.
ImageMDSetObjectSemiDiagonal(^image,^fieldSize)	- Sets the object half diagonal measurement, i.e., radius of a circle circumscribed around the object.
ImageMDSetPMX(^image,^pmxValue)	- Sets the PMX value.
ImageMDSetPMY(^image,^pmyValue)	- Sets the PMY value.
ImageMDSetSimulationDate(^image,^dateString)	- Sets the date when the image simulation was made.
ImageMDSetSym(^image,^symString)	- Sets the symmetry: rotational (ROT) or non-rotational (NON).
ImageMDSetTGR(^image,^tgrValue)	- Sets the TGR value.
ImageMDSetTitle(^image, ^titleString)	- Sets a string for the image title.
ImageMDSetWavelengthsAndWeights(^image,^wvlAndWtArray, ^colorStr, ^numWavelengths)	- Sets wavelengths and weights for one color at a time.
ImageMultiplyByConstant(^imageA, ^constVal)	- Multiplies an image by a constant. Overwrites the starting image. Negative constants are allowed.

ImagePutPixelAt(^image, ^row, ^column, ^component, ^value)	- Writes a particular value to an image pixel.
ImageRead(filename, ^image)	- Reads a 16- or 48-bit PNG file. Metadata is available for 16- or 48-bit PNG files that were written using the SID command in IMS. 16- or 48-bit PNG files that were not written using the SID command can be read and processed but no metadata is available for them.
ImageRestoreFrom(myfile, ^image)	- Reads a standard JPG, BMP, TIF, or PNG image (8 bits/pixel for monochrome or 24 bits/pixel for color) and stores the image data in an IMG variable.
ImageRotate(^startingImage, ^outputImage, ^rotationAngleDegrees)	- Rotates an image, producing a new output image.
ImageSaveAs(^image,^filename,^filetype)	- Saves the image to a file of the designated type. Images are saved at a depth of 8 bits/pixel (monochrome) or 24 bits/pixel (color). The filename is a STR variable, but should NOT have the filetype appended to it. The filetype is also a STR variable. Valid choices are PNG, JPG, BMP.
ImageSubtract(^imageA, ^imageB, ^outputImage)	- Performs the operation ^outputImage = ^imageA - ^imageB.
ImageToArray(^monochromeImage, ^outputArray)	- Reads the data in an image and moves it into a 2D Macro-PLUS array.
ImageWrite(filename, ^image)	- Writes a file from the ^image to a 16- or 48-bit PNG file. The metadata that is in the image will determine whether to write a 16- or 48-bit image.

Array Functions

ARR_TO_BUF(array, num_rows, num_cols, buf_num)	- Copy array to buffer
BUF_TO_ARR(buf_num, array, start_row, end_row, start_col, end_col)	- Copy buffer to array
FFTdDts(cen_in, cen_out, fdata, [num_rows,] num_cols, fwd)	- Fast Fourier Transform of array
GET_COMPLEX_MAGNITUDE(comp, mag, num_mags)	- Magnitudes of complex array
GetDim1Num(^array)	- Returns the number of elements in a 1D array or the number of rows in a 2D array.
GetDim2Num(^array2D)	- Returns the number of columns in a 2D array.
GET_IMAGINARY_PART(comp, imag, num_imags)	- Imaginary parts of complex array
GET_REAL_PART(comp, real, num_reals)	- Real parts of complex array
PAD_REAL_TO_COMPLEX(real, comp, num_reals)	- Create complex array
ReDimNum(^array2D, ^newNumRows, ^newNumColumns)	- Resizes a two-dimensional array variable. If the size of the redimensioned array is larger, the new array positions are filled with zero. If the size of the redimensioned array is smaller, then the original data are truncated.
SCALE_REAL_ARRAY(real, scale, num_vals)	- Scale real array
STDEV(array, num_vals)	- Standard deviation of array
SUMF(array, num_vals)	- Sum of all elements

String Functions

CONCAT(string_expr1, string_expr2)	- Concatenates string 2 to string 1
LENSTR(string_expression)	- Length of string in characters
LOCSTR(string_expression, sub_string_expr)	- Starting character position of substring in string
LOWCASE(string_expression)	- Converts string to lower case
NUM_TO_STR(expression)	- Converts value of expression to a string
RFSTR(expression)	- Converts a replacement field entry to a string
STR_TO_NUM(string_expression)	- Converts first identifiable number in string to a number
SUBSTR(string_expr, beg_expr, length_expr)	- Substring starting with the character location beg_expr, and with the number of characters length_expr
TRUNC(string_expression)	- Returns string with trailing blanks dropped
UPCASE(string_expression)	- Converts string to upper case

File

EOFILE	- TRUE if last READ operation encountered End of File

User-defined Error and Warning Messages

CVERROR(error_msg,cont_line)	- Prints user-defined error message as either first line (cont_line is 0) or continuation line (cont_line is not equal to 0)
CVWARNING(warning_msg,cont_line)	- Prints user-defined warning message as either first line (cont_line is 0) or continuation line (cont_line is not equal to 0)
CVPUTREC(string_expression)	- Prints an informational message of up to 256 characters.

Parallel Processing Functions

THREADNUM	- Returns the thread number of the calling Macro-PLUS code.
INPARALLEL	- Indicates whether the calling Macro-PLUS code is in a parallel region or in a serial region.

User-defined Elements Query

ISFCT (string_expression)	- TRUE if named user-defined function exists
ISLCL (string_expression)	- TRUE if named local variable exists
ISGBL (string_expression)	- TRUE if named global variable exists

Other Operands

User-defined variables and array elements (as defined above)
Numeric constants - in any of the standard CODE V formats (see “Rules For Command Entry” on page 7)
Database items, enclosed in parentheses (see list on next pages)

Operators

Operators

Arithmetic

+, -	- Unary +, -

**	- Exponentiation
*, /	- Multiply, divide
+, -	- Add, subtract

Logical

NOT	- Not true - False
AND	- True if both expressions are true
OR	- True if either expression is true

Relational

<, >	- Less than, greater than
<=, >=	- Less than or equal, greater than or equal
=, <>	- Equal, not equal

Processing hierarchy

In the following order:
Innermost parentheses
Right to left on **, left to right otherwise
Function evaluation, database retrieval
Other operands

Assignment Statement

Assignment statements may appear anywhere. An assignment statement assigns the value of an expression to a user variable:

```
^user_var == expression
```

Expressions

Expressions consist of:

- Operators:	Arithmetic (+, -, *, /, **), relational (<, >, <=, >=, =, <>), logical (NOT, AND, OR)
- Parentheses:	Must be used for enclosing database items, for function argument lists, array indices, and to determine proper order of evaluation. May be used for clarity in grouping subexpressions. Note: Because a database item must be enclosed in parentheses, its use in a single argument function call or singly dimensioned array will give rise to double parentheses, e.g., ABSF((YAN F2)).
- Operands:	Pre-defined functions (math, optical, string and miscellaneous), user-defined variables and array elements, constants or database items.

Control Statements and Commands

Control Statements

Control statements are only valid within sequences, not interactively. Control statements can contain other control statements. So, for example, a WHILE statement can contain an IF statement or even another WHILE statement. May consist of a single line or multiple lines. Whenever { statement(s) } is used, it means that there may be zero or more statements. Statements are assignment, control, I/O, or debug statements.

If Statement

```
IF expression
{  statement(s)  }
{  ELS  IF  expression
{  statement(s)  }  }! The ELS IF portion may be repeated zero or more times
[  ELS
{  statement(s)  }  ]! The ELS portion is optional
END  IF
```

If the IF expression is true then execute the statements. If the ELS IF portion exists, the expressions associated with each ELS IF determine if the corresponding statements will be executed. If the ELS portion exists and the previous expressions were all false, the statements associated with the ELS will be executed.

While Statement

```
WHI expression
{  statement(s)  }
END  WHI
```

The statements will be executed as long as the expression is true. It is possible that the statements may not be executed at all.

Until Statement

```
UNT
{ statement(s) }
END  UNT expression
```

The statements will be executed until the expression is true. The statements will always be executed at least once.

For Statement

```
FOR ^user_var  expr1  expr2  [expr3]
{ statement(s) }
END  FOR
```

where:

^user_var -loop variable	- will initially contain value of expr1
expr1	- starting value of loop variable
expr2	- stopping value of loop value - stop when exceeded
expr3	- optional - increment/decrement for loop variable; if omitted, increment will be 1

Depending on starting and stopping values, the statements may not be executed at all.

GoTo Statement

```
GOT label
```

where:

label	- any group of alphanumeric characters

Control of the sequence will continue at the LBL statement associated with label. DO NOT include a space (GO TO).

Label Statement

```
LBL label
```

where:

label	- the group of alphanumeric characters referenced by a GOT statement

Control transfers to the statement following the LBL statement.

Input Command

```
IN  filespec  [replacement_field....9]
```

Read in the contents of a file (default extender .SEQ) and execute the statements in the file.
Replacement_field values are passed into the data stream before execution.

Replacement Field Default Command

```
RFD  [replacement_field_defaults....9]
                                    - Assign defaults to replacement fields
```

Return Command

```
RTN
```

The sequence will be terminated and control will return to the statement following the IN command.

Input/Output (I/O) Statements

In the following statements:

Qformat_picture - a chain of format symbols (or a scalar string variable containing them) enclosed in double quotes ("); each format symbol is enclosed in single quotes with characters occupying the alpha or numeric columns in the format:

- c - alphabetic character
- d - digit, signs (+, -) for decimal form of floating point
- e - digit, signs (+, -) or E for exponential form of floating point
- g - digit, signs (+, -) for floating point or E for exponential form (form will change depending on size of number)
- 1, 2, .., 132-multiplier of the next symbol
- .- decimal point
- - blank, representing a blank in the data stream

Example:

Q"'4d"3d.2d' '3e.5e' '6c'"

and `Q"'dddd''ddd.dd' 'eee.eeeee' 'cccccc'"`

and `^TABLEN == "'4d' '3d.2d' '3e.5e' '6c'"`, followed by `Q^TABLEN`

are equivalent, and could read or write a data string of

-123+12.25 350.21E+2 AFOCAL.

Note that blanks between format symbols represent blanks in the data. If Qformat_picture is omitted, free format is used where the data stream on input or the expression type on output will determine the format. For E or G format, the precision (number of digits after the decimal point) must be at least 4.

U^unit_number - ^unit_number is a user variable representing the unit from/to which the information will come/go; if omitted, the command prompt is used. ^unit_number can only be a global scalar variable.

Read Command

```
REA [U^unit_number] [Qformat_picture] [variable_list]
```

where:

variable_list - user_var { user_var }

The inputs are assigned in order to the user_var; if the type of variable hasn't been defined, type is assumed to be numeric.

Redefine Prompt Command

```
RPR ['new_prompt_string']
```

where:

new_prompt_string - new prompt to be used

All prompts will have all trailing spaces removed and a single space appended. If the string is omitted, the prompt will be reset to the default ('READ>')

Write Command

```
WRI  [U^unit_number]   [Qformat_picture]   [expression_list]
```

where

Qformat_picture	- format qualifier, see “Format Specification (Q Format Picture)” on page 25A-103 of the CODE V Reference Manual.
expression_list	- expression { expression }

The values of the expressions are assigned in order to the format symbols and written accordingly.

Open File Command

```
OPE  [OLD|NEW|APP]   U^unit_number   filespec
```

where:

OLD	- Usage begins at start of an existing file
NEW	- Usage begins at start of a new file
APP	- Usage continues at end of an existing file
omitted	- NEW
filespec	- Follows the normal CODE V definition, with default extender.DAT

Close File Command

Close the designated unit:

```
CLO  U^unit_number
```

Debugging Aids

Verify - Statement Echoing

```
VER  [COM|CTL|FCT|IO|MAC|SEQ|ALL|LCK]Yes|No                    (Def:  VER  No;  VER  Seq)
```

where:

COM	- Echo full line comments (not trailing comments)
CTL	- Echo control and assignment statements, variable definitions
FCT	- Echo functions at run-time
IO	- Echo REA, WRI, OPE, CLO
MAC	- Includes all of the above (CTL, FCT, IO)
SEQ	- Echo regular CODE V commands (any other commands, not included above)
ALL	- Include all of the above

LCK		- Report when a SHR variable used in a macro or user-defined function that ran in a multi-threaded process was locked or unlocked.
No		- Set all to No but retain original context
Yes		- Restore original context

Check Variable Definitions

CHK	Yes|No	- Require and check that all variables are explicitly defined	(Def: No)

Bounds Checking on Arrays

BND	Yes|No	- Check at run-time that all array subscripts stay within their defined bounds	(Def: Yes)

Error Checking

EXC	Yes|No	- Enable or disable exception handling on errors during macro execution	(Def: Yes)

List Variables and/or Functions

List immediately the name, type and value

```
LVR  [GBL|LCL|FCT]
```

where:

GBL	- List global variables
LCL	- List local variables
FCT	- List user-defined functions
omitted (LVR)	- Include all of the above

Dialog Box Creation

Dialog Box Commands - (ARGn)

```
! ARG0  “description”(80)
```

Description of the macro’s function that is displayed at the top of the dialog box.

```
! ARGn  NAME “argument_name”(40)
```

Names the argument. This is the “prompt” you will see in the dialog box for the argument. Must be enclosed in quotes.

```
! ARGn  TYPE NUM|INT|STR|LITERAL                    (Def: STR)
```

These are the types of variables the argument passes, where:

NUM	- Floating point number
INT	- Integer number (such as for surface numbers or zoom positions)

STR	- String variable. Must be enclosed in quotes.
LITERAL	- Character string (no blanks) passed without quotes (e.g., Yes or No)

```
! ARGn  CHOICE value1 value2....(32)
```

Creates a choice button in the parameter value box. The ARGn TYPE command must be given before this command so the type of the values in the list are known. If the type is STR, then each entry in the choice list must be enclosed in quotes. Up to 32 choices of up to 48 characters each may be entered.

```
! ARGn  DEFAULT default_value
```

Specifies the default value for the parameter. If the type is STR, it must be enclosed in quotes. If a choice list is entered, the default must be one of the choices. The value of the default is dependent on the type of the parameter.

NUM	- Default is 0.0
INT	- Default is 0
STR	- Default is “”
LITERAL	- Default is blank

```
! ARGn  HELP “help_string”(80)                                    (Def: “No help available.”)
```

Gives a one-line help message for the bottom of the dialog box. The message must be enclosed in quotes.

Menu

Search

Database Reference

Database Items

- With few exceptions the available items are those that are the LDM inputs, single ray trace outputs and AUT specific constraints.
- Unless otherwise noted, the numeric value of the quantity is returned.
- For Yes|No commands, the returned value is associated as follows, unless otherwise noted:

  0 = False, No
  non-zero = True, Yes (the returned value sometimes has meaning)
- All strings returned have single quotes (') around them; if no entry was made, it will be a null string (i.e., ' ' zero length string)
- To use a string database item without quotes, define a string variable for the database item, and then use the "User-defined String Replacement" operator (i.e., $). For example:

  ^GLASS == 'BK7' GLA S2 $GLASS
- Usage:

  Enclose each database item in parentheses. For example: ^SINB == (CUY S16 Z2) * (SD S16 Z2)

Lens Database Information

Special Commands without a Corresponding CODE V Input Command

Type of platform used
AR_ - Returns 'DOS'

CODE V Option
CVO - Returns 3 character string for the current CODE V option

CODE V Version
CVV - Returns string with current CODE V version number

Current Directory
CD - Returns string with current directory

Date
DAT - Returns 11 character string with current data in format 'DD-MMM-YYYY'

Filename used for RES and SAV
FIL - Returns string containing filename

Number of CPUs used in parallel processing
MPP - Returns current setting of the MPP command, which sets the maximum number of processors to be used by CODE V for parallel processing.

Menu

Search

Number of available CPUs

NCP - Returns the number of CPUs in the user's computer.

Number of surfaces, wavelengths, fields, zoom positions, zoom parameters, UDEF rays, UDEF aberrations, elements, tolerances, compensators, and variables

NUM S|W|F|Z|ZPR|E|A|ELE|TOL|CMP|VAR

Status of OUT command

OUT - Returns 0 when OUT No has been used; +1 when OUT Y is valid

Query for system mode

SCR - Returns 0 when in command mode; +1 when in GUI mode

BAT - Returns 1 when if running in batch mode; 0 otherwise

Surface pointer position

SFP - Returns the current surface pointer position

Time of Day

TIM PRE - Returns 8-character string with current time in 24 hour format 'HH:MM:SS'. Inclusion of the PRE qualifier returns an 11-character string that includes milliseconds: "HH:MM:SS:ms".

Type of structure - Returns a string to identify the used type of entry; for solves and decenters, if none is entered, a null string is returned.

TYP	APE	- 'EPD'|'FNO'|'NA'|'NAO'
TYP	FLD	- 'ANG'|'OBJ'|'IMG'|'RIH'
TYP	SUR Sk	- 'SPH'|'CYL'|'CON'|'ASP'|'YTO'|'THG'|'SPL'|'AAS'|'GRT'|'HOE'|'MOD'| 'UDS'|'UD2'|'SPS XXX'
TYP	SOL THI Sk	- 'ET'|'OAL'|'HMX'|'HMY'|'HCX'|'HCY'| '
TYP	SOL CUX Sk	- 'UMX'|'UCX'|'IMX'|'ICX'|'AMX'|'ACX'| '
TYP	SOL CUY Sk	- 'UMY'|'UCY'|'IMY'|'ICY'|'AMY'|'ACY'| '
TYP	DEC Sk	- 'DDA'|'DAR'|'BEN'|'REV'|'RET'|'GLB'|'ARR'|'EAR'| '
TYP	GRN Sk [GL1|GL2}	- 'SEL'|'AXG'|'URN'|'LUN'|'SPG'|'MAX'|'UDG. Returns null value if glass is not a GRIN material.

Index of refraction

IND	Sk [Zn] [Wj] [GL1|GL2]	- Returns index of refraction
ABV	Sk [Zn] [SYS] [GL1|GL2]	- Returns Abbe value for glass = $(n_d - 1) / n_F - n_C)$ SYS - uses system wavelengths (first, last, and REF)

Check for data available from option

OPT ACC|ALI|ANA|AUT|BEA|BIO|CAM|CAT|COS|ELE|ENV|FAB|FIE|FMA|FOO|FOV|GDE|GHO|GLD|GLS|IMS|LIB| LSF|MTF|MUL|NAR|PAR|PMA|PSF|QUA|RAD|RIM|SLD|SPE|SPO|TES|TOD|TOL|TOR|TRA|UGR|VIE|WAV|WEI

- Returns
  - 0 = Data from option not available
  - +1 = Data from option is available
  - -1 = Data from option is obsolete due to lens change

Specific zoom parameters

ZPR [Sk] [Fm] [Wj] [Cj] A|AC|ADC|ADE|ADX|ADY|AFI|AFO|AP|APC|, etc. (any potentially zoomable parameter)
- Returns 0 = not zoomed
non-zero = zoomed

From LDM Commands

Title

TIT - Returns 80 character string

Specification Data

Wavelength Specification

WL Wj
REF [Zn]
WTW [Zn] Wj
CWL
FGW Wj

Pupil Specification

EPD|**FNO**|**NA**|**NAO** [Zn]

Aperture Apodization & Polarization - See “Defining Pupil Apodization and Surface Deformations” on page 47 and “Defining Polarization” on page 43.

Field Specification

XIM|**YIM**|**XAN**|**YAN**|**XOB**|**YOB**|**XRI**|**YRI**|**WTF** [Zn] Fm
CRA [Zn] [Rk] Fm [Wj] XAP|YAP|XIN|YIN|TSF
RRA [Zn] [Rk] Fm [Wj] XAP|YAP|XIN|YIN|TSF
ASF|**ASO** [Zn]

Vignetting

VUY|**VLY**|**VUX**|**VLX** [Zn] Fm

Depth of Focus

FFO|**IFO**|**NFO** [Zn]

Output Fiber Location

FLO [Zn] [Fm] [Wj] - Returns 0 = FIX, or 1 = CMP
FBX [Zn] [Fm] [Wj] - Returns FBX value
FBY [Zn] [Fm] [Wj] - Returns FBY value
FBZ [Zn] [Fm] [Wj] - Returns FBZ value
FBA [Zn] [Fm] [Wj] - Returns FBA value
FBB [Zn] [Fm] [Wj] - Returns FBB value

Miscellaneous

AFI|AFO	[Zn]	- Returns focal length if afocal, 0 otherwise
AFC	[Zn]	- Returns 0 (focal) or 1 (afocal)
ACM	[Zn] Fm	- Returns accommodation
ADM		- Returns afocal units: 'RAD'|'MR'|'UR'|'NR'|'DEG'|'MIN'|'SEC'
TEL|XZF	[Zn]	- Returns 0 (No) or non-zero (Yes)
RSR	[Zn] Fm	- Returns reference sphere radius
TEM|PRE		
DIM		- Returns 1 character string 'I'|'C'|'M'
INI		- Returns 3 character string
STO|FOC	[Zn]	- Returns the surface number

Materials

TRN	Sk Wj	
SPG	Sk [GL1|GL2]	
PRC	Sk [GL1|GL2]	- Returns strip price only

Surface Shape & Position

THI	Sk [Zn]	
GLA|GL1|GL2	Sk [Zn] [CAT]	- Returns string with glass name (CAT - catalog only)
GCH|GP1|GP2	Sk [Zn] [CAT]	- Returns string with glass name (CAT - catalog only)
GDP|GD1|GD2	Sk [Zn] [CAT]	- Returns string with glass name (CAT - catalog only)
RMD	Sk [Zn]	- Returns string 'REFL'|'REFR'|'TIRO'|'TIR'
CUX|CUY	Sk [Zn]	
RDX|RDY	Sk [Zn]	
DUM	Sk	- Returns 0 (surface is not a dummy), +1 (dummy), or -1 (dummy, but is a HOE, GRT, or MOD)
TYP DIF	Sk	- Returns string showing diffractive properties applied to a surface: 'None' 'HOE' 'DOE' 'GRT'
BLT	Sk [Zn]	- Returns string showing blaze type: 'IDL' 'KIN' 'STE' 'SIN' 'VHO'
BLD	Sk [Zn]	- Returns number: Blaze depth on surface 0 (if no diffractive properties on surface)
BNS	Sk [Zn]	- Returns number of steps for STE blaze type. If blaze type on Sk is not STE, returns number of steps that would be used if the blaze type were set to STE.

BWL Sk [Zn] - Returns blaze wavelength for GRT surface. If Sk is not GRT, returns the value of the blaze wavelength that would be used if the grating type were changed to GRT.

Surface Numbers and Labels

SLB Sk|S'label' - Returns number:
Surface number
0 (for undefined label)

SLL Sk|S'label' - Returns string:
Surface label
Null string (for unlabeled surface)

Special Surfaces - See "Special Surfaces" on page 21

Solves - See TYP SOL command on page 172

Tilts/Decenters

XDE|YDE|ZDE|ADE|BDE|CDE|XOD|YOD|ZOD Sk [Zn]

RET Sk - Returns, for surface k, the number of the surface "returned to"

GLB Sk - Returns, for surface k, the number of the global reference surface

See TYP DEC command on page 172

Apertures/Edge Definition

CA - Returns 0 (No), +1 (Yes), or -1 (APE)

CIR|REX|REY|ELX|ELY|ADX|ADY|ARO Sk [Zn] [L'label'] [CLR|EDG|OBS|HOL]

MAP Sk [Zk] - Returns maximum aperture for surface

First Surface Mirrors

CUM|THM Sk

GLM Sk [CAT] - Returns string with glass name (CAT - catalog only)

Coating/Cement Data

CIN|CTH|CEM Sk

MLT Sk - Returns 'coating_filename'

THV Sk Cj - Returns coefficient for coating thickness variation

THV XDE Sk - Returns decentration of coating thickness variation in x direction

THV YDE Sk - Returns decentration of coating thickness variation in y direction

Optimization Derivative Increments

DER Ik - Returns derivative increment value

VAR Ik - Returns derivative value string name

NUM VAR - Returns current number of variables

Menu

Search

Tolerances

Centered

DLF|**DLT**|**DLN**|**DLV**|**DLR**|**DLS**|**DLC**|**DAK**|**DAA**|**DAB**|
DAC|**DAD**|**DAE**|**DAF**|**DAG**|**DAH**|**DAJ**|**HOM**|**AXG**|**RAG** Sk [Zn] [L'label'] [C]

Irregularity

CYN|**CYD** Sk [Zn] [L'label'] [C]

Single Surface Decenter & Displacement

DLX|**DLY**|**DLZ** Sk [Zn] [L'label'] [C]
DLA|**DLB**|**DLG** Sk [Zn] [L'label'] [C]
TRX|**TRY** Sk [Zn] [L'label'] [C]

Group Decentering

STX|**STY** Si..j [Zn] [L'label'] [C]
BTX|**BTY**|**BRL** Si..j [Zn] [L'label'] [C] [R]
DSX|**DSY**|**DSZ** Si..j [Zn] [L'label'] [C] [R]
RLX|**RLY** Si..j [Zn] [L'label'] [C] [R]
DOL Si..j [Zn] [L'label'] [C]

Other Controls

TSF - Returns tolerance/compensator scale factor
INC - Returns 0 (No) or non-zero (Yes)
FRW - Returns fringe wavelength
SVT - Returns the Singular Value Decomposition (SVD) threshold value.
MCP - Returns the maximum number of compensators to be used in the system.

Other

Zoom Facility

POS [Zn] - Returns 0 (No) or non-zero (Yes)

Symmetry

SYM - Returns 3 character string:
'ROT'- rotational symmetry
'Y–Z' - Y–Z symmetry
'NON'- no symmetry

Special Surfaces

See TYP SUR command on page 172

K|**A**|**B**|**C**|**D**|**E**|**F**|**G**|**H**|**J** Sk [Zn]
IC Sk [Zn] - Returns 0 (No) or non-zero (Yes)
CUF Sk [Zn]
TA1|**TA2** Sk
TBE Sk Wj

SP0|SP1|SP2|SP3|SP4|H1|H2|H3|H4	Sk [Zn]	
KY|AR|BR|CR|DR|KX|AP|BP|CP|DP	Sk [Zn]	
GRO|GRS|GRX|GRY|GRZ	Sk [Zn]	
HTO	Sk	- Returns 'SPH'|'XTO'|'YTO'|'PAR'|'ASP'
HOR|HWL	Sk [Zn]	
HX1|HY1|HZ1|HX2|HY2|HZ2	Sk [Zn]	
HV1|HV2	Sk [Zn]	- Returns 'REA'|'VIR'
HCT	Sk	- Returns 'XY'|'R'|'AXY'|'XAY'|'XYA'|'AR'|'USR'
HCO	Sk [Zn] Cj	
HTH|HIN|HDI|HSW|HDN	Sk [Zn]	
MOD	Sk	- Returns 'CHR'|'ACH'|' '
MFL|MRD|MFF|MBF|MEN|MFD|MED	Sk [Zn]	
MWL	Sk Wj	
MCO	Sk [Zn] Cj	
UCO	Sk [Zn] Cj	
SCO	Sk [Zn] Cj	
UMC	Sk [Zn] [UDS|UD1|UD2|UD3|HOE|HO2|USP]	
UMF	Sk [UDS|UD1|UD2|UD3|HOE|HO2|USP]	
UMO	Sk [Zn] [UD1|UD3|HO2|USP] Cj	
UMR	Sk [UDS|UD1|UD2|UD3|HOE|HO2|USP]	

Array Elements

ARX|ARY|ARS|AMX|AMY	Sk	
AEX|AEY|AEZ|AEA|AEB|AEG|APD|APT	Sk Cj	

Non-Sequential Surfaces

When optional [Si] is omitted, data is returned for the first range in system. If no ranges exist, 0 is returned.

NSS	NS1[Si]	- Returns 0 if i is not in an NSS range, first surface of range otherwise
NSS	NS2[Si]	- Returns 0 if i is not in an NSS range, last surface of range otherwise
NSS	NSP[Si]	- Returns 0 if i is not in an NSS range, exit port surface of range otherwise
NSS	ROO[Si]	- Returns 0 if i is not in a ROO NSS range, first surface of the ROO otherwise
NSS	CCR[Si]	- Returns 0 if i is not in a CCR NSS range, first surface of the CCR otherwise
NSP	[Si]	- Returns exit port thickness for port on surface i
RMC	FIR|SEC Si	- Returns number of hits, before mode change; Si required FIR - for first mode change SEC - for second mode change
CCR	[Si]	- Returns corner cube apex length
CCR	E12|E23|E13 [Si]	- Returns corner cube angle errors
ROO	[Si]	- Returns roof apex length
ROO	E12 [Si]	- Returns roof angle error
RMD	Sk [Zn	- Returns string 'REFL'|'REFR'|'TIRO'|'TIR'
GLA|GL1|GL2	Sk [Zn] [CAT]	- Returns string with glass name (CAT - catalog only)
GCH|GP1|GP2	Sk [Zn] [CAT]	- Returns string with glass name (CAT - catalog only)
GDP|GD1|GD2	Sk [Zn] [CAT]	- Returns string with glass name (CAT - catalog only)

TRN|TR1|TR2 Sk
MXH

Gradient Index Materials
GRN Sk Cj [Wm] [Zn] - Returns coefficient

Aperture Apodization
PUI|PUX|PUY [Zn]

Polarization
POL - Returns 0 (No) or non-zero (Yes)
PTP|POR|PRO|PFR SPC [Zn] [Fm] - Returns input specifications
JXM|JYM|JXP|JYP [Zn] [Fm] - Returns input specifications
ST1|ST2|ST3 [Zn] [Fm] - Returns input specifications
PXI|PYI|PTP|POR|PRO|PFR[Sk] [Zn] [Fm] [Wj] [R0|R1]
- Returns output for ray (see page 180 for details)
NEO [UNI|CUB] Sk Wj - Returns value of Ne-No for material following the specified surface
UNI returns value for uniaxial crystal;
CUB returns value for cubic crystal.
CAO Sk
CAD [UNI] L|M|N - Returns direction numbers for uniaxial birefringent crystal.
CAD CUB Sk LY|MY|NY|LZ|MZ|NZ
- Returns the Y and Z cubic crystal axis orientation values.
POP Sk FAR - For Faraday rotator. Returns value (in degrees) of polarization rotation.
POP Sk LIN - For ideal linear polarizer. Returns value of attenuation factor.
POP Sk RET - For ideal retarder. Returns value of retardation waves.
POP Sk USP - Returns 0 if Sk is not assigned a user-defined surface properties sub-routine, and 1 if it is.
BIR Sk [Zj] - Returns:
"None" if Sk is not defined to be birefringent
"ORD" for BIR ORD
"EXT" for BIR EXT
"AVE" for BIR AVE
"AVO" for BIR AVO
"ORO" for BIR ORO
"EXO" for BIR EXO

Interferometric Deformations/Intensity Apodization
INT Sk [L'label'] - Returns 'int_filename'
or **INT** ENP|EXP [Fk] [Zn] [L'label']
IMI Sk [L'label'] -Returns 'XC'|'YC'|' '
or **IMI** ENP|EXP [Fk] [Zn] [L'label']
ISF|IRO|INR|INX|INY Sk [L'label']
or **ISF|IRO|INR|INX|INY** ENP|EXP [Fk] [Zn] [L'label']

Optical Database Information

Optical Definitions

EFL|TT|IMD|IMC	[Zn]
RED	[Wk] [Zn]
EFX|EFY|FPX|FPY	[Si..j] [Wk] [Zn]
ENP|EXP|DIX|DIY|XFO|YFO	[Zn] [Fm]
EPD|ENP|EXD|FNO|NA|NAO	[Zn]
YNI	Sk [Zn]
AFN	[Si..j] [Zn]

Manufacturing & Packaging

CT|ET|SD|BLO	Sk [Zn]
OAL	[Si..j] [Zn]
ASC|BSC|CSC|XSC|YSC|ZSC|LSC|MSC|NSC	Sk [Zn] Gj
SNS	Sk [Zn]

Paraxial Ray Trace Data

UMX|UMY|HMX|HMY|IMX|IMY|UCX|UCY|HCX|HCY|ICX|ICY [Sk] [Zn] [Wj]

First & Third Order Aberrations

AX|LAT	[Sk|Si..j] [Zn] [Wj..k]
SA|TCO|SAS|TAS|PTB|DST|PTZ	[Sk|Si..j] [Zn] [Wj]

Real Ray Trace Data

See Single ray trace (RSI, SIN) below

Available Outputs from LDM Operations

Lens scaling

SCA - Returns last scale factor used (Default: 1.0)

Single ray trace (RSI, SIN) - Returns single item for designated ray, tracing only when needed; if Ri is omitted, Fm and Wj are ignored and value returned is for last RSI traced.

X|Y|Z|L|M|N|AOI|AOR| [Sk] [Zn] [Fm] [Wj] [Gj] [Ri]
SRL|SRM|SRN

(L,M,N, are for ray following the surface)

OP	[Si..j] [Zn] [Fm] [Wj] [Ri] [RFS]	- The optional keyword RFS specifies that the optical path length from the object surface to the first surface is measured from a reference sphere centered at the object. This can be useful for systems with long object distances. If RFS is omitted, the optical path length is measured from the object point. RFS is only valid when the first surface number of the specified range is the object surface.
OPR	[Si..j] [Zn] [Fm] [Wj] [Ri]	- Equivalent to the OP database item with the RFS keyword. Can be a user-defined constraint in AUTO.
OPD	[Zn] [Fm] [Wj] [Ri]	

PXI|PYI|PTP|POR|PFR [Sk] [Zn] [Fm] [Wj] [R0|R1]
PRO [Sk] [Zn] [Fm] [Wj] [Ri] [R0|R1] - Returns:
-1 = Left-handed polarization
1 = Right-handed polarization
0 = Linear polarization

JR1|JR2|JR3|JR4 [Sk] [Zn] [Fm] [Wj] [R0|R1]
JI1|JI2|JI3|JI4 [Sk] [Zn] [Fm] [Wj] [R0|R1]
MGS|MGP|PHS|PHP [Sk] [Zn] [Fm] [Wj] [R0|R1]
DEP|HFR|HFA [Sk] [Zn] [Fm] [Wj] [Ri]
Not available: TNX|TNY|LEN (Use L/N for TNX, M/N for TNY; use OP/IND for LEN)

BLS - For last single ray, returns surface number at which ray is first blocked by an aperture or obscuration
<0 = Ray is blocked by obscuration
>0 = Ray is blocked by aperture
0 = Ray is not blocked

RER - For last single ray, returns ray error flag
0 = Trace successful
>0 = Value is surface number where failure occurred
<0 = Ray failed when corresponding chief ray (RSI only) failed to trace through the center of the stop; |RER| is surface number where failure occurred

Option Database Information

Available Outputs - After running the option

AUT - Automatic Design

AUT.ERF - Error function value
AUT.XCN [Zn] [Fm] - X centroid value
AUT.YCN [Zn] [Fm] - Y centroid value
ABR Ak - Value of user-defined aberration Ak in a user-defined error function
or **ABR** Fk Rk|Ek [Wk] [Zk] [Sk] [Gk] [Hk] or user-defined aberration specified by its non-default qualifiers
X|Y|Z|L|M|N|SRL|SRM|SRN|AOI|AOR|LEN|OPL|DX|DY|OPD|DMD

Worksheet Buffer Database

Refer to last page of Macro-PLUS Worksheet Buffer section for information on Worksheet Buffer Database Items.

Menu

Search

Worksheet Buffer

Worksheet Buffer Commands

Output Collection On/Off

```
BUF  Yes|No                                (Def: No)
```

Enable/disable data collection into worksheet B0. When on, all CODE V output is appended to end of B0. Data collection is independent of OUT command, but is affected by VER and ECH.

Worksheet Status

```
BUF  ?
```

Report status of all worksheets.

Copy Cells

```
BUF  COP  [Bn] [Ik|Ii..j] [Jm|Jr..s] [TRN] [VAL|FMT]
```

Copy cells from specified area of specified worksheet to current worksheet at the current position; if destination cells do not exist they are created. Source and destination cells cannot overlap.

TRN	Transpose data upon copy (rows into columns and columns into rows)
VAL	Copy cell values but not formats
FMT	Copy cell formats but not values

Delete Worksheet Buffer

```
    BUF  DEL  Bk|Bi..j
or  BUF  DEL  [Bn] Ik|Ii..j
or  BUF  DEL  [Bn] Ik|Ii..j  Jm|Jr..s
```

Delete specified buffers or portions of a specified buffer. First form completely deletes a buffer or range of buffers. If current buffer is deleted, B0 is made current buffer. Second form deletes a specified row or row range in the specified buffer (default is current buffer). Leftover rows are moved up. Third form deletes a specified column or column range in a specified row or row range in the specified buffer (default is current buffer); leftover columns are moved left. Third form does not delete rows; deleting all columns in a row leaves a blank row.

Difference Function

```
BUF  DIF  [Bn] [Ik|Ii..j] [Jm|Jr..s]
```

Compare the range of cells specified to an area of the same size located at the current buffer location and generate a report listing the differences. The default for rows is Ia (all rows) and the default for columns is Ja (all columns); the default for the buffer is the current buffer.

Export to File

```
BUF  EXP  [Bn] [li..j] [Jk..l]  [SEP] [filename]
```

Export all or a portion of a worksheet to a tab-delimited file (default filename CODEV.DAT, default extender .DAT). SEP uses separator defined by BUF SEP to be used as delimiter instead of tabs.

Output Format

```
BUF FMT  [Bn] [Ik|li..j] [Jm|Jr..s] 'format_spec'...
```

Specify output format for specified cells. Multiple formats may be given; formats are filled over the cells left to right, top to bottom. If number of cells exceeds number of formats, the pattern is repeated.

Find Match

```
    BUF FND  [Bn] [Ik|li..j] [Jm|Jr..s] [FWD|REV] [OR|AND|ADJ] "expression"|word|num...
or  BUF FND  [FWD|REV]
```

Find first and successive matches of given expressions, words, or numbers in the specified area of the specified buffer. The following special characters are defined for matching expressions:

?	- Matches 1 of any character
[char-class]	- Matches a single character in char-class
*	- Matches 0 or more of the preceding character, character list, or word list
@	- Matches 1 or more of the preceding character, character list, or word list
{expr-list}	- Matches any expression in expr-list
<	- Matches the following text only if a space, tab, or cell boundary precedes the text
>	- Matches the preceding text only if a space, tab, or cell boundary follows
^	- If the first character in the expression, anchors the match to the beginning of a cell
$	- If the last character in the expression, anchors the match to the end of a cell
\c	- Matches character c literally, so \? matches a "?".

Worksheet current location is set to location of beginning of match. The second form of the command finds the next occurrence.

FWD	Search in forward direction (default)
REV	Search in reverse direction
OR	Find rows containing one or more cells matching any of the expressions, words, or numbers (default)
AND	Find rows containing cells which match all of the set of expressions, words, or numbers in any order
ADJ	Find rows containing adjacent cells matching all the set of expressions, words or numbers in the order given.

Import Data

```
BUF  IMP  [Bn] [LIS|SEP] filename
```

Import data from a tab-delimited text file (default extender .DAT) to the end of the specified worksheet (you cannot import to buffer B0). If importing non-tab delimited files, use either LIS or SEP qualifier; LIS uses the default parsing algorithm, SEP uses separator defined by BUF SEP to be the delimiter.

Insert Rows and Columns

```
BUF  INS  [Bn] [lk] [num_rows]
BUF  INS  [Bn] [lk|i..j] Jm [num_columns]
```

Insert rows or columns into specified buffer (default is current buffer). First form inserts blank rows above row k; default is to insert one row at current row (lc). If row k does not exist, rows are added as needed. Second form inserts columns to the left of column m in the specified rows; default is to insert one column at column m in all rows (la). If column m does not exist, columns are added as needed. Does not move buffer position pointer.

Maximum Number of Lines

```
BUF  LEN  maximum_B0_lines                    (Def: 10000)
```

Specify the maximum number of lines in read-only buffer B0.

List Specified Worksheet

```
BUF  LIS  [Bn] [lk|li..j] [Jm|Jr..s] [NOL] [OR|AND|ADJ] ["expression"|word|num...]
```

List specified area of specified worksheet.

NOL	Do not print line numbers (default: print line numbers)
OR	List rows containing one or more cells matching any of the expressions, words or numbers (default)
AND	List rows containing cells matching all of the set of expressions, words, or numbers in any order
ADJ	List rows containing cells matching all of the set of expressions, words, or numbers in the order given

Move Inside Buffer

```
BUF  MOV  [Bn] [lj] [Jk]
```

Specify current buffer and current buffer location. If requested buffer does not exist, it is created.

Reparse Rows

```
BUF  PRS  [lk|li..j] ["format_str"]
```

Reparse the specified rows of buffer B0, using the specified format string (Q qualifier format).
If format string is omitted, default parsing is performed.

Put Values in Cells

```
BUF  PUT  [Bn] [lk|li..j] [Jm|Jr..s] "string"|num...
```

Put one or more values into specified area of specified worksheet. Values are filled left to right, top to bottom.
If I and J ranges are specified and the number of cells to be filled exceeds the number of inputs, data are repeated over the area.

Restore Worksheet

```
BUF  RES  [Bn] filename
```

Restore worksheet from the specified file (default extender .BUF) into specified empty buffer (default current buffer).

Save Worksheet

```
BUF  SAV  [Bn] [filename]
```

Save entire specified worksheet in specified file (default extender .BUF, default file CODEV.BUF). File is binary and cannot be edited.

Cell Separator String

```
BUF  SEP  [separator_string](Def: " ")
```

Define string used to separate cells in BUF LIS.

Sort Rows

```
BUF  SRT  [Bn] [Ii..j] Jk [ASC|DES]
```

Sort specified rows of specified worksheet according to the contents of column J. Order is empty cells (lowest), followed by numeric cells sorted numerically, followed by string cells sorted alphabetically (case independent).

ASC	Sort in ascending order, lowest value to highest (default)
DES	Sort in descending order, highest value to lowest

Worksheet Buffer Database Items

In all database items, if any optional buffer, row, or column qualifiers are omitted, the current worksheet and cell locations are used. Be sure to enclose each database item in parentheses.

BUF.B		- Returns the number of the current worksheet
BUF.COL	[Bn] [Ik]	- Returns number of cells in row Ik
BUF.EMP	[Bn]	- Returns 0 = worksheet is not empty 1 = worksheet is empty
BUF.FMT	[Bn] [Ik] [Jm]	- Returns the Q format picture string for the given cell
BUF.FND		- Returns 1 = last BUF FND command was successful 0 = last BUF FND command was not successful
BUF.FST	[Bn]	- Returns number of first row in Bn (=1 for B1 and greater)
BUF.I	[Bn]	- Returns row position of current cell in worksheet Bn
BUF.J	[Bn]	- Returns column position of current cell in worksheet Bn
BUF.LEN		- Returns maximum number of rows allowed in worksheet B0
BUF.LST	[Bn]	- Returns row position of last row in worksheet Bn
BUF.MXJ	[Bn]	- Returns largest column for all rows in worksheet Bn
BUF.NUM	[Bn] [Ik] [Jm]	- Returns numeric representation of specified cell (error if cell not type NUM)

BUF.ON		- Returns 1 = output being collected in B0 0 = output not being collected in B0
BUF.STR	[Bn] [Ik] [Jm]	- Returns string representation of specified cell (error if cell of type UNKNOWN)
BUF.TXT	[Bn] [Ik]	- Returns a properly formatted, concatenated string containing all cell contents in row Ik
BUF.TYP	[Bn] [Ik] [Jm]	- Returns test string with the type of the specified cell "NUM" - numeric cell "STR" - string cell "UNKNOWN" - cell that does not exist or has no value assigned

Command Index

Important Commands
  Options
    GO - Execute this option
    CAN - Cancel all input to this option
    Ctrl-**BREAK** - Emergency keyboard intervention to exit computation in this option at the first available opportunity

  Exit
    EXI - Normal exit from CODE V to operating system
    ALT+F4 - Keyboard intervention to exit CODE V immediately

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