RIM-Ray Aberration Curves/OPD Aberration Curves

The Ray Aberration Curves option (RIM) plots ray or wave aberrations vs. ray position in the aperture for X and Y fans.

When to Use the Ray Aberration Curves/OPD Aberration Curves Option

The Ray Aberration Curves option (RIM) provides a graphic display of lens aberrations ("rimray," "ray-fan plot," "fans"). It can display two types of aberration:

- Transverse aberration (real-ray position measured from real chief-ray position on image surface vertex tangent plane in lens units). This is the default.
- Wave aberrations (optical path difference, or OPD, in waves at each wavelength)

Default Operation

A bordered, titled, single page aberration plot is drawn for each zoom position (for up to five fields; more than five fields will generate multiple plots as necessary). Fans are traced and the ray aberration in the image surface is plotted at a default scale factor vs. the ray's intersection point with the aperture stop surface. At a general field angle, four fans are traced (+Y, -Y, +X, -X in the pupil); if the system is rotationally symmetric, the - X fan is dropped and on axis only the + X fan is traced. Only wavelengths with non-zero weights (wavelength weight values defined in the LDM) are plotted. In the plots, the Y ray aberration is plotted vs. the Y aperture stop coordinates for Y fans and similarly for X fans. The default scale factors are:

- 0.001 in for lens dimensions in inches
- 0.005 cm for lens dimensions in centimeters
- 0.050 mm for lens dimensions in millimeters

Command Mnemonics
(alphabetical)

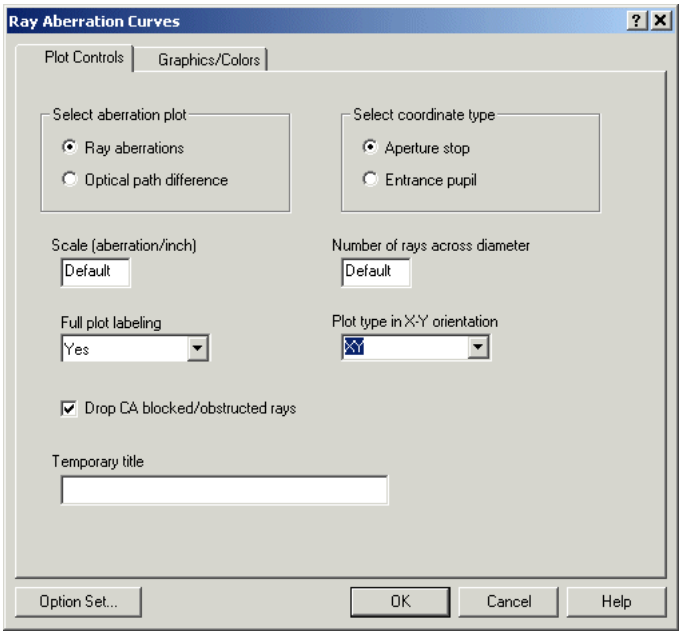
CAB	EP	LAB	NRD	SF	SSI
TIT	TYP	WFR	WVL		

Defining Plot Controls

To define plot controls for the Ray Aberration Curves/OPD Aberration Curves option:

- To plot transverse aberration, choose the **Analysis** > **Diagnostics** > **Ray Aberration Curves** menu. The **Ray Aberration Curves** dialog box displays with the **Plot Controls** tab in the foreground.
- To plot wave aberrations, choose the **Analysis > Diagnostics** > **OPD Aberration Curves** menu. The **OPD Aberration Curves** dialog box displays with the **Plot Controls** tab in the foreground.

Define the controls as described in the following table.



Command Syntax		
Screen Control	**Explanation**	**Default**
WFR Yes | No....z		
Select aberration plot	Selects plotting of either transverse aberration or wave aberration. Is a zoomable parameter; right-click over either the **Ray Aberrations** or **Optical Path Difference** buttons to access the **Zoom Editor**. **Ray Aberrations** Plots transverse aberration (real-ray position measured from real chief-ray position on image surface vertex tangent plane in lens units). Is the default. Equivalent to WFR No. **Optical Path Difference** Plots wave aberration (OPD - optical path difference) in waves, instead of ray aberration. Each wavefront is plotted as a fraction of its own wavelength. Equivalent to WFR Yes.	Transverse aberration is plotted (WFR No).

Command Syntax		
Screen Control	**Explanation**	**Default**
EP Yes | No....z		
Select coordinate type	Selects plotting relative to either the entrance pupil or aperture stop. Is a zoomable parameter; right-click over either the **Aperture Stop** or **Entrance Pupil** buttons to access the **Zoom Editor**. **Aperture Stop** Plots relative to aperture stop. Plotting relative to stop (default) is best for most lenses, particularly for wide angle lenses with pupil expansion. Equivalent to EP No. **Entrance Pupil** Plots relative to entrance pupil. This setting is appropriate for telecentric lenses or ones with uncontrolled stop penetration points. Equivalent to EP Yes.	Plot relative to aperture stop (EP No).
SSI aberration_for_plotted_inch....z		
Scale (aberration/inch)	Scales size in aberration per plotted inch, in waves for OPD and lens units for ray aberrations.	For wave aberration: 1 For ray aberration: In inches: 0.001 In cm: 0.005 In mm: 0.050
NRD num_rays_across_diameter		
Number of rays across diameter	Specifies number of rays across diameter spline fitted for plot. Range: 20 to 200. When CAB Yes is used, no spline fit is performed.	100
LAB Yes | No | color....z		
Full plot labeling: Yes/No/Color	Specifies plot labeling style. Is a zoomable parameter; right-click over any of the buttons to access the **Zoom Editor**. **Full plot labeling: Yes** Labels plots with default color. **Full plot labeling: No** Eliminates plotting of border, title, and annotation for zoom position(s); this is a quick plot. To suppress the automatic time and date stamp on plots, use the TAD No command. See “Plot Labeling” on page 1-87 for details. **Full plot labeling: Color** Designates color for plot labeling.	Yes. Labeling is included in default color.
CAB Yes | No		
Drop CA blocked/ obstructed rays	Eliminates plotting of any rays which are clipped by active apertures or obscurations. Rays are plotted as traced with no spline fit. CAB No cancels this command.	No. Keep rays whether clipped or not.

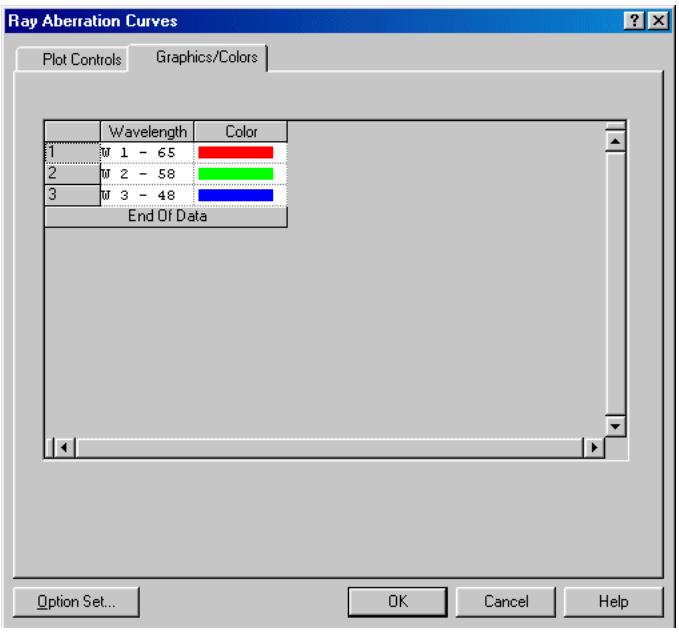
Command Syntax		
Screen Control	**Explanation**	**Default**
TIT 'temporary_title' (20+20)....z		
Temporary title	Plots up to 40 characters in two 20-character lines for the title of the designated zoom position. Is a zoomable parameter; right-click over this field to access the **Zoom Editor**. If no zoom position is designated, the title is applied to all positions.	Uses the first 40 characters of the system title.
TYP XY | XX | YY | YX....z		
Plot type in X-Y orientation	Selects type of format: **XY** Plots X coordinate of X fans, Y coordinate of Y fans. **XX** Plots X coordinate of X fans and Y fans. **YY** Plots Y coordinate of X fans and Y fans. **YX** Plots Y coordinate of X fans, X coordinate of Y fans.	XY

Defining Wavelength/Color Settings

To define wavelength/color settings for the Ray Aberration Curves/OPD Aberration Curves option:

- For transverse aberration, choose the **Analysis** > **Diagnostics** > **Ray Aberration Curves** menu. The **Ray Aberration Curves** dialog box displays. Click the **Graphics/Colors** tab.
- For wave aberrations, choose the **Analysis > Diagnostics** > **OPD Aberration Curves** menu. The **OPD Aberration Curves** dialog box displays. Click the **Graphics/Colors** tab.

Define the settings on the **Graphics/Colors** tab as described in the following table.



Command Syntax		
Screen Control	**Explanation**	**Default**
WVL Yes | No | color....w		
Color	Designates individual wavelength colors in plotted output. You can: • Enter a color name. • Enter **No** to eliminate plotting of the wavelength. • Enter **Yes** to plot wavelength using colors set by CLS WVL command.	Colors set by CLS WVL. Reference wavelength is plotted in first color. Line styles set by STL. Reference wavelength is plotted in first style.
Wavelength	Specifies wavelength to be plotted.	Wavelength 1.

Discussion of Input and Computations

What to Include in the LDM Data

No added LDM data is required.

Usage

Ray aberration curves are a traditional diagnostic tool for the lens designer. The shapes of these curves give information about the types and amounts of aberration present. For example, a parabolic shape is associated with coma. Of course, mixes of aberrations are typical in real systems. For information on the interpretation of curve shapes, see (for example) W. J. Smith, *Modern Engineering*, McGraw-Hill, New York (1966), pp. 68-71.

With the Ray Aberration Curves/OPD Aberration Curves option (**Analysis** > **Diagnostics** > **Ray Aberration Curves** or **Analysis** > **Diagnostics** > **OPD Aberration Curves** menu), you can analyze any type of lens, including all surface types, decentered systems, and zoom systems. A CODE V-supported graphics device (printer, plotter, or screen display) is required to view the output from RIM.

Aberration is plotted vertically; the horizontal coordinate represents the position in the aperture of the entering ray, either in the aperture stop (default) or on the entrance pupil (selected with the **Entrance pupil** setting in the **Ray Aberration Curves** dialog box, or with the **EP** Yes command). Either the X or Y component of the aberration can be plotted for each fan direction (**Plot type in XY orientation** setting or **TYP** command); the default, XY, is the usually desired case for centered systems. Both X and Y fans (sagittal and tangential for rotationally symmetric lenses) are plotted for each defined object point. See “Default Operation” on page 18-155 for a discussion of which fans are traced as a function of lens symmetry.

The scaling and appearance of the plot can be controlled. The vertical scale (as shown at the top of each set of axes) can be set with the **Scale (aberration/inch)** setting (**SSI** command). Labeling information can be included or suppressed; if drawn, its color can be chosen with the plot labeling setting (**LAB** command). The individual wavelengths can be assigned colors in addition to the standard use of line types to differentiate plotted curves on the **Graphics/Colors** tab (**WVL** command). (See “Defining Configuration - Graphics” on page 24-16.) The title placed on the plot can be temporarily changed from that of the lens (**TIT**). For some systems, you may need to change the number of rays traced to get a more accurate plot (e.g., systems with high-order aspheres; **NRD**). You can also eliminate plotting of any rays which are clipped by active apertures or obscurations using the **Drop CA blocked/obstructed rays** setting (**CAB** command). When you specify CAB Yes, the default NRD is 100 to make a smoother curve, since rays are plotted as traced with no spline fit. Otherwise, when CAB No is used, the default NRD is 20 and a spline fit is done.

In *Description of Output*, Figure 1 (default input with transverse aberration) and Figure 2 (modified input with OPD) are typical RIM plots.

Description of Output

The normal output of the Ray Aberration Curves option (RIM) is graphical only. Text output is used only for error and warning messages (the most common warning message is “Some points have been suppressed,” indicating aberrations whose size exceeds the paper limits at the current scale size; the plot is done with the curves clipped at the borders).

For each active zoom position, a single page (or screen) plot is done (for up to five fields; more than five fields will generate multiple plots as necessary). Detailed labeling and a border are drawn unless suppressed with the **No Full plot labeling** setting (or **LAB** N command). For each defined field position, X and Y curves are drawn. In the absence of rotational symmetry, the curves are labeled “X-fan” and “Y-fan,” and four fans are traced (+Y, -Y, +X, -X in the pupil). When rotational symmetry is present, the -X fans are dropped, and the curves are labeled “Tangential” (Y) and “Sagittal” (X). The Y ray aberration is plotted versus the Y aperture stop coordinates (similarly for X); you can change the plotted aberration with the **Plot type in X-Y orientation** setting (**TYP**) and the reference coordinates with the **Entrance pupil** setting (**EP**).

Aberrations in all defined wavelengths are drawn for each field using a distinctive line type for each wavelength. The default color is used unless changed with the **Color** and **Wavelength** settings on the **Graphics/Colors** tab (or with the **WVL** command). (See “Defining Configuration - Graphics” on page 24-16.)

Examples

Example 1. The minimum input possible (default run) for a Cooke triplet lens.

The output is shown in Figure 1.

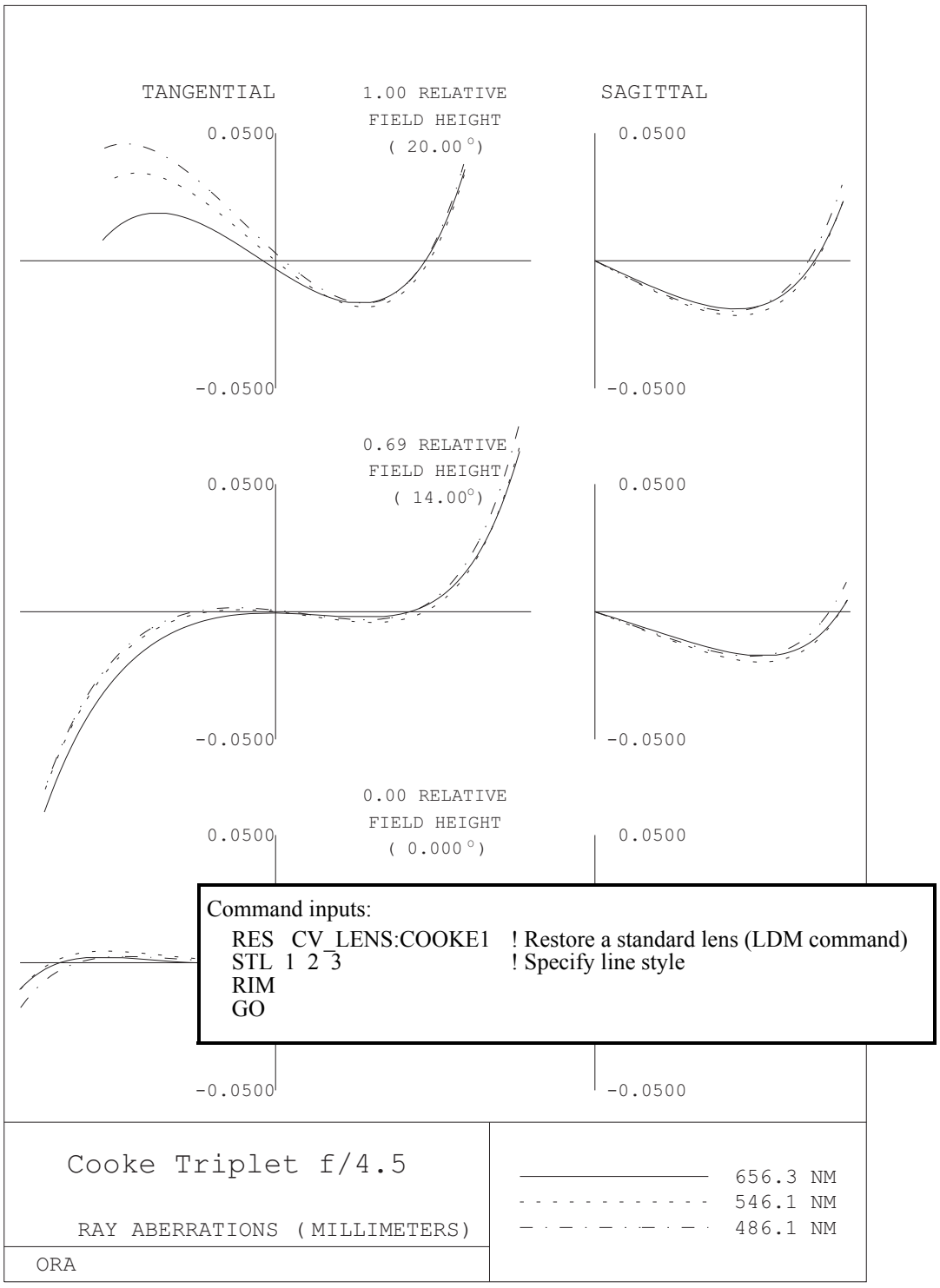


Figure 1. Default RIM plot for Cooke triplet

Example 2. Typical input changes for a Schmidt telescope including an aspheric element.

Scale (SSI) changes are quite common; see comments for other commands. The output is shown in Figure 2.

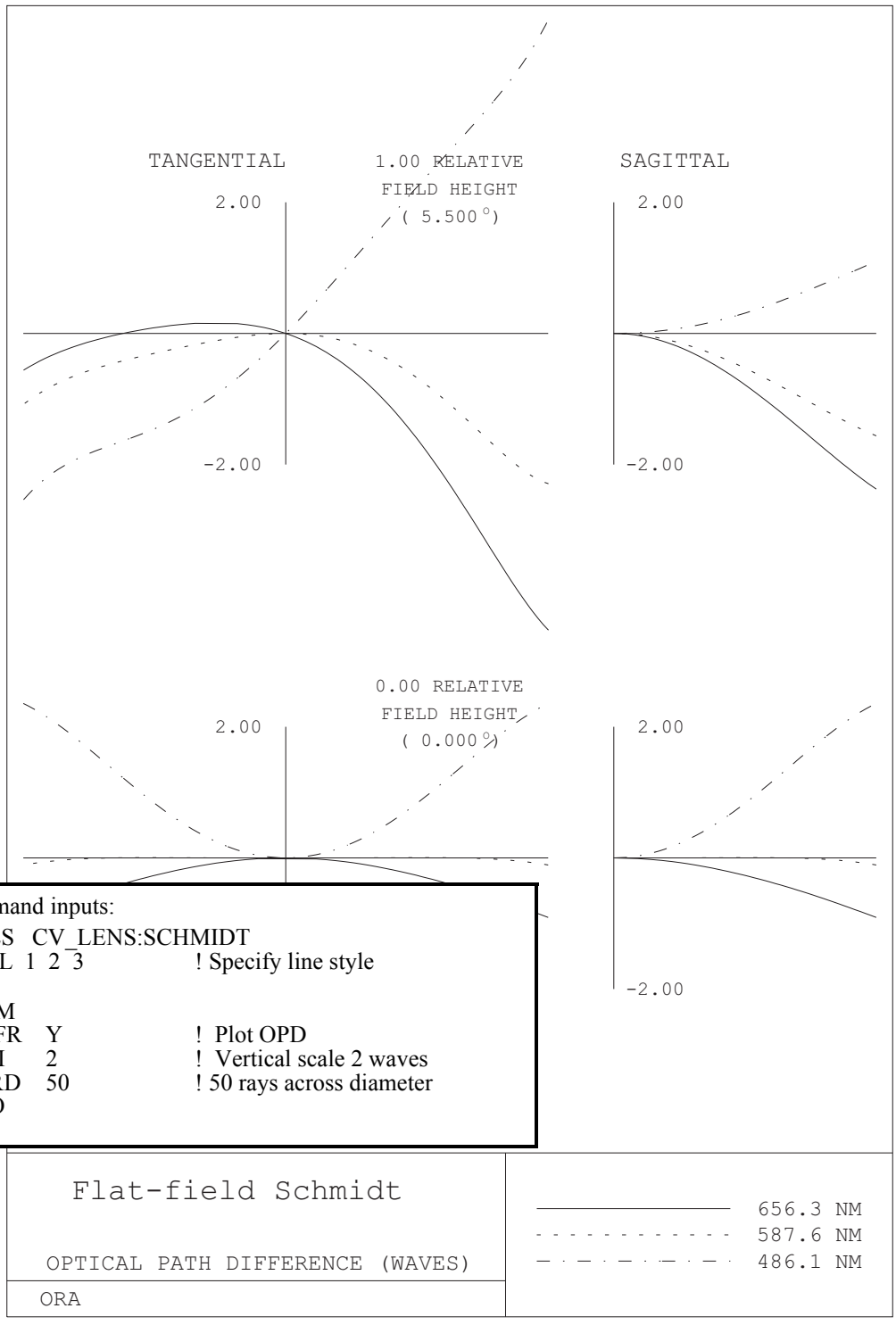


Figure 2. Enhanced RIM output

Example 3. Some possible input changes for a zoom lens (the combination of commands is fairly arbitrary, but illustrates how commands can be changed by zoom position).

```
Command inputs:
 RES          CV_LENS:COOKE1
 ZOO          3                          ! 3-position zoom
 STL          1        2        3        ! Specify line style

 RIM
 SSI          .05   .10   1.0            ! Different scales for each position
 LAB          N                          ! Suppress labels for all zoom positions (Z1
                                         ! fills across)
 WFR          N   N   Y                  ! Plot OPD for Z3
 NRD          30                         ! NRD applies to all zoom positions
 TIT          Z1   'First Position'
 TIT          Z2   'Second Position'     ! Temporary titles for plots
 TIT          Z3   'Third Position - WFR'
 GO
```

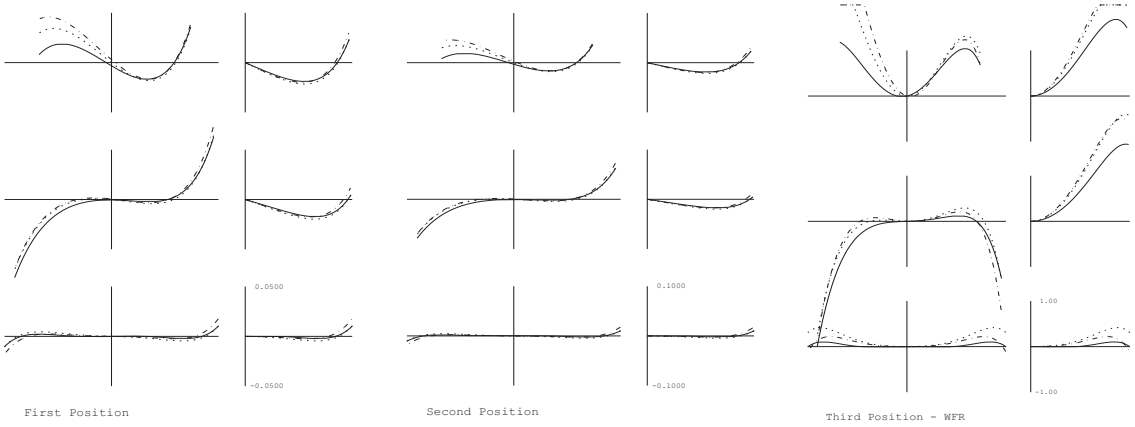


Figure 3. Possible input changes for a zoom lens

Example 4. Excluding plotting of rays clipped by active apertures or obscurations

```
Command inputs:
 RES        CV_LENS:CASSRC
 RIM
 CAB        Yes                    ! Exclude blocked rays from plot
 WFR        Yes                    ! Plot optical path difference (OPD)
 SSI        .2                     ! Scale size, in waves
```

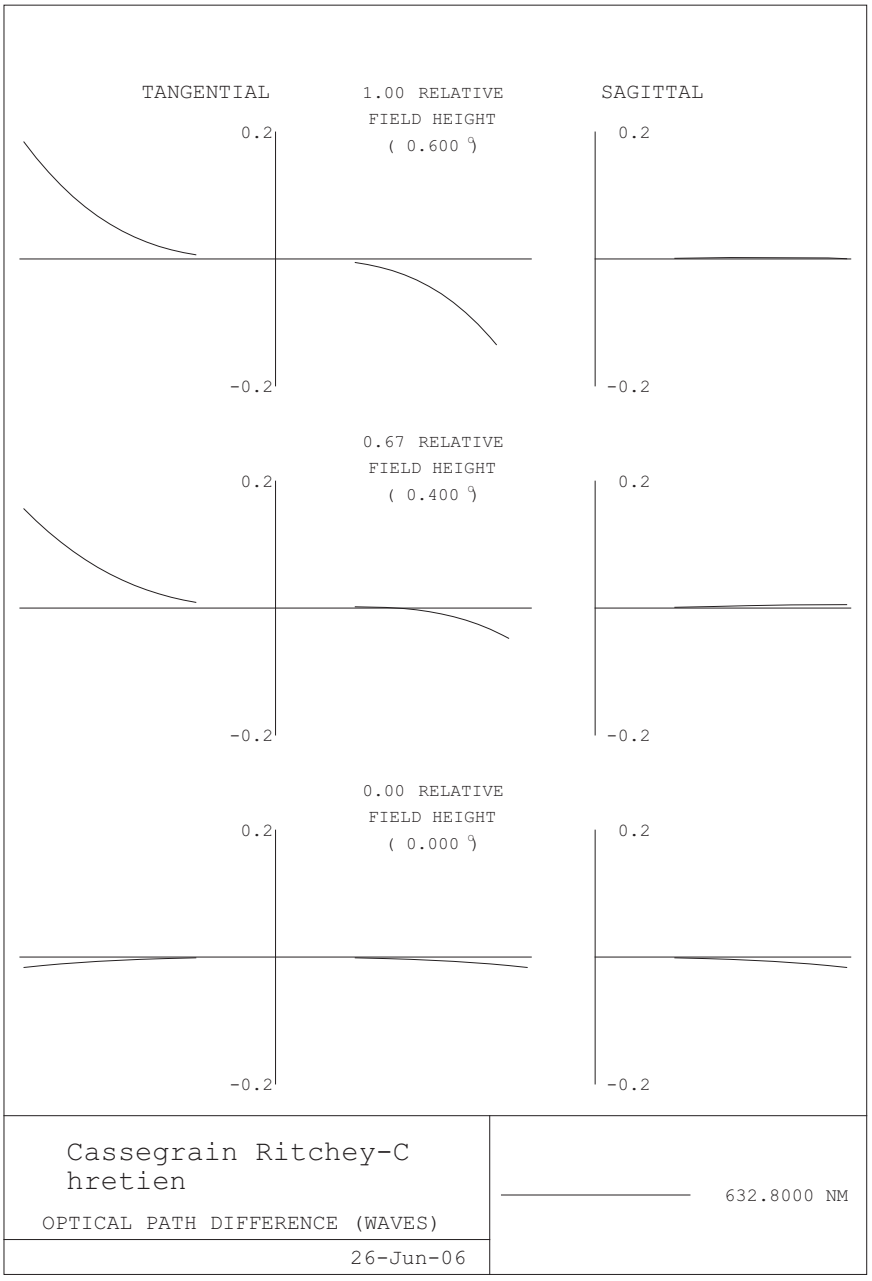


Figure 4. Exclusion of blocked rays from RIM output