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RSI/SIN-Real Ray Trace

The Real Ray Trace feature (RSI/SIN) allows you to trace single rays in designated wavelengths, with user-defined formatting.

Performing Real Ray Traces

CODE V provides two forms of a real ray trace:

- The single ray trace (SIN command) traces any arbitrary ray, defined by actual coordinates and angles. Go to “Performing Single Ray Traces” on page 18-165 for details.
- The relative single ray trace (RSI command) traces a ray defined by relative field and pupil coordinates. Go to “Performing Relative Single Ray Traces” on page 18-168 for details.

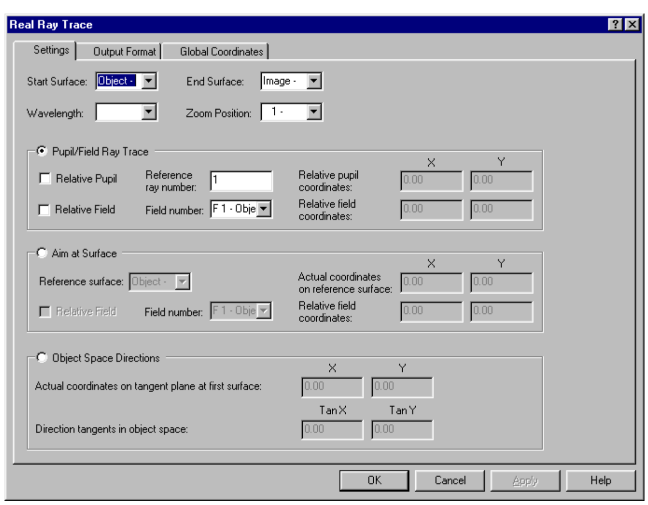
The single ray trace and relative single ray trace features are complementary to each other and have different uses. The **relative single ray trace** is the more commonly used feature; it is easy to use since its arguments are relative entrance pupil coordinates and relative field locations, and, because it is a relative ray, it also outputs the OPD between the ray and its chief ray. However, the relative single ray trace does require that the chief ray for the requested relative field traces to the image plane. The **single ray trace** feature has no such restriction. It will trace any arbitrary ray, although you have to be specific in defining the ray’s entrance coordinates to the optical system and its direction tangents. The single ray trace feature is especially useful when the chief ray for a given field angle will not trace.

You can also define the output format for both forms of the real ray trace. Go to “Defining the Single Ray Trace Output Format” on page 18-173 for details. To find out about obtaining ray trace output in global coordinates, go to “Local vs. Global Output (GLO Command)” on page 18-177.

These simple calculations, along with the text and graphical display operations discussed in “Displaying and Reviewing Lens Data” on page 15-5, allow you to verify lens data and diagnose data mistakes before invoking the more comprehensive option calculations. If you’re using these quick analysis features from the command line, none of them move the surface pointer.

Performing Single Ray Traces

To perform a single ray trace, choose the **Analysis** > **Diagnostics** > **Real Ray Trace** menu. The **Real Ray Trace** dialog box is displayed, with the **Settings** tab automatically selected. Define the controls on this tab as described in the following table.



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Command Syntax	
Screen Control	**Explanation**
SIN[Sk | Si..j] [Zk] [Wn]x_1st_surf_tan_plane y_1st_surf_tan_plane x_dir_tan y_dir_tan or **SIN**[Sk | Si..j]	
Object Space Directions	Traces single ray, for designated **Zoom Position** (Zk) and **Wavelength** (Wn), defined by: Actual coordinates on tangent plane at first surface: **X** (x_1st_surf_tan_plane) Specifies X coordinate on tangent plane of first surface **Y** (y_1st_surf_tan_plane) Y coordinate on tangent plane of first surface Direction tangents in object space: **TanX** (x_dir_tan) Specifies X field coordinate, expressed as a direction tangent in object space (L / N) **TanY** (y_dir_tan) Specifies Y field coordinate, expressed as a direction tangent in object space (M / N) Output will be for surface(s) specified in the **Start Surface** and **End Surface** fields (Sk|Si..j); all surfaces (SA) is the default. If zoom position Zk is omitted, the ray is traced for all zoom positions. On the command line, the second form of SIN shown above will trace ray defined by last SIN command. The listing generated includes up to 20 components as selected on the **Output Format** tab, or ROF command. If global coordinates are active, as specified on the **Global Coordinates** tab, or GLO command, these components for all surfaces are relative to the single coordinate system of the GLO command; otherwise, the components for each surface are relative to each surface's local coordinate system. **Note**: Only the one ray is traced; no corresponding chief ray needs to be traceable, as with relative single ray traces (RSI). The X and Y coordinates on the tangent plane of the first surface are interpreted as being on the plane tangent to the first surface before any tilts or decenters are applied to the surface.

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What You Need to Know About the Single Ray Trace (SIN Command)

The single ray trace feature (**SIN** command) is used to trace an arbitrary ray into the optical system. It does not trace a chief ray, and does not depend on any other ray being able to trace. Because it does not trace a chief ray first, no OPD output is made for **SIN**. Also, because there is no object point specified (only a ray direction), optical path (OP) is only calculated from the tangent plane of the first surface, rather than from a sphere centered on the object. The tangent plane of the first surface is interpreted as being the plane tangent to the first surface before any tilts or decenters are applied to the surface.

In the GUI, the single ray trace is available in the **Analysis** > **Diagnostics** > **Real Ray Trace** menu.

The data inputs for the single ray trace are actual X and Y coordinates on the tangent plane of the first surface (not on the first surface, unless it is plano), and actual X and Y direction tangents in object space. The X and Y coordinates on the tangent plane of the first surface are interpreted as being on the plane tangent to the first surface before any tilts or decenters are applied to the surface. This is shown in Figure 1.

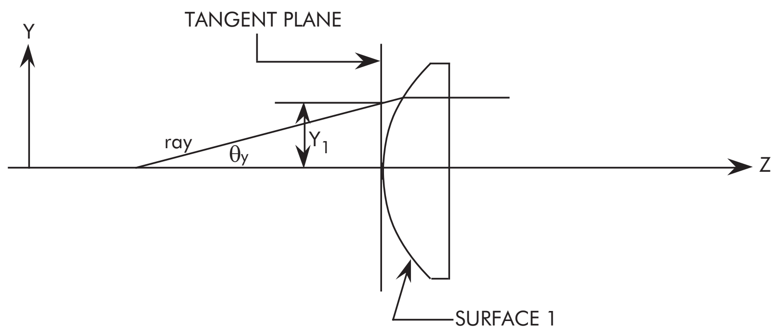

Figure 1. Data inputs for SIN

The SIN command also accepts W, Z, and S qualifiers in the same way as the relative single ray trace (RSI) to specify a wavelength, zoom position, or surface output range.

```
SIN  0 0 .3 .4                ! Trace a ray with direction tangents of .3 in X and .4
                              !  in Y which hits the vertex of the first surface
SIN  .6 .7 0 0                ! Trace an on axis ray which hits the first
                              !  surface at .6 in X and .7 in Y
SIN  .3 .4 0 .2               ! Trace a ray with a Y direction tangent of .2 which
                              !  hits the tangent plane of the first surface at .3
                              !  in X and .4 in Y
SIN  0 0 0 TANF(20/57.295)    ! Trace a ray at 20 degrees in Y which hits the
                              !  vertex of the first surface
```

Note that the X and Y direction tangents are the ratios of the X and Z direction cosines (L/N) and ratios of the Y and Z direction cosines (M/N), respectively.

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Performing Relative Single Ray Traces

To perform a relative single ray trace, choose the **Analysis** > **Diagnostics** > **Real Ray Trace** menu. The **Real Ray Trace** dialog box is displayed, with the **Settings** tab automatically selected. Define the controls on this tab as described in the table below.

Command Syntax	
Screen Control	**Explanation**
RSI [Sk | Si..j] [Zk] [Wn] x_fract_pupil y_fract_pupil x_fract_max_x_field y_fract_max_y_field or **RSI** [Sk | Si..j] [Zk] [Wn] Fm x_fract_pupil y_fract_pupil or **RSI** [Sk | Si..j] [Zk] [Wn] Fm Rs or **RSI** [Sk | Si..j]	
Pupil/Field Ray Trace	Traces a single ray, for the designated zoom position and wavelength. The various forms of the command allow several different methods of specifying field and entrance pupil coordinates. The first form of this command, selected in the GUI with the **Relative Field** checkbox, uses fractional field and pupil coordinates defined by: **Relative pupil coordinates: X** (x_fract_pupil) Specifies X pupil coordinate, as a fraction of unvignetted pupil radius. **Relative pupil coordinates: Y** (y_fract_pupil) Specifies Y pupil coordinate, as a fraction of unvignetted pupil radius. **Relative field coordinates: X** (x_fract_max_x_field) Specifies X field coordinate, as a fraction of maximum |X| field coordinate, retaining the sign. **Relative field coordinates: Y** (y_fract_max_y_field) Specifies Y field coordinate, as a fraction of maximum |Y| field coordinate, retaining the sign. Output will be for surface(s) specified in the **Start Surface** and **End Surface** fields (Sk|Si..j); all surfaces (SA) is the default. If **Zoom Position** (Zk) is omitted, the ray is traced for all zoom positions. The second form of this command, selected in the GUI with the **Relative Pupil** checkbox, uses a numbered field designated in **Field number** (Fm) to specify the field coordinates while allowing you to enter the fractional pupil coordinates (**Relative pupil coordinates** fields) to specify the entrance pupil coordinates. The third form of this command (in the GUI you leave both the **Relative Field** and **Relative Pupil** checkboxes unselected) allows you to specify one of the five reference rays (**Reference ray number**) from a particular field (**Field number**). On the command line, the final form of the RSI command shown above will trace the ray that was traced by the last RSI command. Listing includes up to 20 components as selected on the **Output Format** tab (ROF command). If global coordinates are active, as specified on the **Global Coordinates** tab (GLO) command, these components for all surfaces are relative to the single coordinate system of the GLO command; otherwise, components for each surface are relative to each surface's local coordinate system. **Note**: RSI also traces a chief ray from the same object point; both rays must be traceable. If chief-ray aim points have been entered (CRA), then they will be used only if the field is specified by entering a field number (i.e. the second and third forms of the command).

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Command Syntax	
Screen Control	**Explanation**
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 or **RSI** [Sk | Si..j] [Zk] [Wn] Fm x_ref_surf y_ref_surf num_of_ref_surf or **RSI** [Sk | Si..j]	
Aim at Surface	Traces a single ray for the designated zoom position and wavelength. In one form of the command, the field can be specified as a numbered field (**Field number**). Another form of the command, specified in the GUI by selecting the **Relative Field** checkbox, allows you to specify the field as fractional field coordinates: **Relative field coordinates: X** (x_fract_max_x_field) Specifies X field coordinate, as a fraction of maximum |X| field coordinate, retaining the sign. **Relative field coordinates: Y** (y_fract_max_y_field) Specifies Y field coordinate, as a fraction of maximum |Y| field coordinate, retaining the sign. The final information needed to select a ray are the X and Y coordinates on a user selected reference surface: **Actual coordinates on reference surface: X** (x_ref_surf) Specifies actual X coordinate on reference surface. **Actual coordinates on reference surface: Y** (y_ref_surf) Specifies actual Y coordinate on reference surface. **Reference surface** (num_of_ref_surf) Specifies number of the target surface on which the X and Y coordinates are designated. Output will be for surface(s) specified in the **Start Surface** and **End Surface** fields (Sk|Si..j); all surfaces (SA) is the default. If **Zoom Position** (Zk) is omitted, the ray is traced for all zoom positions. On the command line, the third form of the RSI command shown above will trace the ray defined by the last RSI command. Listing includes up to 20 components as selected on the **Output Format** tab (ROF command). If global coordinates are active, as specified on the **Global Coordinates** tab (GLO command), these components for all surfaces are relative to the single coordinate system of the GLO command; otherwise, components for each surface are relative to each surface's local coordinate system. **Note**: RSI also traces a chief ray from the same object point; both rays must be traceable. If chief-ray aim points have been entered (CRA), then they will be used **only if** the field is specified by entering a field number (i.e. the second form of the command).

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What You Need to Know About the Relative Single Ray Trace (RSI Command)

In the **Real Ray Trace** dialog box, in the **Pupil/Field Ray Trace** area, the arguments for the relative single ray trace (**RSI** command) are generally the X and Y relative pupil coordinates, and the X and Y relative field angles, but short forms can be used for pupil and field. If the desired field is one of the 25 fields (F2, F2, F3, F4, F5, etc.) in the specification data, the field can be specified in **Field number** (F qualifier). A **Reference ray number** value (R qualifier) can be used for the pupil coordinates to select one of the five reference rays (R1, R2, R3, R4, R5) but only if an F qualifier has also been used.

Other qualifiers for the **RSI** command are **Wavelength** (W), **Zoom Position** (Z), and **Start Surface** and **End Surface** (S). Rays are traced in the reference wavelength unless specified with the W qualifier. The chief ray in the reference wavelength for that field is traced first; in addition, if the requested wavelength is a wavelength other than the reference wavelength, a chief ray is also traced at the requested wavelength; for **RSI**, these chief rays must be traceable. The requested ray is traced for all zoom positions; a Z qualifier will limit the output to only one zoom position. The default is to list ray trace output for all surfaces from object to image, unless limited with an S qualifier.

On the command line, an **RSI** command with no qualifiers or data will retrace the last ray traced. If only the S qualifier is given, the last ray is traced again, with data output for the new surface range. This is helpful when you are making changes to the lens data and testing with a ray.

If the R and F qualifiers are not used, pupil and/or field coordinates are given in relative values. The X and Y pupil coordinates are relative to the circular pupil for the requested relative field angle. The pupil used is the paraxial entrance pupil diameter located at the real entrance pupil location for that field. A value of 1 for relative X or relative Y means trace the ray at the edge of the pupil in that direction. Vignetting values are ignored by **RSI**. Since the vignetting values change for different fields, **RSI** can not know what the vignetting value would be for an arbitrary field, hence **RSI** does not use any vignetting values. You must manually take them into account. This is true even when using the F qualifier, even though the specified fields do have defined vignetting values. Note also that **RSI** ignores any CRA specification unless the field is specified with an F qualifier, in which case the CRA specification is used.

```
YAN 0 10
VUY 0 .3
RSI 0 1 0 1                ! Traces the ray at the upper rim of the pupil at
                           !  the maximum field (vignetting value is ignored)
RSI 0 .7 0 1               ! Traces a ray at a relative pupil position
                           !  of 0.7 in Y (the same as the vignetted
                           !  marginal ray) at the full field
RSI 0 1-(VUY F2) 0 1       ! Traces the upper Y vignetted ray (same as R2)
                           !  for full field
RSI F2 0 1                 ! Traces the ray at the upper rim of the pupil
                           !  (vignetting is ignored) for field 2
RSI F2 0 1-(VUY F2)        ! Traces the upper Y vignetted ray for field 2
                           !  (same as R2)
```

If the R qualifier is used, then the reference rays are traced, and these reference rays do take into account any vignetting.

```
YAN 0 10
VUY 0 .3
RSI F2 R2                  ! Traces the upper vignetted marginal ray for field 2
                           !  (reference ray R2)
```

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The field angle inputs to the **RSI** command are relative to the maximum X and Y values for any of the 25 field angles specified in the LDM (regardless of whether the largest value is the 25th field or not); the X and Y maximums are selected separately and may thus come from different field points. The sign of the maximum value is retained as the definition of the "largest" field. Thus, if the maximum field angle specified in the LDM is negative, then a relative field of +1 in **RSI** corresponds to the negative angle. If there are both a positive and a negative field angle with the same absolute maximum value, the positive value is retained for the maximum. X and Y relative angles are calculated separately for the X and Y field specifications. If there are no X field specifications, then any relative X field in a **RSI** command will trace a 0 field, since the maximum value is 0; if you want to trace a ray from an X field, you must first have a non-zero X field specification entered in the LDM.

```
YAN   0 10 20
RSI   0 0 0 1       ! Traces a ray at +20 degrees

YAN   0 -10 -20
RSI   0 0 0 1       ! Traces a ray at -20 degrees
RSI   0 0 0 -1      ! Traces a ray at +20 degrees

YAN   0 -10 10
RSI   0 0 0 1       ! Traces a ray at +10 degrees

YAN   0 10
XAN   0 0
RSI   0 0 1 0       ! Traces an on-axis ray (no X field specified)

YAN   0 10
XAN   0 5
RSI   0 0 1 0       ! Traces a ray at +5 degrees in X
RSI   0 0 1 1       ! Traces a ray at 5 degrees in X and 10 degrees in Y
```

Since object heights are stored in CODE V, relative angles do not multiply the angle value, but multiply the tangent of the maximum angle.

```
YAN   0 10
RSI   0 0 0 1      ! Traces a ray at 10 degrees

RSI   0 0 0 .5     ! Traces a ray at 5.038369 degrees (the angle
                   !  whose tangent is half the tangent of 10 degrees)
```

What is used by **RSI** is the maximum value of the field specifications. It does not matter what the other values are or how many there are.

```
YAN   10
RSI   0 0 0 .5            ! Trace a ray at 5.038369 degrees
YAN   1 2 10 3 4
RSI   0 0 0 .5            ! Trace a ray at 5.038369 degrees
```

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If the F qualifier is used, then both the X and Y field specifications are used for that field number. For example, set up three fields on-axis and along the diagonal of a square format:

```
YAN   0 5 10
XAN   0 5 10
```

There is no F qualifier for these fields which will represent a ray at 10× in Y only. To trace such a ray, relative fields must be used, as in:

```
RSI   0 0 0 1       ! Trace a ray at 10 degrees in Y and 0 degrees in X
```

Relative Real Ray Trace – Targeted to a Spot on a Surface

The relative real ray trace (**RSI** command) also allows targeting of a ray to a specific spot on a specific surface. In the GUI, select the **Aim at Surface** button to enable this option. On the command line, this is accomplished by adding a fifth entry to the **RSI** data arguments. This fifth entry is the surface number of the targeted surface (**Reference surface** field in the GUI). If this is used, then the first two entries are not relative pupil coordinates, but are actual X and Y positions on the targeted surface (**Actual coordinates on reference surface** in the GUI). CODE V will then iterate to find the ray from the specified field which hits the targeted surface at the targeted spot. The field may be specified with a **Field number** (F) qualifier. If the F qualifier is used, then the surface number is the third entry.

```
RSI   .3 .5 0 1 7     ! Trace a ray at full field in Y which hits
                      !  surface 7 at an X value of .3 and a Y value of .5
RSI   F1 1 2 5        ! Trace a ray at the first specified field to
                      !  hit surface 5 at a point of 1 in X and 2 in Y
```

If the F qualifier is used, then any CRA specifications are used, otherwise they are ignored. The CRA will only affect the chief ray traced, and will have no effect on the targeted ray. Note that since **RSI** requires the chief ray to trace, the CRA and F qualifier can be used to trace a ray that would normally not be traced due to chief ray failure.

In a non-sequential system, if a ray is requested to hit a surface at a specific point, and the ray can hit the surface two or more times, the target is applied to the first hit at the surface. (Note that in Automatic Design, ray data for the last hit on the surface is the data retained and used for any constraints.)

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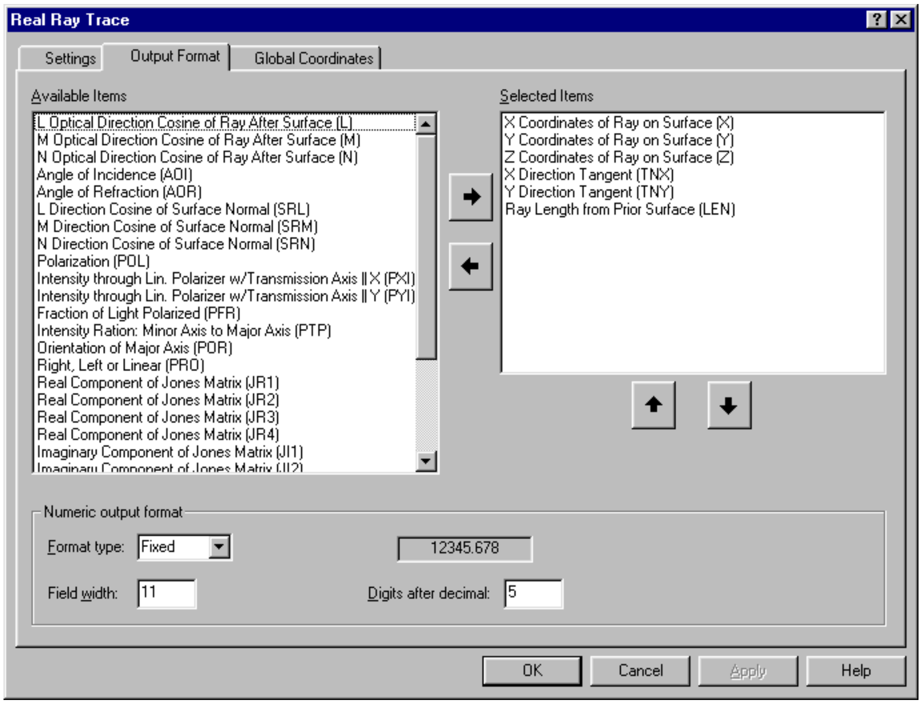
Defining the Single Ray Trace Output Format

To define the output format of a single ray trace, choose the **Analysis** > **Diagnostics** > **Real Ray Trace** menu. The **Real Ray Trace** dialog box is displayed. Click the **Output Format** tab, and define the settings on this tab as described in the table below.



On the **Output Format** tab, the **Available Items** area lists the items you can include in ray trace output. The **Selected Items** area lists the items that are currently selected to be included in ray trace output. To add items to the Selected Items area, click the button. To remove items from the **Selected Items** area, click the button. You can add or remove several items at once by first holding down the CTRL key, clicking the items, and then clicking the right- or left-arrow buttons. Also, you can arrange the order of items included in ray trace output by selecting an item in the **Selected Items** area and clicking the up- or down-arrow buttons (or).

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Command Syntax		
Screen Control	**Explanation**	**Default**
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...20]		
Available Items **Selected Items**	Specifies ray output format for single ray tracing (RSI and SIN); select for listing, up to 20 of the following parameters: **X,Y,Z Coordinates of ray on surface** (X, Y, Z) **L,M,N Optical direction cosines of ray after surface** (L, M, N) **X, Y direction tangents** (TNX, TNY) (L/N, M/N) **Angle of incidence** (AOI) **Angle of refraction** (AOR) **Ray length from prior surface** (LEN) **Direction cosines of surface normal** (SRL, SRM, SRN) POL: Equiv: ROF PXI PYI PFR PTP POR PRO **Intensity through linear polarizer with transmission axis parallel to X, Y axis** (PXI, PYI) **Fraction of light polarized** (PFR) **Intensity ratio: minor axis to major** (PTP) **Orientation of major axis** (POR) **Right, left or linear** (PRO) **Real components of Jones matrix** (JR1,JR2,JR3,JR4) **Imaginary components of Jones matrix** (JI1, JI2, JI3, JI4) **Magnitude of s and p components of polarization** (MGS, MGP) **Phase (in degrees) of s and p components of polarization** (PHS, PHP) **Jones Matrix Output Summary** (JNS): Equiv: all 4 Jones matrix real and imaginary components plus MGS MGP PHS PHP, output in two rows per surface **Surface Label** (SLB) adds a column listing any surface labels present in the system. (Polarization output only available if POL command is activated.) These are listed in the order specified. Note that more than six items may require greater than 80 columns of output.	X Y Z TNX TNY LEN

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Command Syntax		
Screen Control	**Explanation**	**Default**
Numeric output format	Specifies the format of ray output data selected to be listed. On the command line: 'format' is Fortran format for output ('F|D|E|Gn.d') Format type: **Fixed** format (F) **Scientific** (exponential) format (E+xx) (E) **ScientificD** (exponential) format (D+xx) (D) **General** format (G) Field width: (n) Range: 7 to 20) **Digits after decimal:** (d) Range: 0 to n-2) Default format: 'F11.5' Maximum printed width is 120 characters	'F11.5'

What You Need to Know About Formatting Ray Trace Output (ROF Command)

The ray trace output format (ROF command) lets you select which ray trace output is displayed and the format of the output; in the GUI, you specify the output format in the **Real Ray Trace** dialog box, on the **Output Format** tab. You have a choice of 20 different output data items, although 6 of the data items relate only to polarization properties. Up to ten may be selected for output with a single **ROF** command. More than 6 may result in output wider than 80 columns, which may truncate or wrap (depending on display settings) on a standard display. By setting the display to display wider output, more output may be viewed on a single line.

The default **ROF** is the X, Y, and Z coordinates at the surface plus the X and Y directions tangents after refractions and the ray length from the previous surface (note that the ray length is geometric only - it is not an optical path length). The default format is 'F11.5'. An **ROF** command with ray trace outputs listed but no format specified will use the previous format. An **ROF** command with only a format specification will not change the list of ray trace outputs. An **ROF** command with no qualifiers (format or ray outputs) will reset both the format and list of ray trace outputs to the defaults.

Format types F (fixed format), E (exponential, form E±xx), D (exponential, form D±xx), and G (general format) may be used. The first number in the format (integer before the decimal) specifies the field width (total characters, including sign, decimal, and any exponent); the field width can range from 7 to 20 (limited to a maximum of 11 in screens). The second number in the format (integer after the decimal) specifies the number of digits after the decimal, and can range from zero to two less than the field width. The specified format is used for all outputs on the line; the total number of characters output is restricted to 120 columns (including the surface numbers and one intervening blank between fields).

Note that if direction cosines are chosen for output (L, M, or N) that they are for the ray after refraction/reflection/diffraction. Also note that the direction cosines are optical direction cosines, i.e., they are multiplied by the refractive index of the medium.

Polarization data items are only available if polarization ray tracing has been enabled with the POL command. A POL qualifier will select all 6 polarization related outputs for display.

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```
ROF X Y Z TNX TNY LEN            ! Default
ROF Y Z M N                      ! Select reduced output for meridional rays
ROF                              ! Restores default ROF setting
ROF POL                          ! Selects all 6 polarization outputs
ROF PXI PYI PFR PTP POR PRO      ! Same as ROF POL
ROF X Y POL                      ! Selects X and Y output plus the 6 polarization
                                 !  outputs (eight outputs in all)
ROF 'E15.6'                      ! Change format, do not change output list
ROF 'F9.3' Y Z                   ! Change format and output list
```

Note: The LEN output is simply the geometrical length of the ray from the previous surface intersection to the current surface intersection. It is not an optical path, as index is not included. Optical path from surface-to-surface is not a displayable ray trace item with ROF, but it is available through the Macro-PLUS database item OP. This OP also includes the optical path contribution of diffractive optics (such as HOEs), lens modules, and interferogram effect (.INT files).

Description of Ray Trace Output

The output of a relative single ray trace (RSI) or single ray trace (SIN) is a line for each requested surface with the surface number followed by the output data selected with the **ROF** command. If the ray was traced with **RSI**, the output is followed by the OPD of the ray with respect to its chief ray. If the ray has a HOE with a diffraction efficiency less than 100%, then the **RSI** output is followed by the ray transmittance. If polarization ray tracing has been enabled, the output is followed by polarization phases and ray intensity. Refer to “Use of Polarization Ray Trace Information by CODE V” on page 9-27 for a description of these outputs.

The OPD is calculated as the difference of the ray’s optical path and its chief ray’s optical path. These optical path calculations are made from a reference sphere at the first surface tangent plane centered on the object point to a reference sphere at the exit pupil centered on the image point.

If the requested ray fails to trace, a diagnostic is given. There are three possibilities for ray failure:

1. The ray encountered a total internal reflection (or refracted when TIRO mode was specified).
2. The ray missed a surface.
3. The iteration to a special surface failed to converge.

For non-sequential surfaces there are also other ray failure modes. In any of these cases, the ray is traced up to the failure point. In the case of an **RSI**, if the chief ray for the requested relative field fails to trace, then a message to that effect is given, and there is no ray trace output. If a ray fails to trace for any reason, a Macro-PLUS database item RER (ray error) is set to the surface number of the ray failure; the sign tells whether it was the requested ray (+) or the chief ray (-) that failed. If the ray traces correctly, RER is set to zero.

Three other diagnostics are supplied with the ray trace output:

- The first one relates to negative edge thicknesses. If the ray length from the last surface is negative at any surface in the lens, indicating virtual ray tracing (tracing backwards along the ray), then an E (for edge error) is listed next to the surface number in the ray trace output. The usual reason for this is negative edge thickness on a lens, but it also can occur in decentered systems, especially on dummy surfaces used to reorient the coordinate system (in which case the E flag can be ignored).

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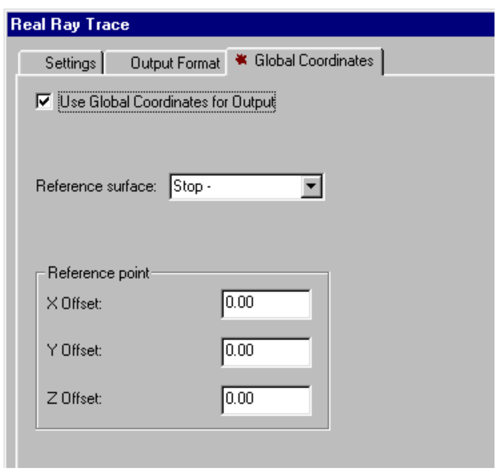
- The other two diagnostics relate to the ray encountering an aperture or an obscuration. The output of these diagnostics depends on the setting of the **Apertures Used** field in the **System Data** window (**Lens** menu), or CA command (CA NO, CA YES, or CA APE). In CODE V a ray traced with either **RSI** or **SIN** is traced to the image plane without regard to apertures or obscurations. In the ray trace output, however, if a ray hits a surface outside the apertures (user-defined or default) and the CA status is YES (the default for CA), an A (for aperture) is listed next to the surface number. If the ray encounters an obscuration, an O (for obscuration) is listed next to the surface number. Note that the E diagnostic will override the A or O diagnostics in the output. If the CA status is APE (for user-defined apertures only), then the check is only made on user-defined apertures, i.e., default apertures are ignored. If the CA status is NO, then no check is made at all.

  If the ray encounters an aperture or obscuration and sets the A or O diagnostic, a Macro-PLUS database item called BLS (blocking surface) is set to the surface number. If the ray passes outside the aperture on more than one surface, BLS is set to the number of the first such surface. In the case of the ray hitting a surface inside an obscuration, BLS is set to the negative of the surface number. If the ray encounters neither (i.e., passes inside all apertures and outside all obscurations), BLS is set to zero. Thus, macros can interrogate RER and BLS to determine the status of traced rays.

Local vs. Global Output (GLO Command)

The ray trace output is by default in local surface coordinates. The output can also be in global coordinates, where the global coordinate origin is specified to be at some specified x,y,z offset from the local origin of a specified surface (note the global origin can be offset from the specified surface origin but cannot be tilted with respect to it). The setting of the global coordinates is done on the **Global Coordinates** tab in the **Real Ray Trace** dialog box, or with the GLO command. For details about how to define global coordinates, go to “Entering Global Coordinates” on page 6-24.



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Examples of Ray Tracing

We will work with the doublet which is supplied with CODE V. This lens is stored in the directory CV_LENS.

```
CODE V> RES CV_LENS:DOUBLET

WARNING - Glass SSK4 is no longer available from SCHOTT
          A replacement glass is SSK4A
File CV_LENS:DOUBLET.LEN has been restored
Lens title: " Doublet"
```

First we will trace an on-axis upper marginal ray. The relative height is 1 for rays at the edge of the pupil.

```
CODE V> RSI 0 1 0 0

  Doublet
   Position 1, Wavelength =   587.6 NM
         X           Y           Z           TANX         TANY        LENGTH
OBJ    0.00000     0.00000     0.00000     0.00000      0.00000
STO    0.00000    16.66667     2.31817     0.00000     -0.10730      2.31817
  2    0.00000    16.15024    -3.21473     0.00000     -0.07560      4.84036
  3    0.00000    15.75919    -0.39303     0.00000     -0.16803      5.18773
IMG    0.00000     0.15898     0.00000     0.00000     -0.16803     94.14463
                         OPD =   -8.153 Waves
```

If we try to trace a ray at twice the pupil height, the ray will strike the first surface outside its default aperture, as indicated by the A in the output. Note that the ray also is beyond where the first and second surfaces cross, and thus there is also an edge thickness error, indicated by the E.

```
CODE V> RSI 0 2 0 0

      Doublet
      Position 1, Wavelength =   587.6 NM
            X           Y           Z           TANX         TANY      LENGTH
OBJ       0.00000     0.00000     0.00000     0.00000      0.00000
STO A     0.00000    33.33333     9.89894     0.00000     -0.23751      9.89894
  2 E     0.00000    40.25901   -29.60644     0.00000      0.04655    -29.97092
  3 A     0.00000    41.61842    -2.75143     0.00000     -0.01519     29.23792
IMG       0.00000    40.17249     0.00000     0.00000     -0.01519     95.21249
                           OPD = ******** Waves
```

Now, we will change the Ray Trace Output Format (**ROF**) to display just Y-oriented data for marginal rays, and then trace the on-axis marginal ray.

```
CODE V> ROF Y Z M N TNY LEN
CODE V> RSI 0 1 0 0

    Doublet
      Position 1, Wavelength =   587.6 NM
           Y           Z           M          N           TANY        LENGTH
OBJ      0.00000     0.00000     0.00000    1.00000      0.00000
STO     16.66667     2.31817    -0.17259    1.60841     -0.10730      2.31817
  2     16.15024    -3.21473    -0.12945    1.71247     -0.07560      4.84036
  3     15.75919    -0.39303    -0.16570    0.98618     -0.16803      5.18773
IMG      0.15898     0.00000    -0.16570    0.98618     -0.16803     94.14463
                           OPD =   -8.153 Waves
```

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Now, reset the **ROF** to the default, and trace an off axis chief ray for the second field.

```
 CODE V> ROF
 CODE V> RSI F2 R1

      Doublet
      Position 1, Wavelength =   587.6 NM
               X            Y            Z          TANX         TANY        LENGTH
OBJ       0.00000     -0.33E+11     0.00000      0.00000      0.03492
STO       0.00000      0.00000      0.00000      0.00000      0.02158      0.00000
  2       0.00000      0.22324     -0.00059      0.00000      0.02063     10.34745
  3       0.00000      0.27176     -0.00012      0.00000      0.03483      2.35225
IMG       0.00000      3.49195      0.00000      0.00000      0.03483     92.50626
                          OPD =     0.000 Waves
```

Next, trace a ray from the second field point which hits surface 3 at an X value of 0 and a Y value of 10.

```
 CODE V> RSI F2 0 10 3

      Doublet
      Position 1, Wavelength =   587.6 NM
               X            Y            Z          TANX         TANY        LENGTH
OBJ       0.00000     -0.33E+11     0.00000      0.00000      0.03492
STO       0.00000     10.46235      0.90283      0.00000     -0.04475      0.90338
  2       0.00000     10.09461     -1.22588      0.00000     -0.02767      8.22515
  3       0.00000     10.00000     -0.15820      0.00000     -0.07044      3.42027
IMG       0.00000      3.47659      0.00000      0.00000     -0.07044     92.83775
```

The previous examples have all been **RSI** commands. Now we will trace an ray which strikes the first surface tangent plane at an X value of 0 and a Y value of 5 with a Y direction tangent of 0.1.

```
 CODE V> SIN 0 5 0 .1

      Doublet
      Position 1, Wavelength =   587.6 NM
               X            Y            Z          TANX         TANY        LENGTH
OBJ       0.00000     -0.94E+11     0.00000      0.00000      0.10000
STO       0.00000      5.02067      0.20672      0.00000      0.02981      0.20775
  2       0.00000      5.31292     -0.33598      0.00000      0.03544      9.80729
  3       0.00000      5.40652     -0.04623      0.00000      0.04861      2.64268
IMG       0.00000      9.90244      0.00000      0.00000      0.04861     92.60552
```

Note that the Y value at surface 1 is not exactly equal to 5. 5 is the value of the ray at the tangent plane to surface 1, and since surface 1 is curved, the Y value will be different. The **SIN** command does not accept a R or F qualifier, as these are used with relative rays only.

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