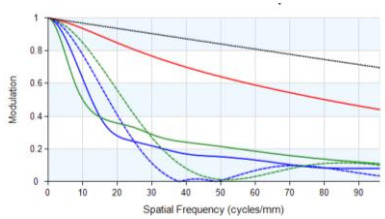
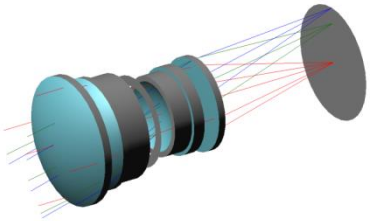


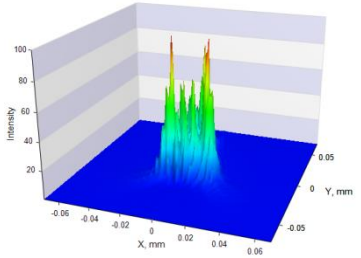
CODE V® New User Orientation

A Brief Introduction to CODE V

Design and Analysis Software for Imaging Systems

For OPTI517





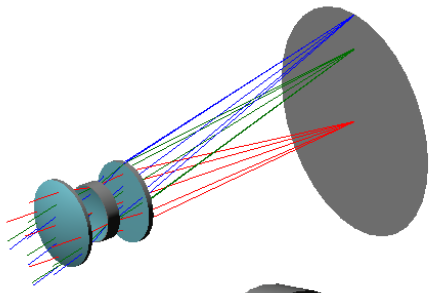
Craig Pansing: cpansing@synopsys.com

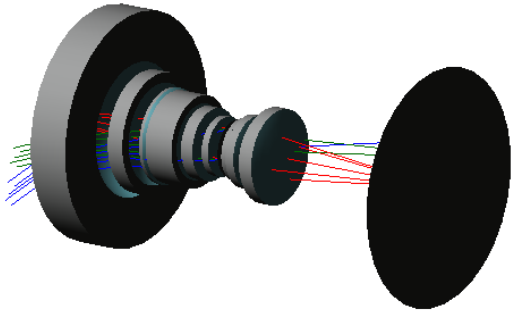
August 25th, 2017

Purpose

- Provide you with an overview of CODE V structure, interface, and capabilities for optical system:

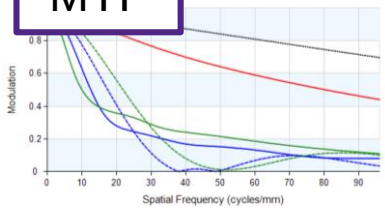
Modeling





Analysis

MTF



PSF

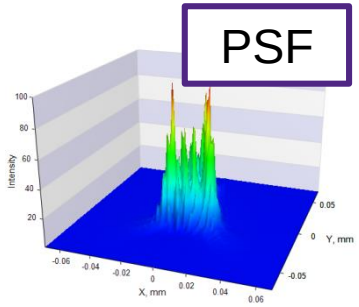
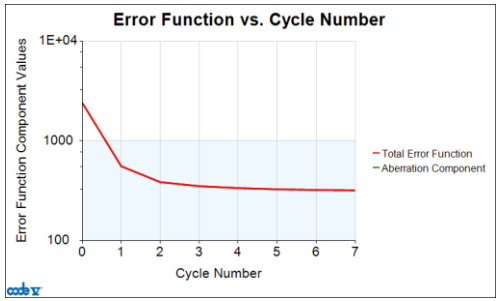


Image Simulation

Optimization



Where do I get CODE V?

CODE V Access for Distance Students

Please allow 5-10 business days for processing…we receive many requests this time of year

- Send email to osg_educ@synopsys.com, indicate you need CODE V for your distance learning class, include:
  1. Your full contact information (full name, phone number, and university/college address)
  2. Answer the following questions:
     1. Are you a citizen of Cuba, Iran, North Korea, Sudan, or Syria? If yes, then answer question
     2. Are you a permanent documented legal resident or dual citizen in a country other than Cuba, Iran, North Korea, Sudan, or Syria?
  3. Go to: http://optics.synopsys.com/support/support-host-id.html Download and save the GetHostID.exe program to the desktop of your computer that you will use the software. Right-click on the program and select '**Run as Administrator**'. An error message will appear "No hardware dongle detected, continue?" select yes. The GetHostID dialog box will appear, copy the Hardware Host ID (4-XXXXX) and send it to us via email.
  - Note: Your license will only work on the computer you provide the Hardware Host ID from and it is not possible to use the license on another computer.

- Local students: Contact Ms. Ruth Corcoran (rcorcoran@optics.arizona.edu) in the academic office

Education for CODE V Users

Customer Support Portal, and Training

Resources for Learning CODE V

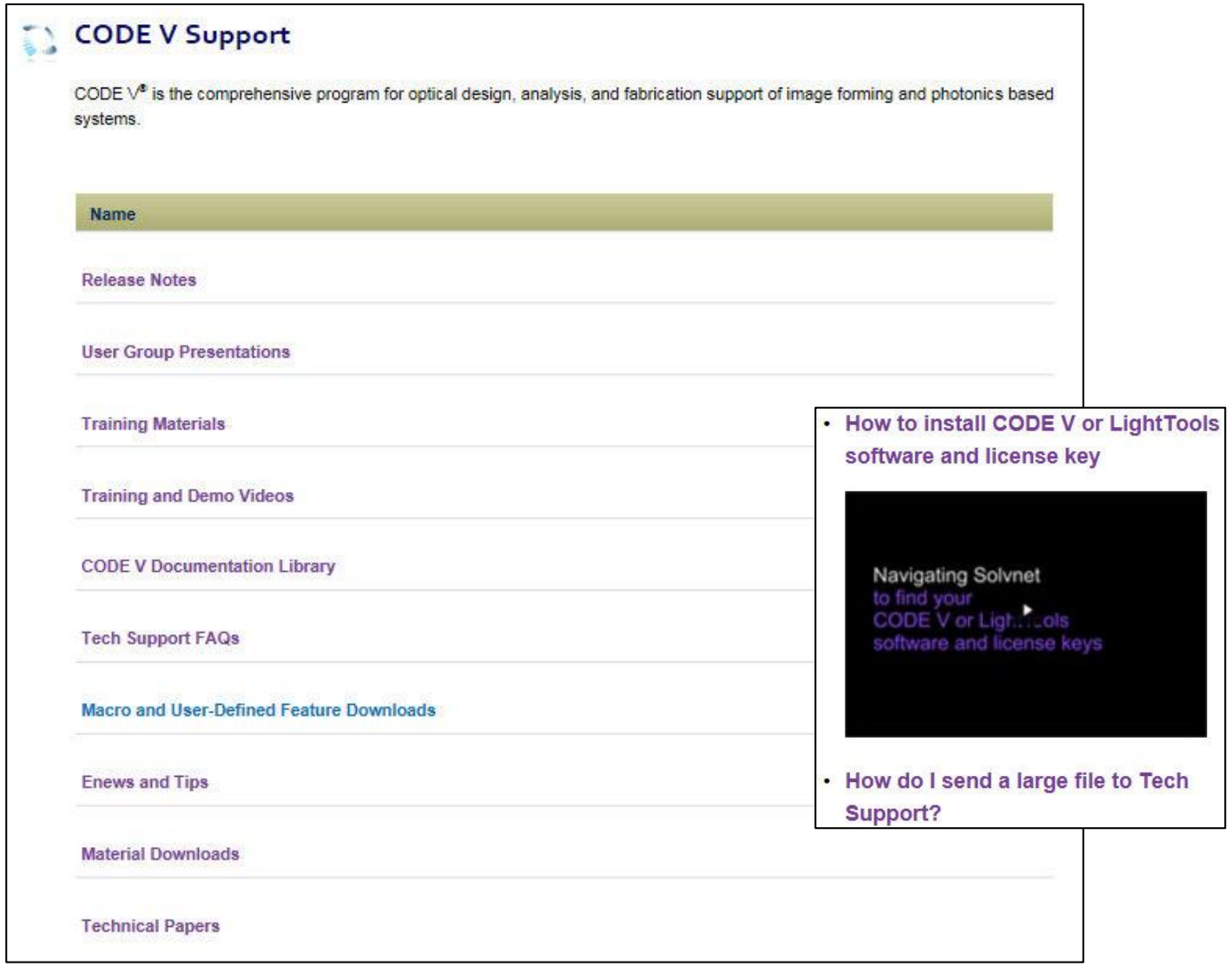
- Various CODE V Help Choices (**HELP > …**)
- The Customer area of the ORA website: *support.opticalres.com*
  - **Introductory & Advanced Training presentations**
  - CODE V User Group meeting presentations
  - CODE V Webinar recordings
  - Release notes
  - E-news Tips
  - Tech Support FAQs
  - Macro downloads
  - Technical papers

Intro Topics in CODE V Training

Optics 101
Digital Camera
User Interface
Tech Talk
Apertures/Vignetting
Performance Eval.
Optimization
Reflective Systems
Tilts/Decenters
Non-Spherical
Afocal
Zoom
Tolerance Analysis
Macros

The Synopsys Optics Customer Support Portal contains resource to help you learn and stay up to date

- http://support.opticalres.com/
- The material is exclusive to Synopsys Optics software users, so requires a different log in from SolvNet
- Training Videos
- Training Presentations
- User Group Presentations
- Glass catalog updates



Training Courses and User Group Meetings

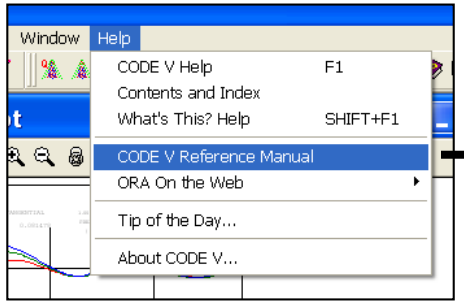
- Introduction to CODE V:
  - September 25-29, 2017, in Pasadena, CA (Los Angeles area)

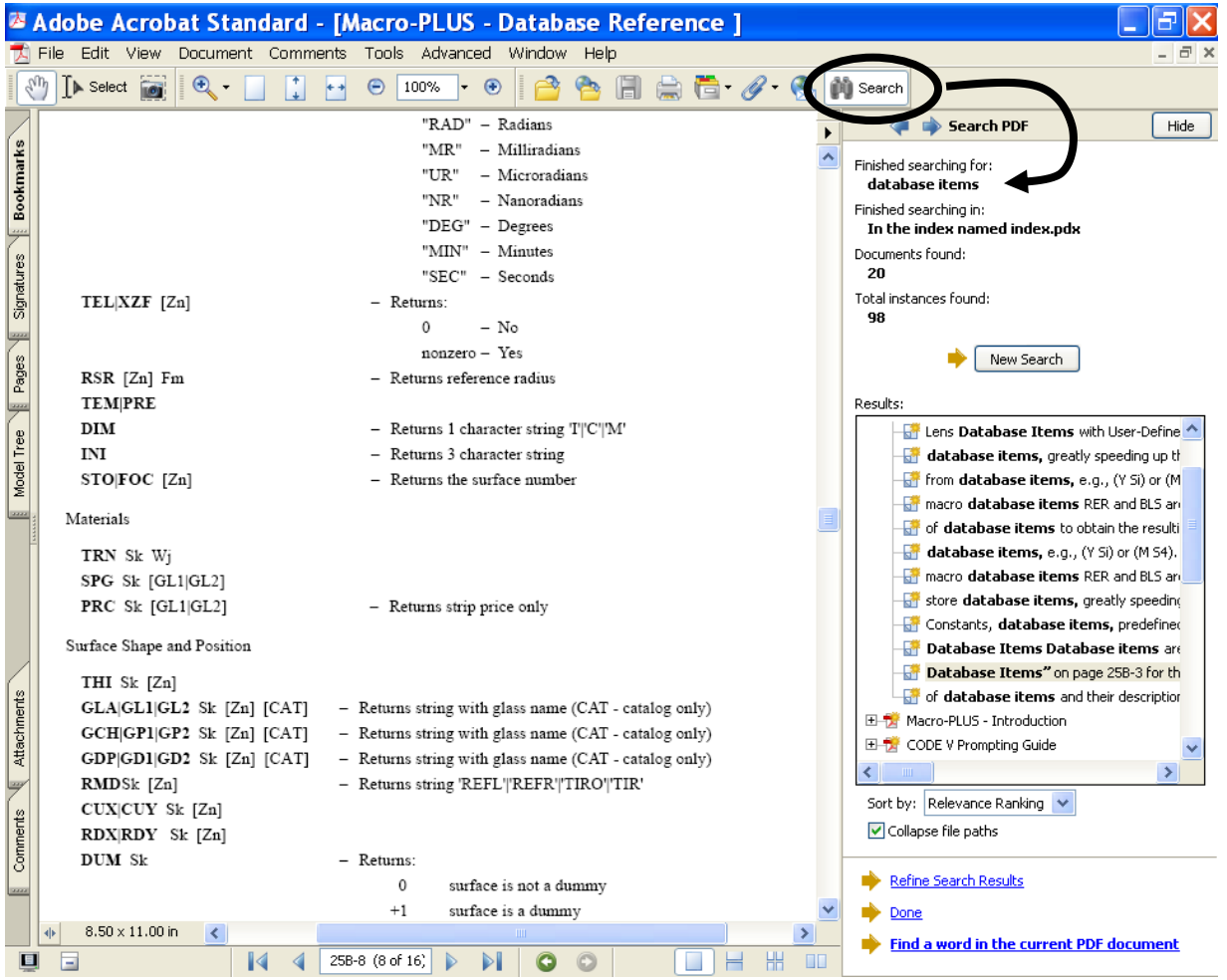
- Advanced Topics in CODE V:
  - October 23-25, 2017, in Mt. View, CA (San Jose area)

- CODE V User Group Meetings, typically held in June
  - Free, 1-day meetings held in Mountain View, CA (San Jose area), Pasadena, CA (Los Angeles area), and Rochester, NY
  - Topics from 2017
    - CODE V 11.0 New Features and Future Plans
    - Tools for Wide Angle Systems
    - Tips and Tricks
    - Color Correction: Fundamentals and Techniques
    - Topics in Interferograms
    - Beam Synthesis Propagation with Lens Arrays

CODE V Help

- CODE V reference manual (PDF) has the most info

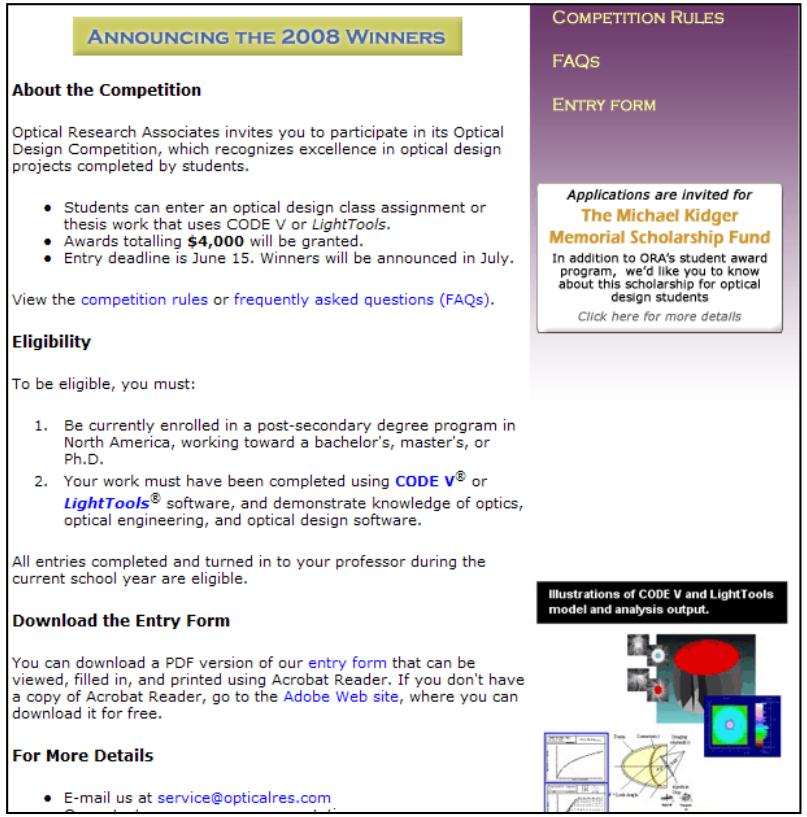




e.g. Search on “database items” provides links to syntax for various database info (curvatures, thicknesses, pupil size… any CODE V info)

Robert E Hilbert Student Design Competition

- Be sure to submit your best CODE V project to our annual Student Design Contest (optics.synopsys.com)
  - $4,000 in prizes awarded each year



ANNOUNCING THE 2008 WINNERS

COMPETITION RULES
FAQS
ENTRY FORM

About the Competition

Optical Research Associates invites you to participate in its Optical Design Competition, which recognizes excellence in optical design projects completed by students.

- Students can enter an optical design class assignment or thesis work that uses CODE V or *LightTools*.
- Awards totalling **$4,000** will be granted.
- Entry deadline is June 15. Winners will be announced in July.

View the competition rules or frequently asked questions (FAQs).

Applications are invited for
The Michael Kidger Memorial Scholarship Fund
In addition to ORA's student award program, we'd like you to know about this scholarship for optical design students
Click here for more details

Eligibility

To be eligible, you must:

1. Be currently enrolled in a post-secondary degree program in North America, working toward a bachelor's, master's, or Ph.D.
2. Your work must have been completed using **CODE V®** or ***LightTools®*** software, and demonstrate knowledge of optics, optical engineering, and optical design software.

All entries completed and turned in to your professor during the current school year are eligible.

Illustrations of CODE V and LightTools model and analysis output.

Download the Entry Form

You can download a PDF version of our entry form that can be viewed, filled in, and printed using Acrobat Reader. If you don't have a copy of Acrobat Reader, go to the Adobe Web site, where you can download it for free.

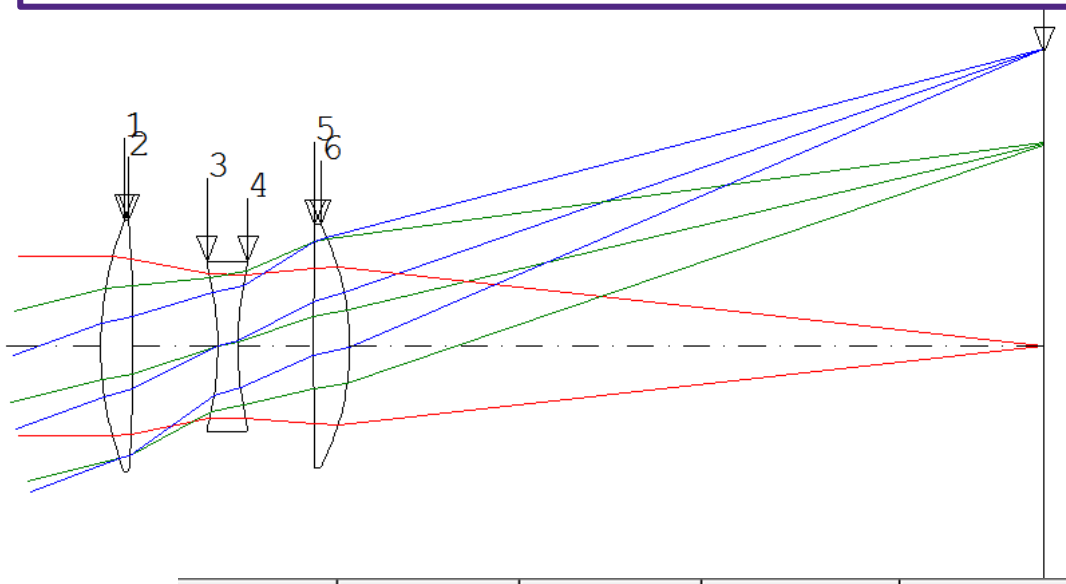
For More Details

- E-mail us at service@opticalres.com

Now…let’s get started with CODE V

CODE V is a Sequential Ray Tracer*

Rays trace from surface 1 -> surface 2 -> surface 3 ->…->until the image



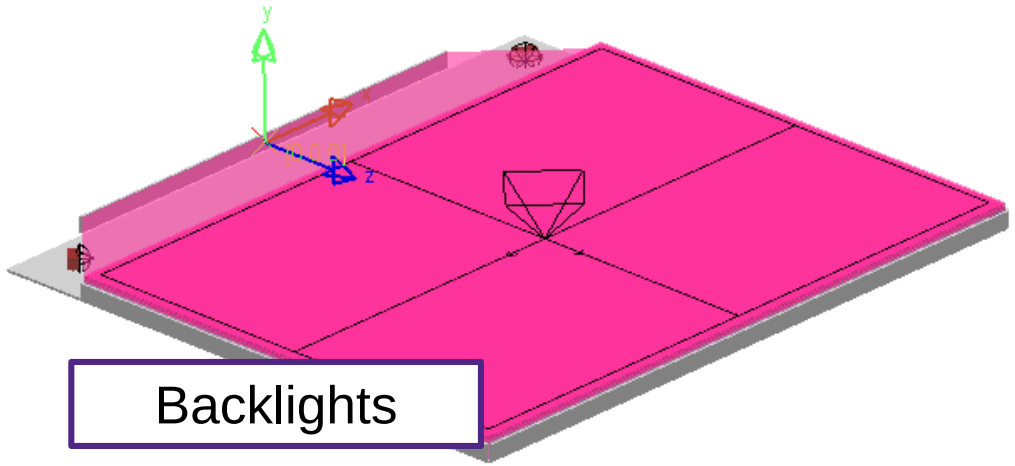
Used for imaging systems

Surface #	Surface Name	Surface Type	Y Radius	Thickness	Glass	Refract Mode	Y Semi-Aperture
Object			Infinity	Infinity			
1			21.4814	2.0000	SK16_SCH		7.0000
2			-124.1000	5.2600			6.8124
Stop			-19.1000	1.2500	F4_HOYA		4.4892
4			22.0000	4.6900			4.6320
5			328.9000	2.2500	SK16_SCH		6.5000
6			-16.7000	43.0505 S			6.7462
Image			Infinity	0.0289 V			18.4699

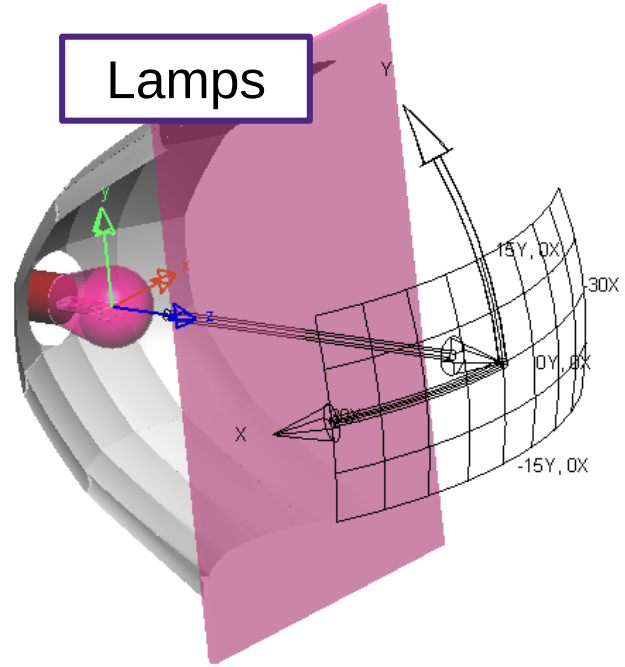
*There is a non-sequential mode…but we won't talk about that today

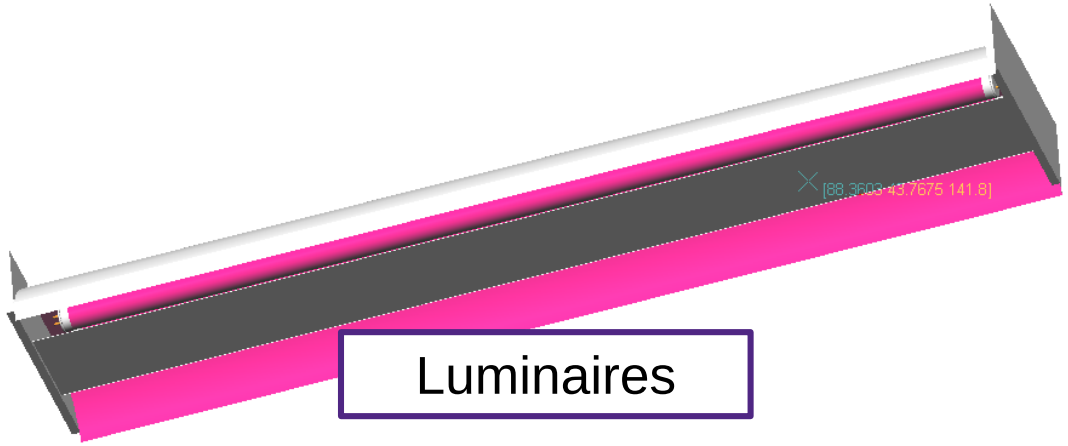
…compared to a non-sequential ray trace program

Rays start from source(s) ->bounce around geometry -> Measure illumination pattern on receiver(s)



Backlights



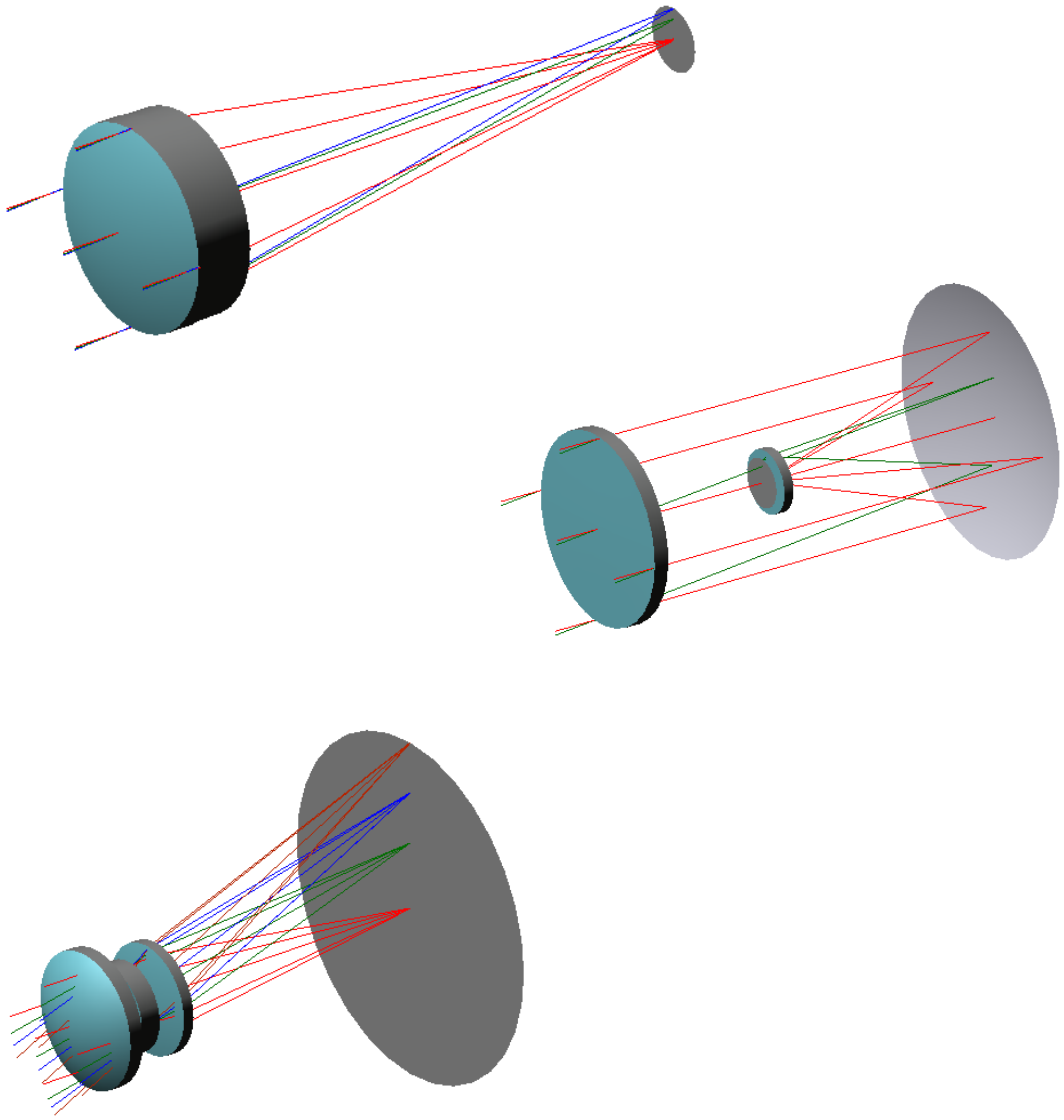


Luminaires

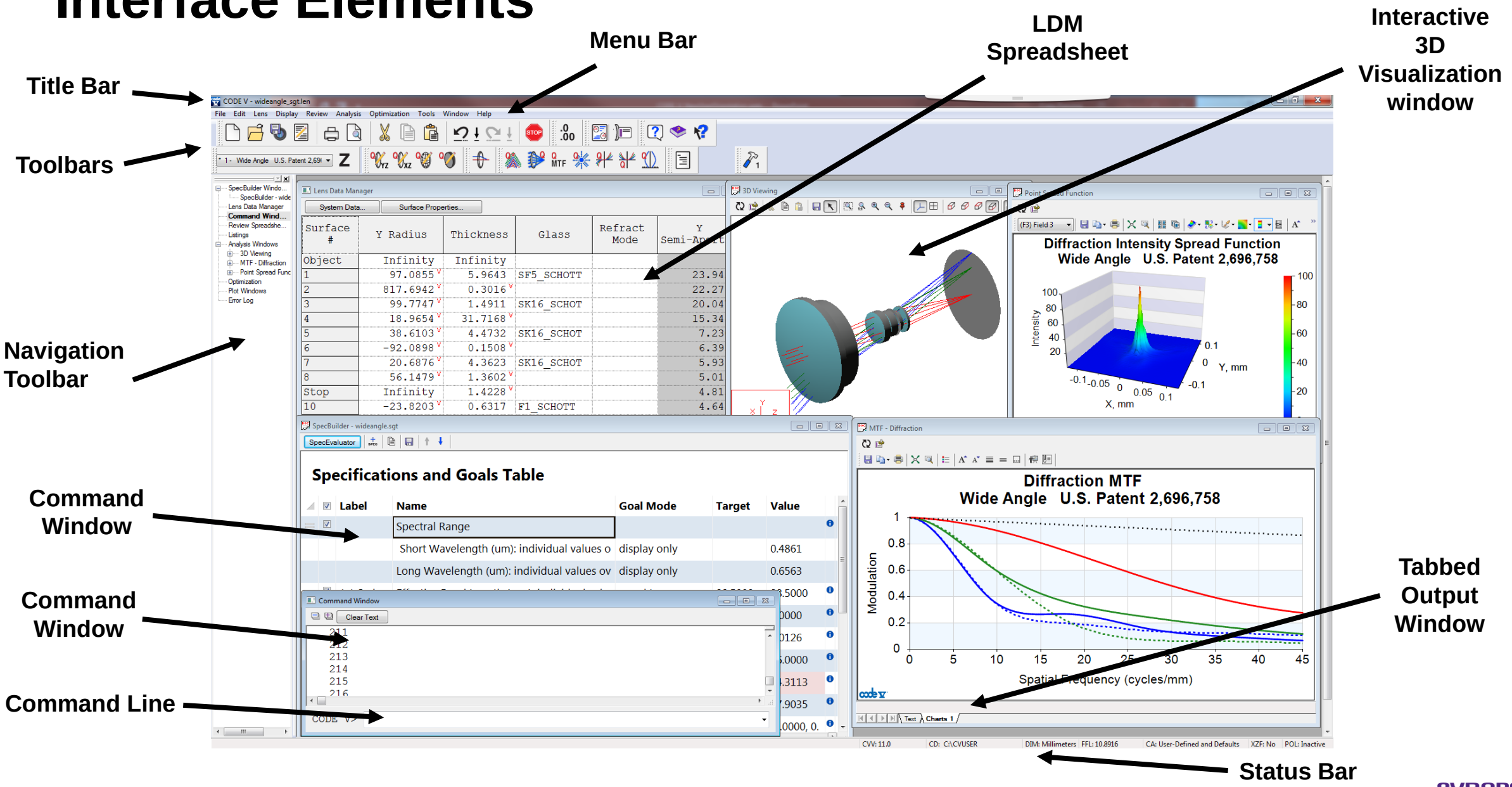
Used for illumination systems, stray light, etc.
Images from LightTools®

This presentation covers…

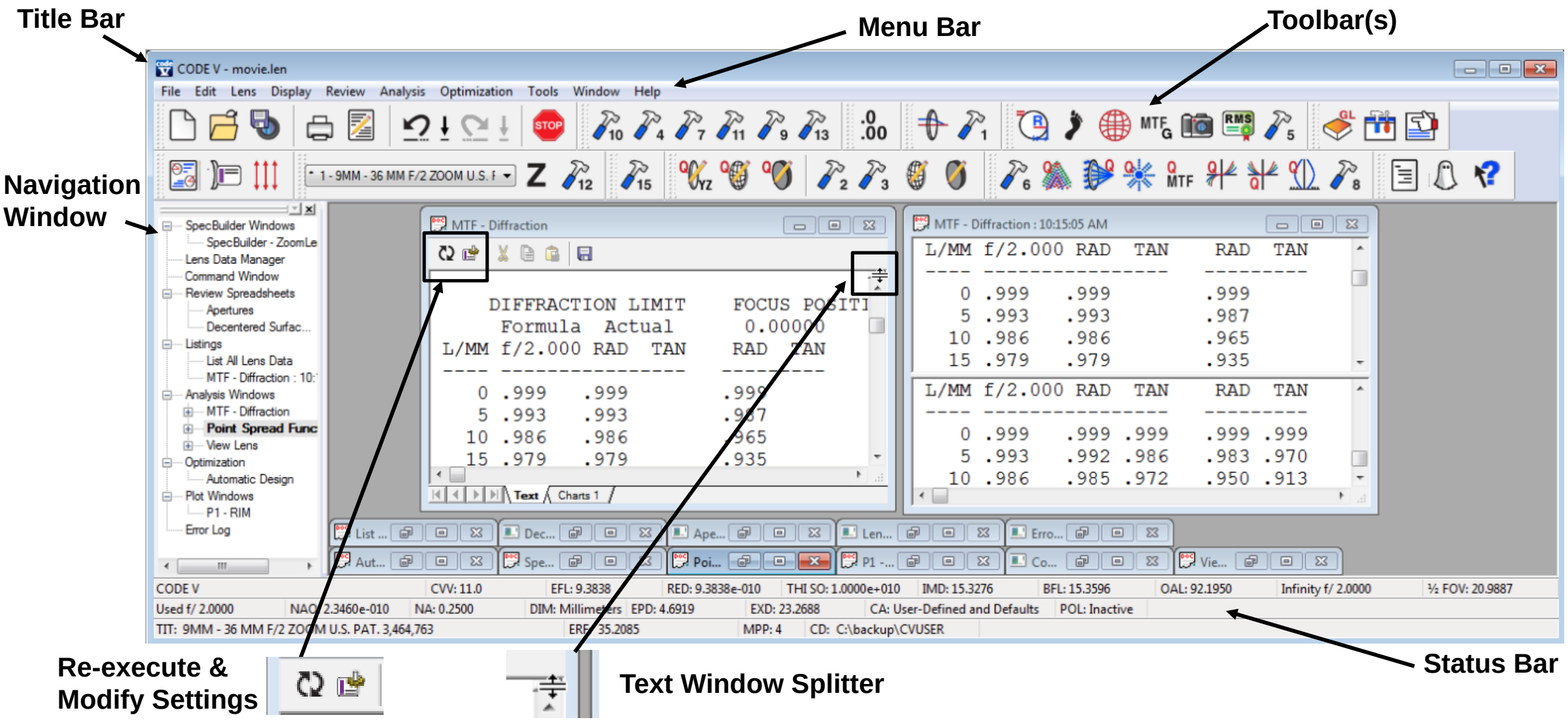
- Refractive system data entry
- Reflective system data entry
- Interacting with analysis options
- Design example: Digital Camera
  - Finding a starting system
  - Setting up a specifications table
  - Optimizing for improved performance



Interface Elements



CODE V Interface (GUI Components)



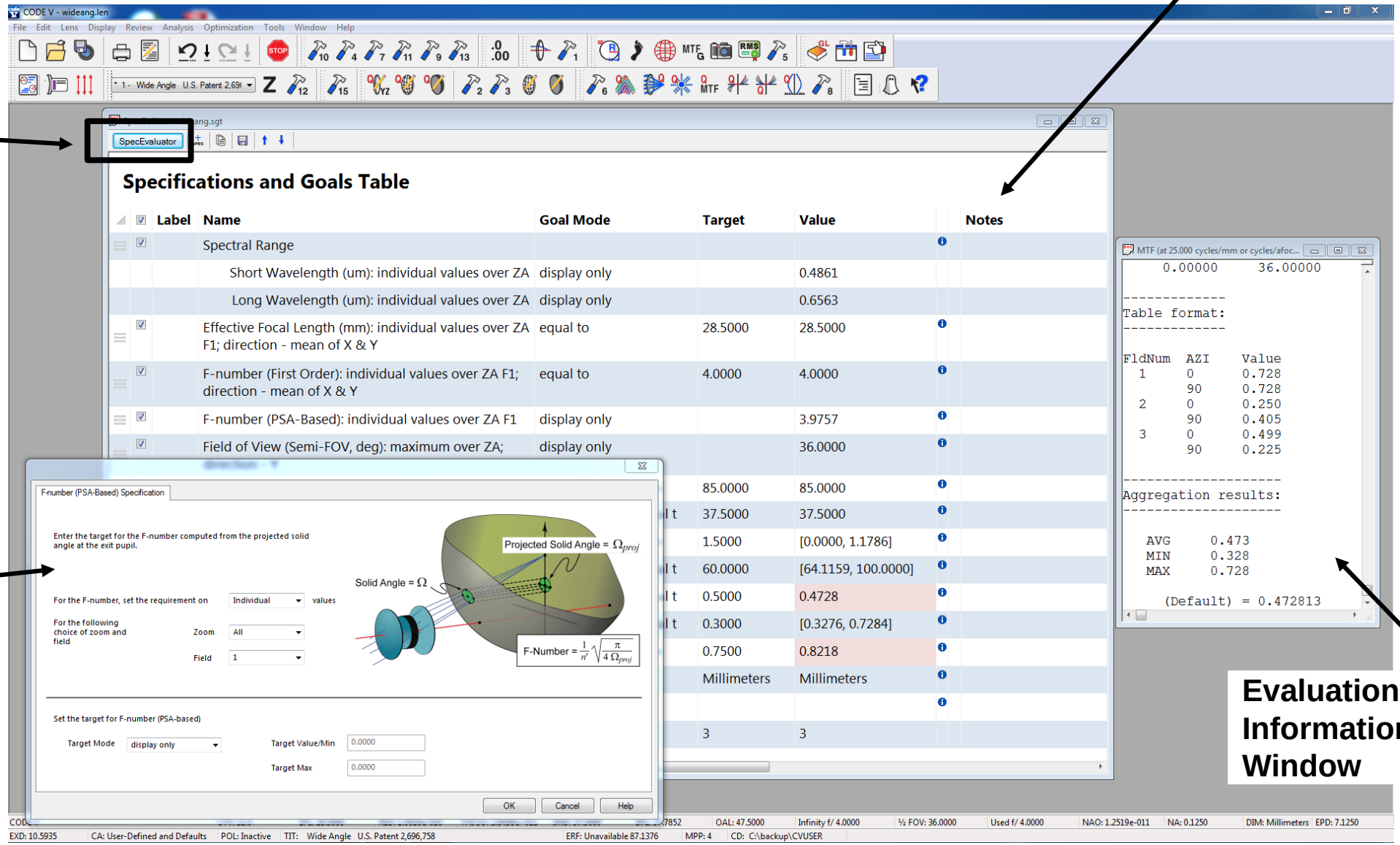
CODE V Interface (SpecBuilder™)

SpecEvaluator™ Button

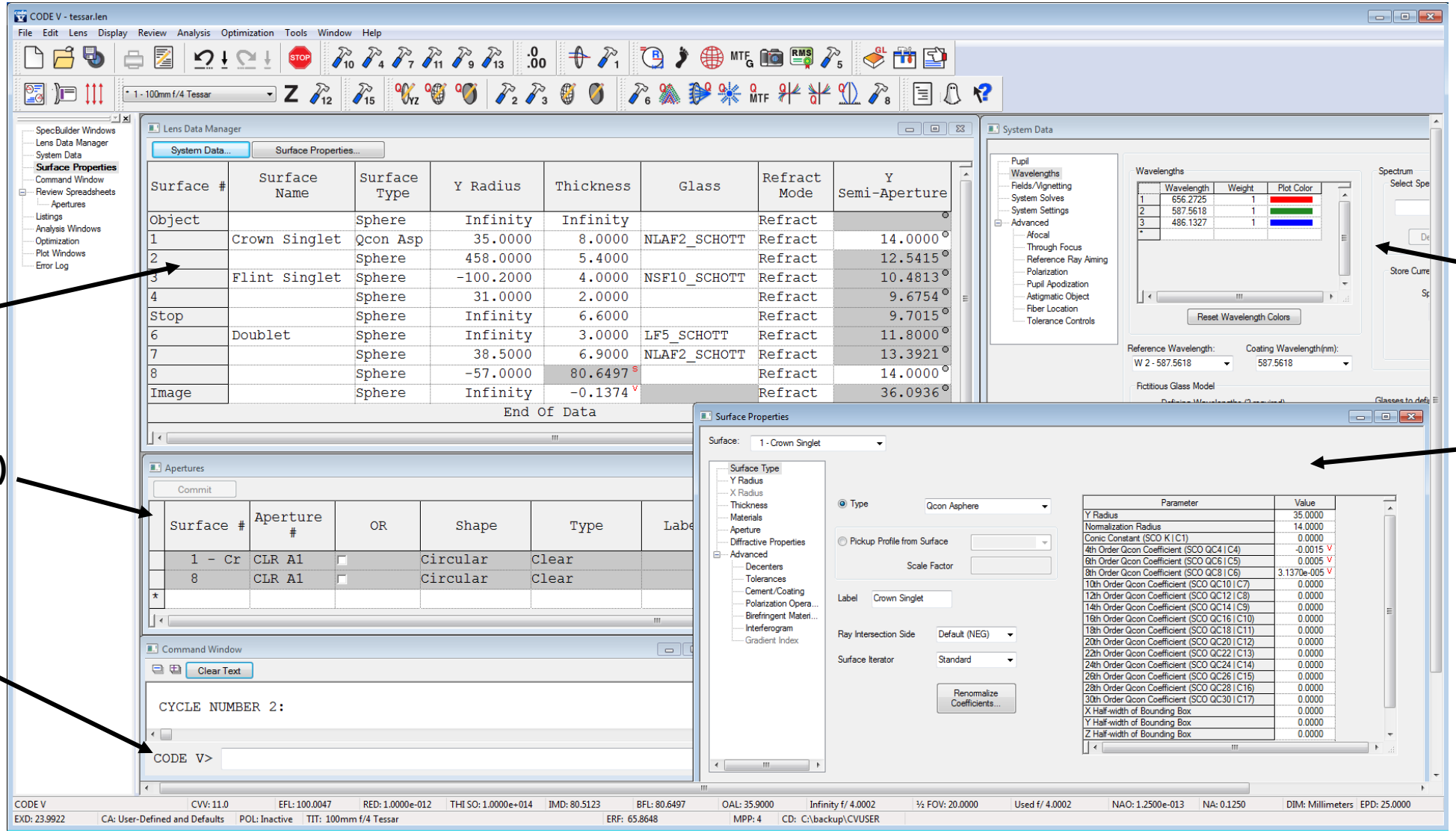
SpecBuilder Window

Insert/Edit Specification dialog

Evaluation Information Window



CODE V Interface (Input)



LDM Spreadsheet

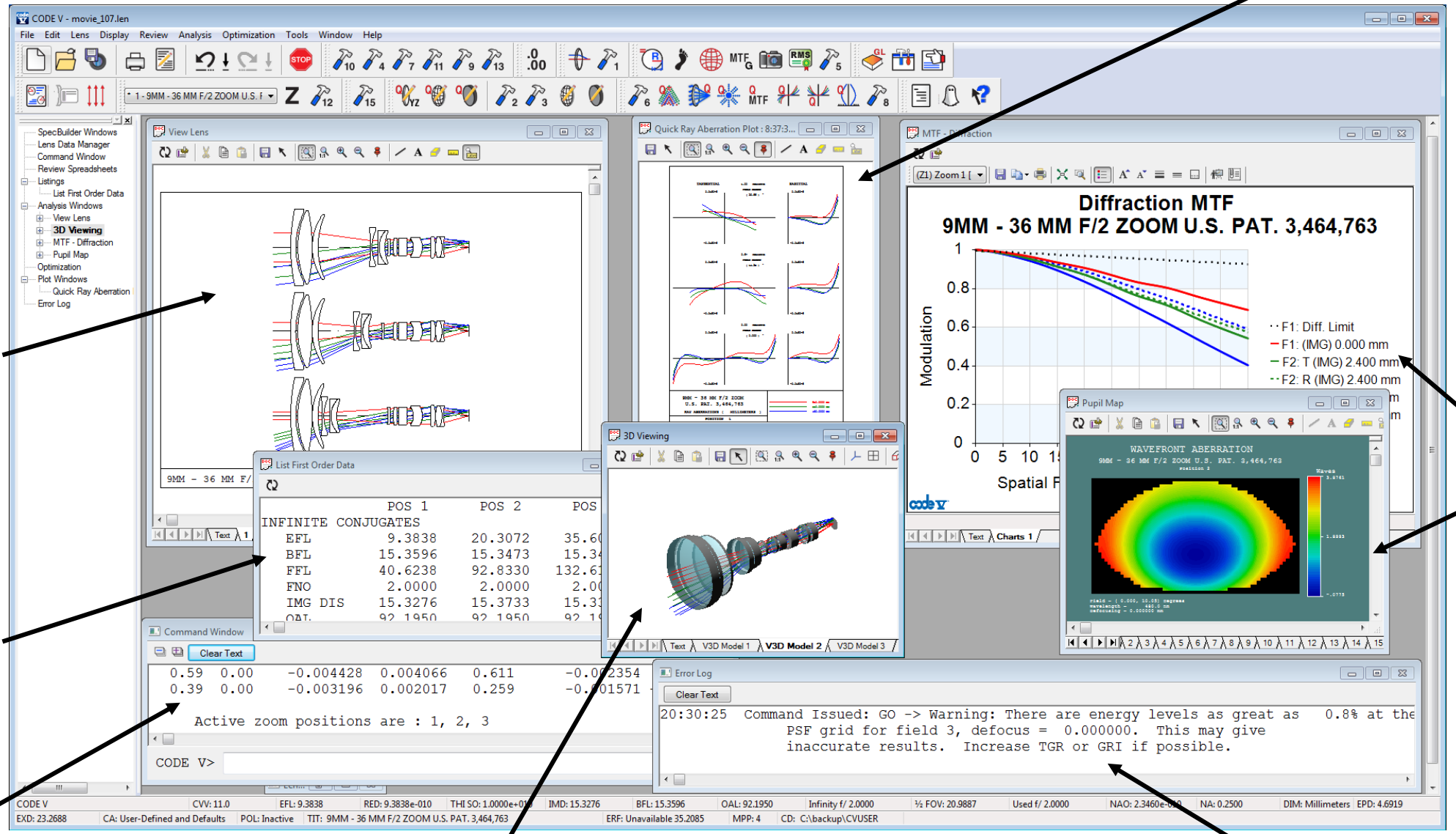
Review Spreadsheet(s)

Command Line

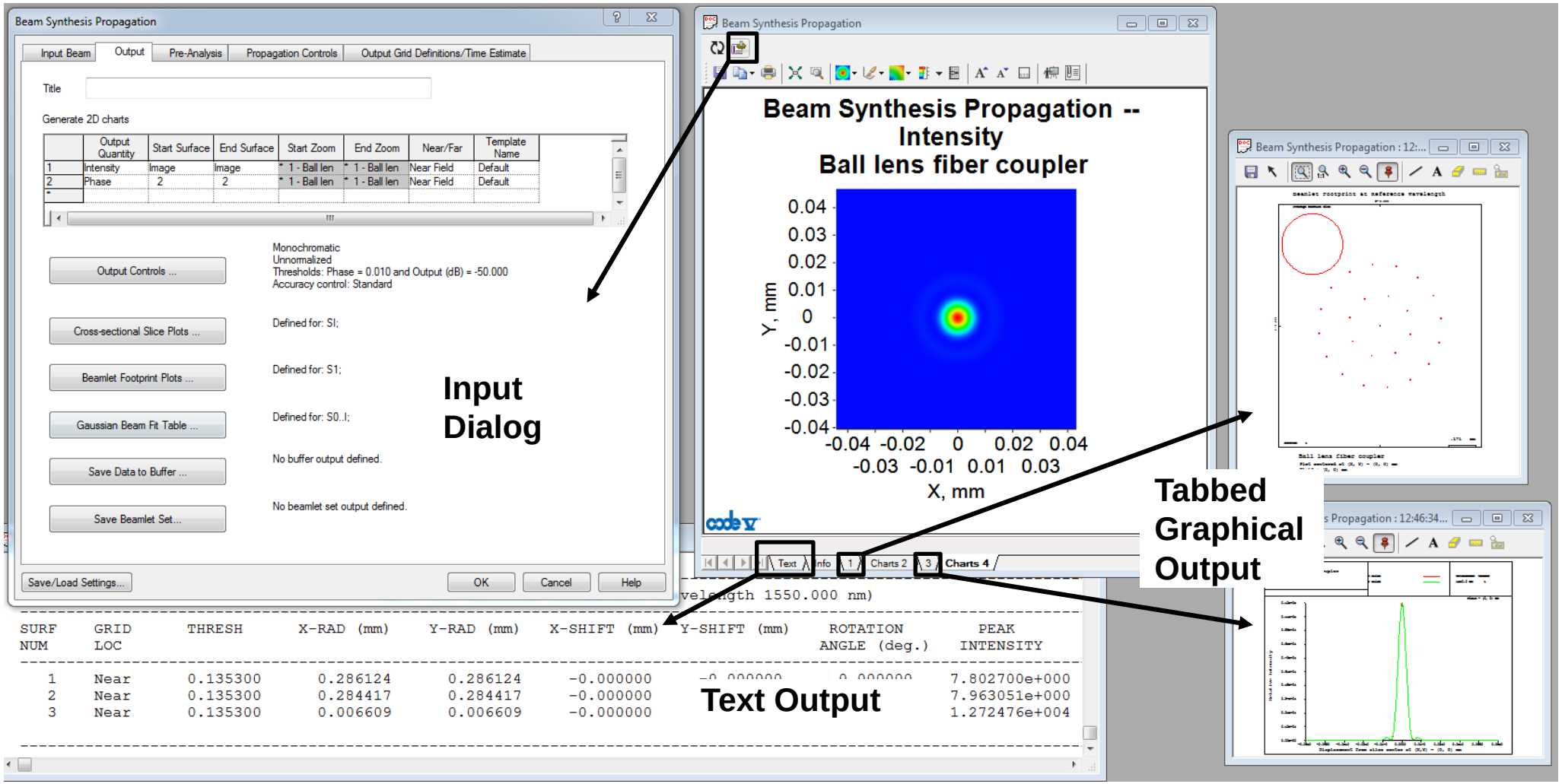
System Data Window

Surface Properties Window

CODE V Interface (Output)



CODE V Interface (Tabbed Output Window Components):



SpecBuilder Features at a Glance

Select All ☐ and copy & paste the table into another application

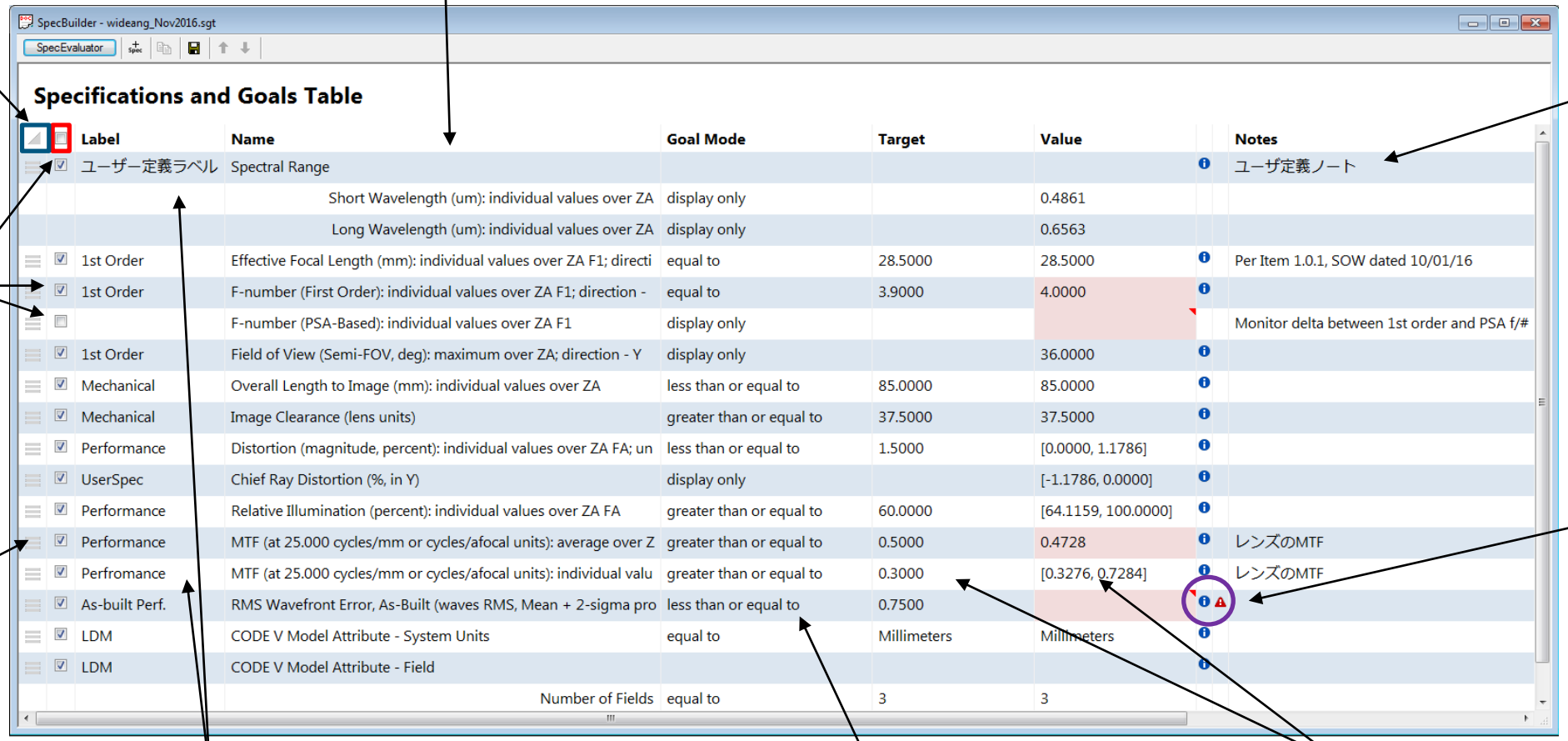
Specs for 1st Order & other System Parameters, Mechanical Constraints, Nominal & As-Built Performance, Attributes Specific to the CODE V model, and User-Defined specifications

Specs can be active or inactive (use ☐ check box for “all active/all inactive”

Re-orderable rows

User-Specified Notes, with double-byte character support

Supporting information accessible via the ℹ icon and error/warning information via the ⚠ icon



Label	Name	Goal Mode	Target	Value	Notes
ユーザー定義ラベル	Spectral Range				ユーザ定義ノート
	Short Wavelength (um): individual values over ZA	display only		0.4861	
	Long Wavelength (um): individual values over ZA	display only		0.6563	
1st Order	Effective Focal Length (mm): individual values over ZA F1; directi	equal to	28.5000	28.5000	Per Item 1.0.1, SOW dated 10/01/16
1st Order	F-number (First Order): individual values over ZA F1; direction -	equal to	3.9000	4.0000	
	F-number (PSA-Based): individual values over ZA F1	display only			Monitor delta between 1st order and PSA f/#
1st Order	Field of View (Semi-FOV, deg): maximum over ZA; direction - Y	display only		36.0000	
Mechanical	Overall Length to Image (mm): individual values over ZA	less than or equal to	85.0000	85.0000	
Mechanical	Image Clearance (lens units)	greater than or equal to	37.5000	37.5000	
Performance	Distortion (magnitude, percent): individual values over ZA FA; un	less than or equal to	1.5000	[0.0000, 1.1786]	
UserSpec	Chief Ray Distortion (%, in Y)	display only		[-1.1786, 0.0000]	
Performance	Relative Illumination (percent): individual values over ZA FA	greater than or equal to	60.0000	[64.1159, 100.0000]	
Performance	MTF (at 25.000 cycles/mm or cycles/afocal units): average over Z	greater than or equal to	0.5000	0.4728	レンズのMTF
Perfromance	MTF (at 25.000 cycles/mm or cycles/afocal units): individual valu	greater than or equal to	0.3000	[0.3276, 0.7284]	レンズのMTF
As-built Perf.	RMS Wavefront Error, As-Built (waves RMS, Mean + 2-sigma pro	less than or equal to	0.7500		
LDM	CODE V Model Attribute - System Units	equal to	Millimeters	Millimeters	
LDM	CODE V Model Attribute - Field				
	Number of Fields	equal to	3	3	

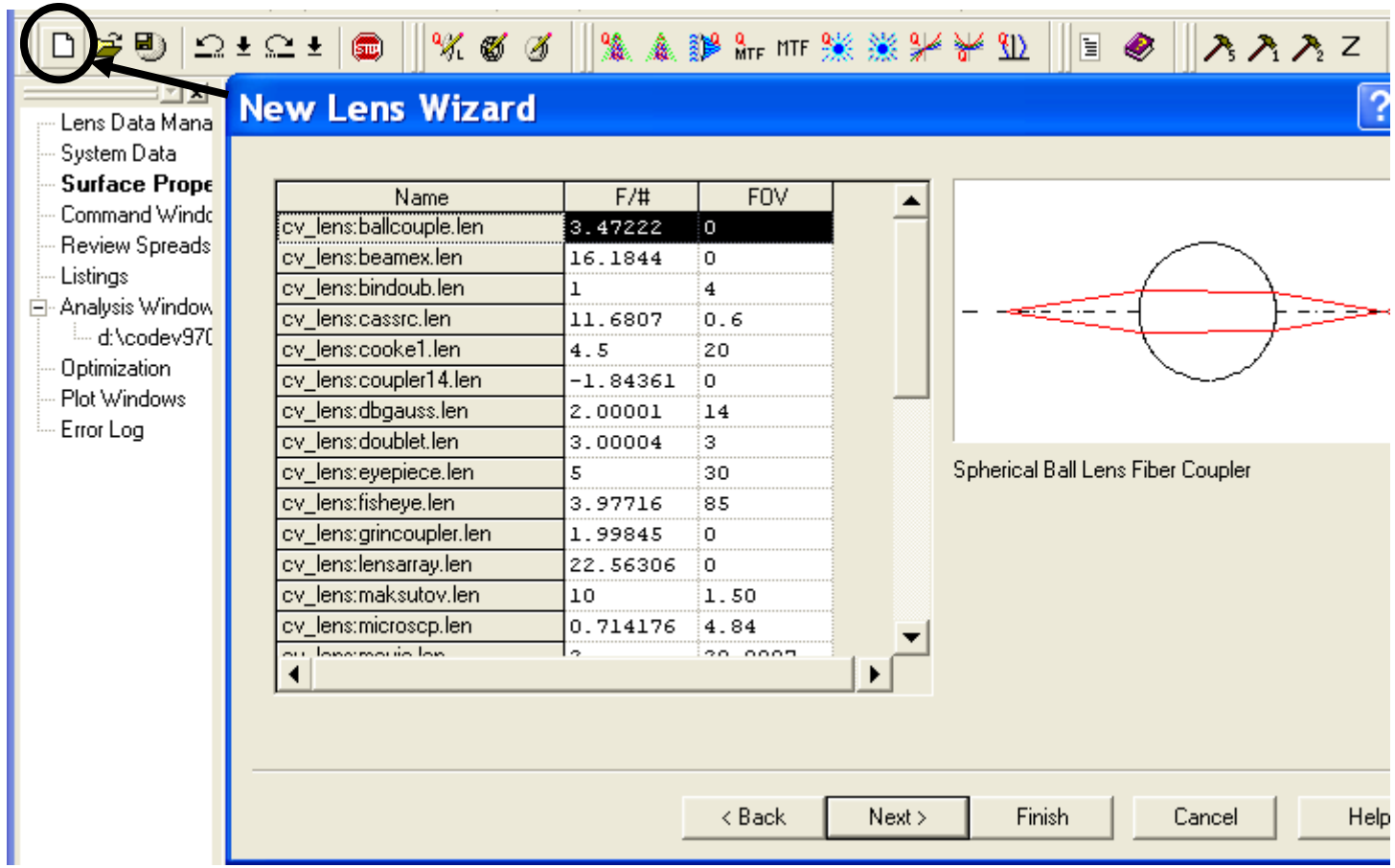
User-Specified labels, with double-byte character support

User-specified “Goal Mode” defines the comparison of the current spec value against the spec target

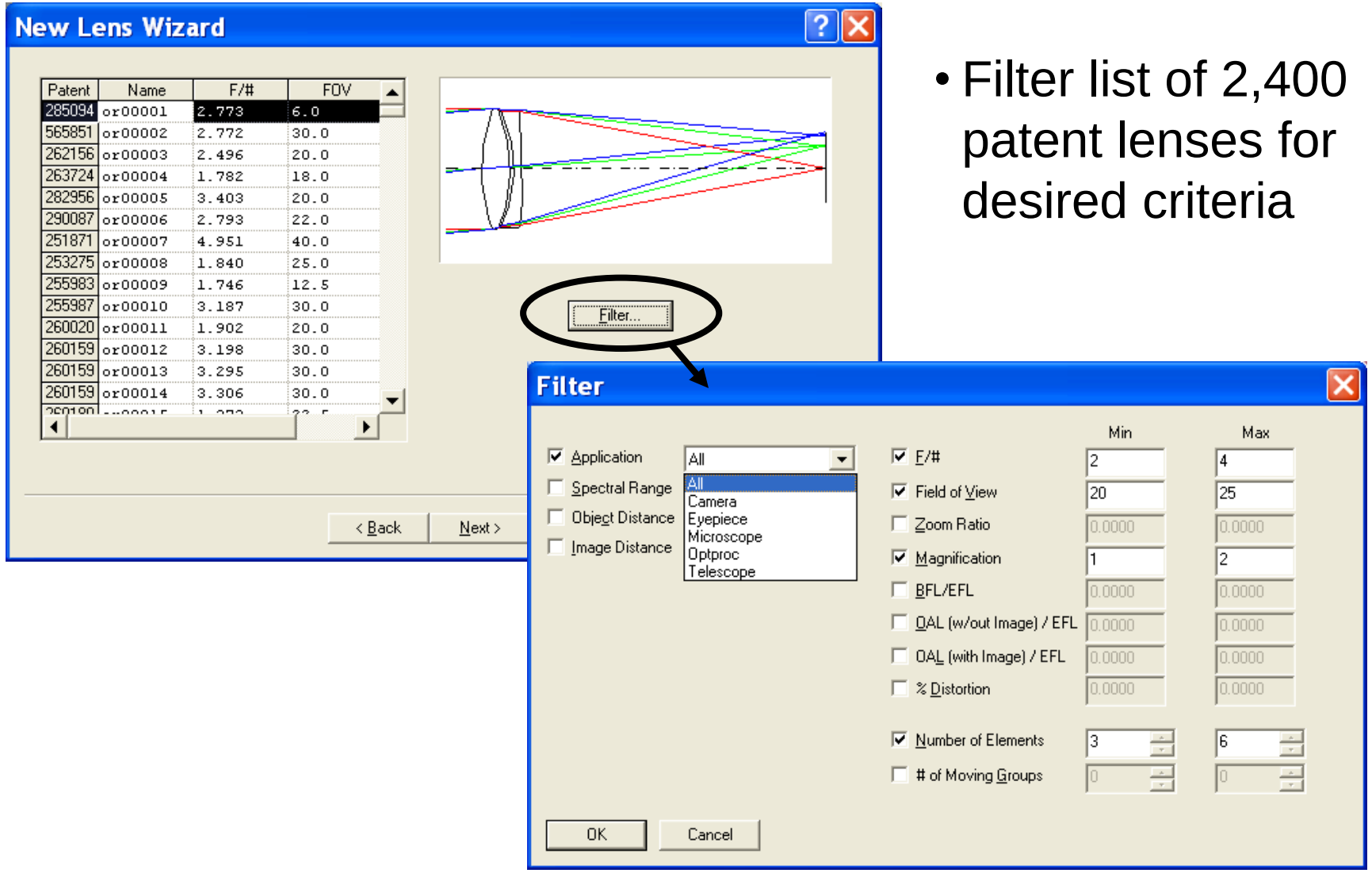
User-specified Target & the current, or min/max Values. Highlighted cells for “Values” out of “spec”

Opening a Lens

- **New Lens Wizard** can open a blank lens, CODE V sample lens, or a patent lens



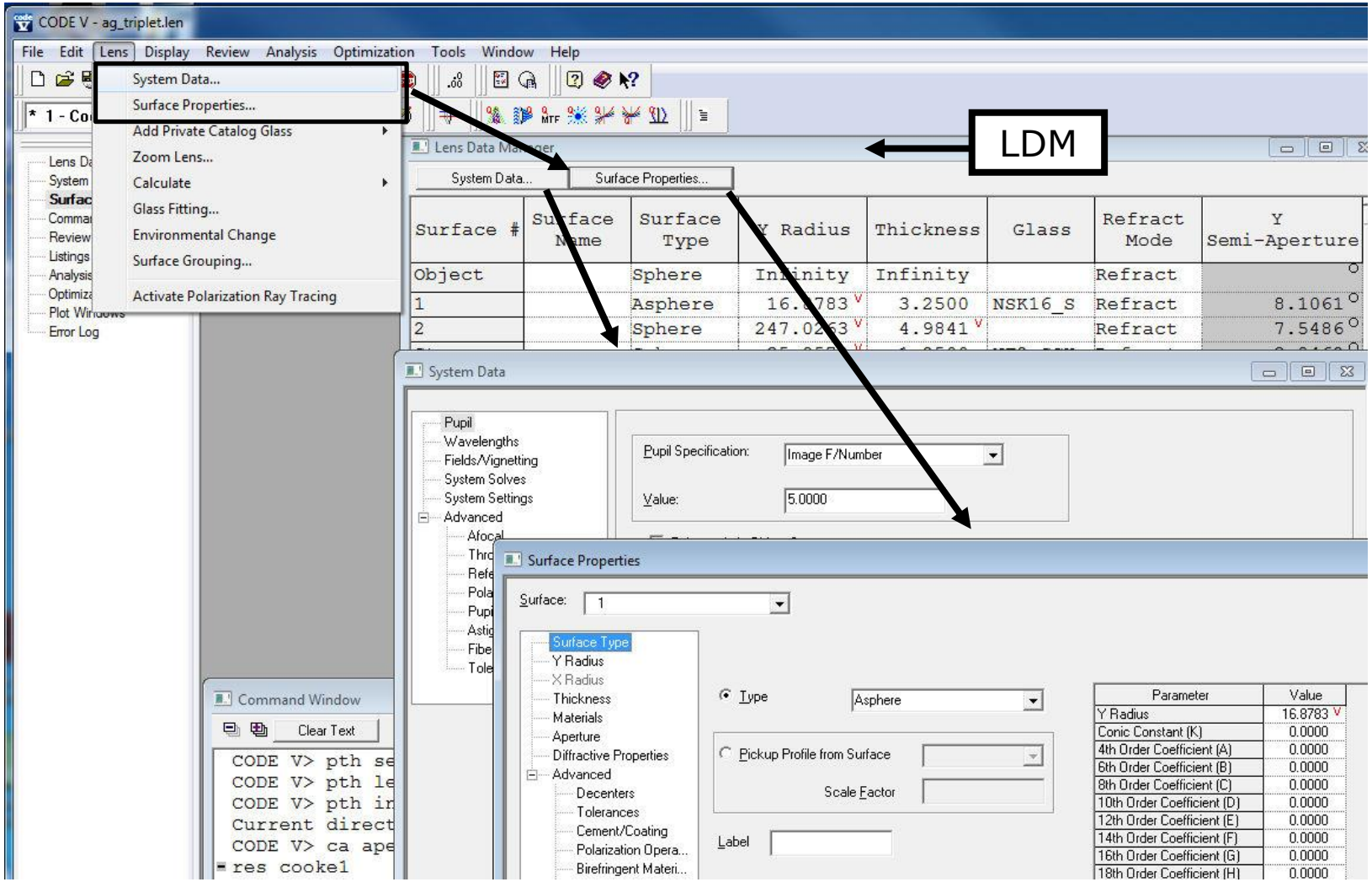
Opening a Lens



- Filter list of 2,400 patent lenses for desired criteria

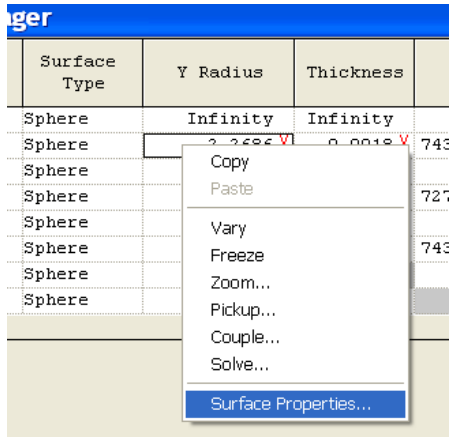
Data Entry

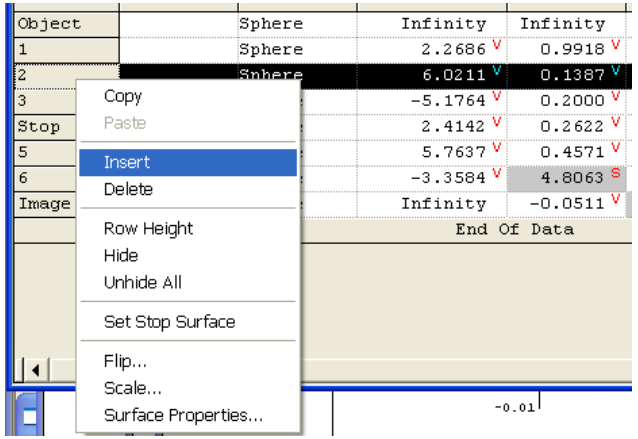
- 3 main windows for entering data
  - –Lens Data Manager (LDM): radius, thickness, glass, circular apertures, and indicators
  - –System Data
  - –Surface Properties



Data Entry

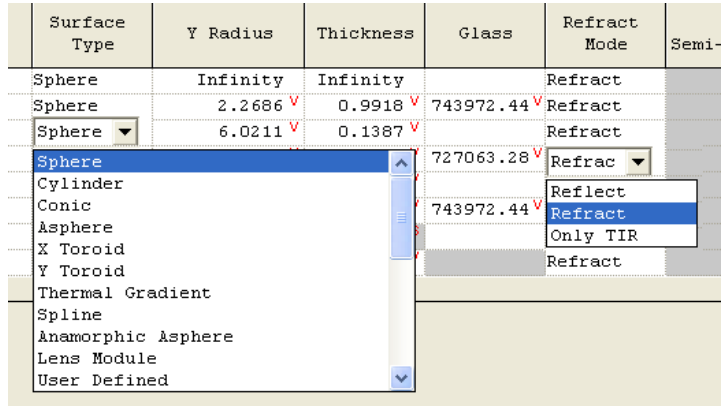
- Right-click for context sensitive menus





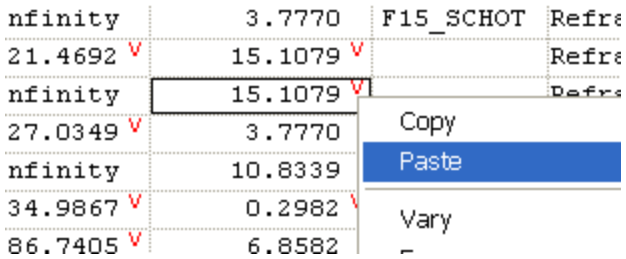
- Some operations (e.g. insert, delete) require you to highlight the row first

- Some fields (e.g. Surface Type, Refract Mode) you double-click for a drop down list



Data Entry

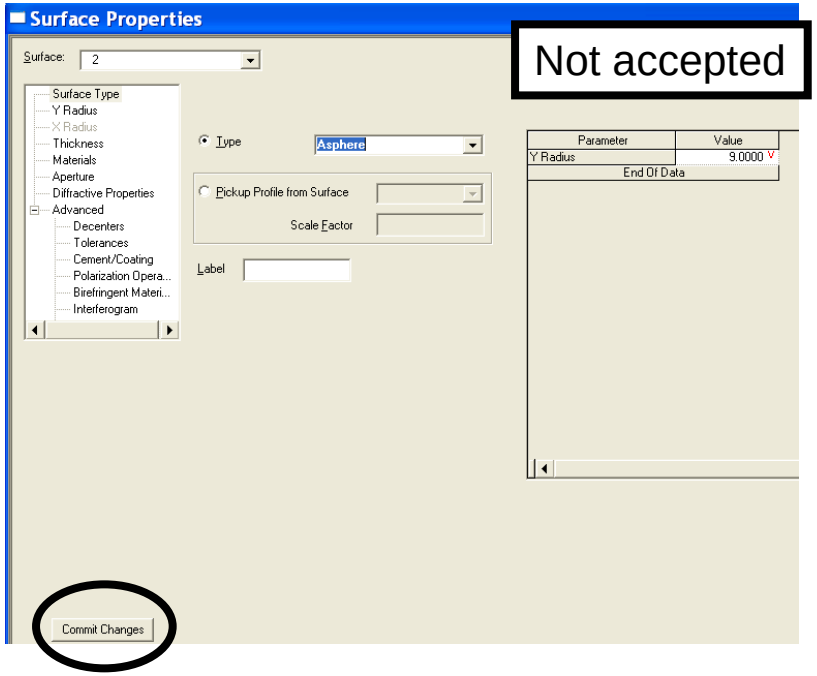
- Allows copy/paste of cell values or a range of cells

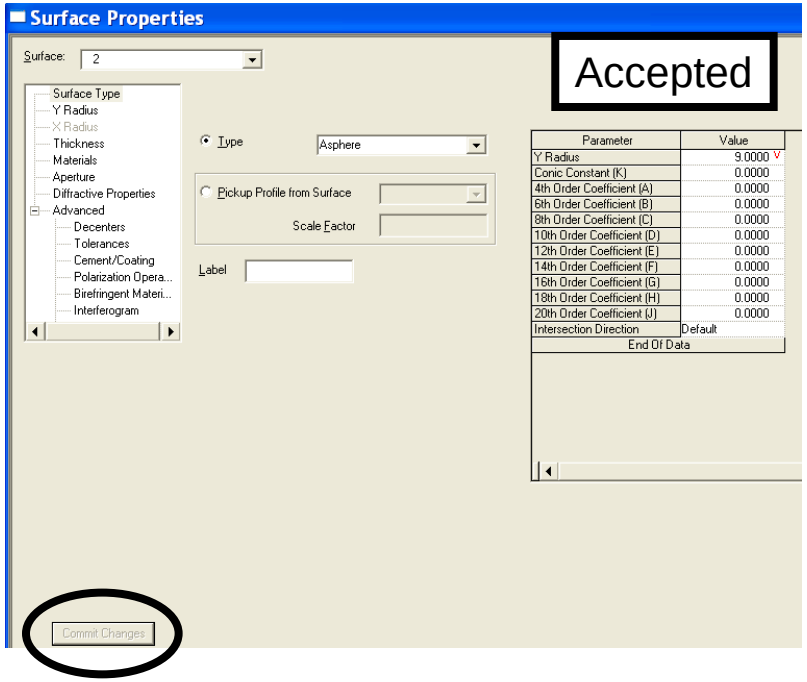


- Allows use of expressions in cells

Data Entry

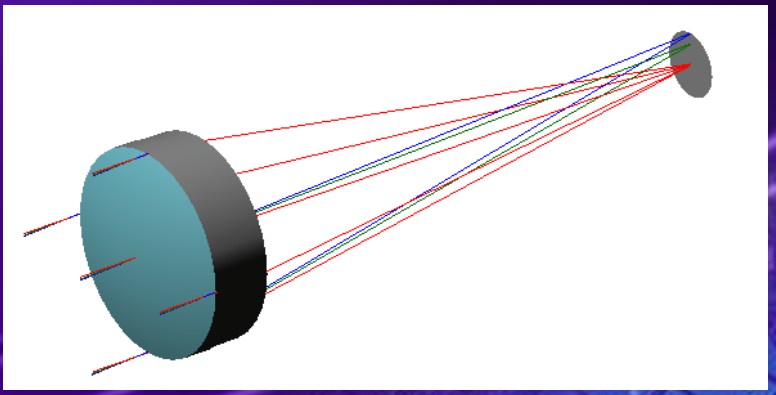
- Be sure that the program accepts data that is entered by one of these methods:
  - Clicking on a different cell
  - Clicking the “Commit Changes…” button
  - Hitting the TAB key
  - Hitting the ENTER key





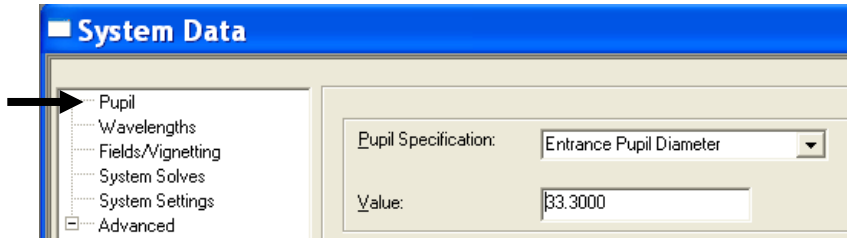
Demo: Lens Data Entry

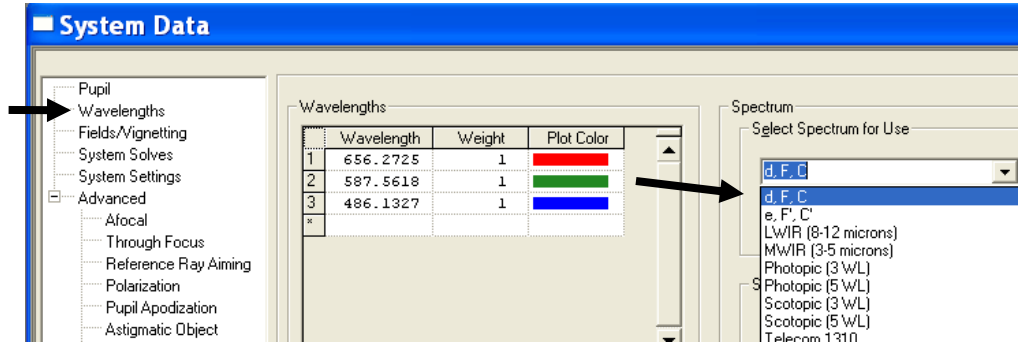
Getting to know the Lens Data Manager

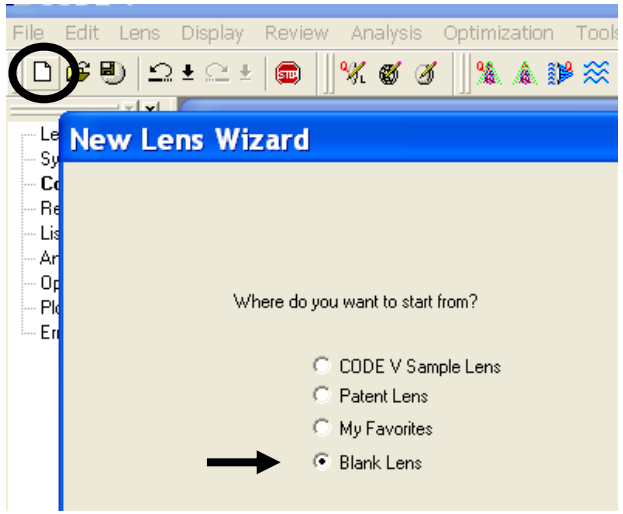


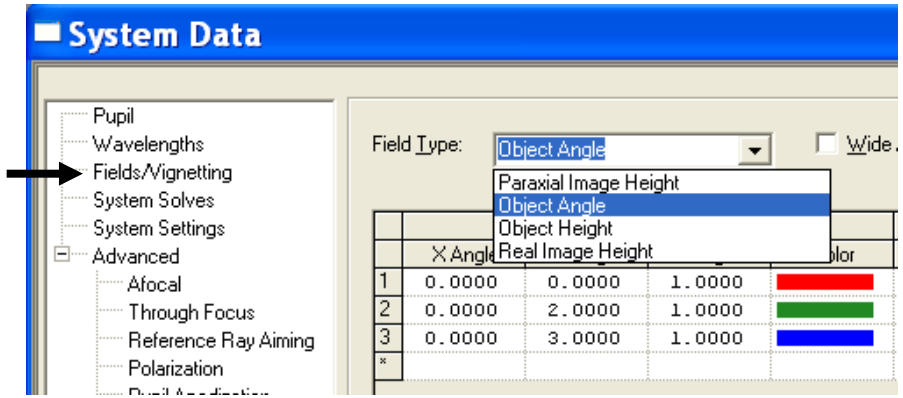
Data Entry – Ex. Doublet

- Open a blank lens from New Lens Wizard
- From menus open **Lens > System Data**
- Set pupil size, Entrance Pupil Diameter = 33.3
- Use F,d,c wavelengths (can use a pre-stored spectrum)
- Define fields as Object Angle, 0, 2, and 3 degrees







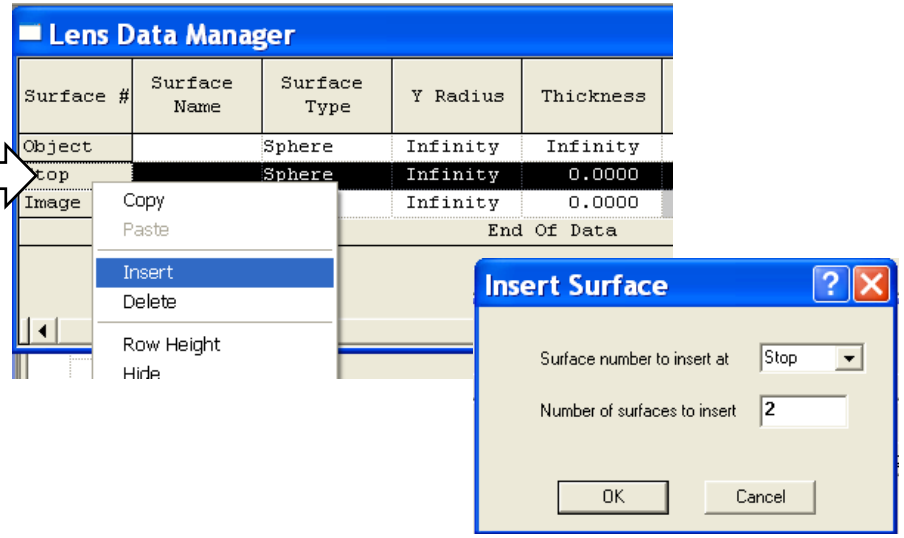


Data Entry – Ex. Doublet

- Insert 2 surfaces

(Or press “Insert” button twice)

Right-click



- Enter data for thicknesses and curvatures
  Type BSM24 and SF1 for glass material (automatically searches the catalogs)

Lens Data Manager

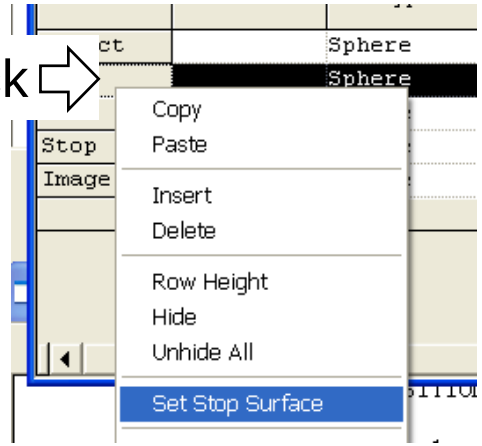
Surface #	Surface Name	Surface Type	Y Radius	Thickness	Glass	Refract Mode	Y Semi-Apertur
Object		Sphere	Infinity	Infinity		Refract	
1		Sphere	61.0722	10.3456	BSM24_OHA	Refract	16.9651
2		Sphere	-42.1754	2.3513	SF1_SCHOT	Refract	16.3051
Stop		Sphere	-316.1385	0.0000		Refract	15.7427
Image		Sphere	Infinity	0.0000		Refract	15.6891
End Of Data							

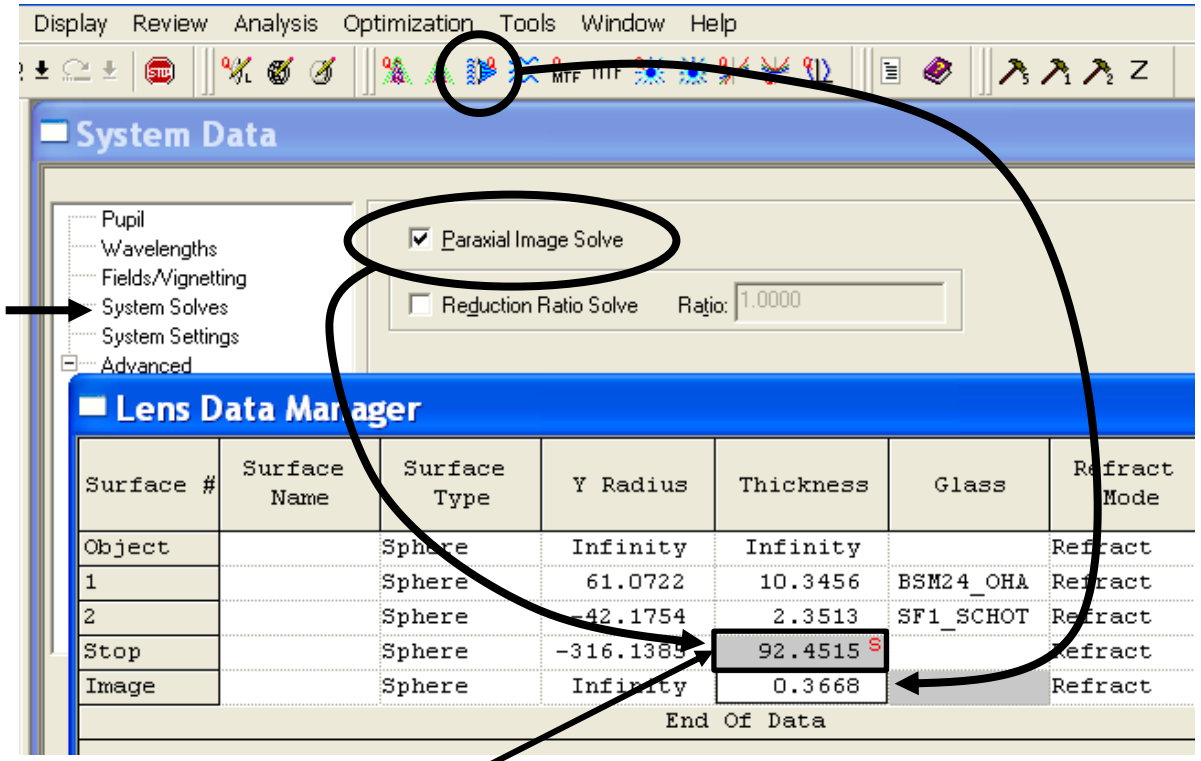
Data Entry – Ex. Doublet

- Add a paraxial image solve and do a quick best focus

- Set surface 1 to be the stop

Right-click



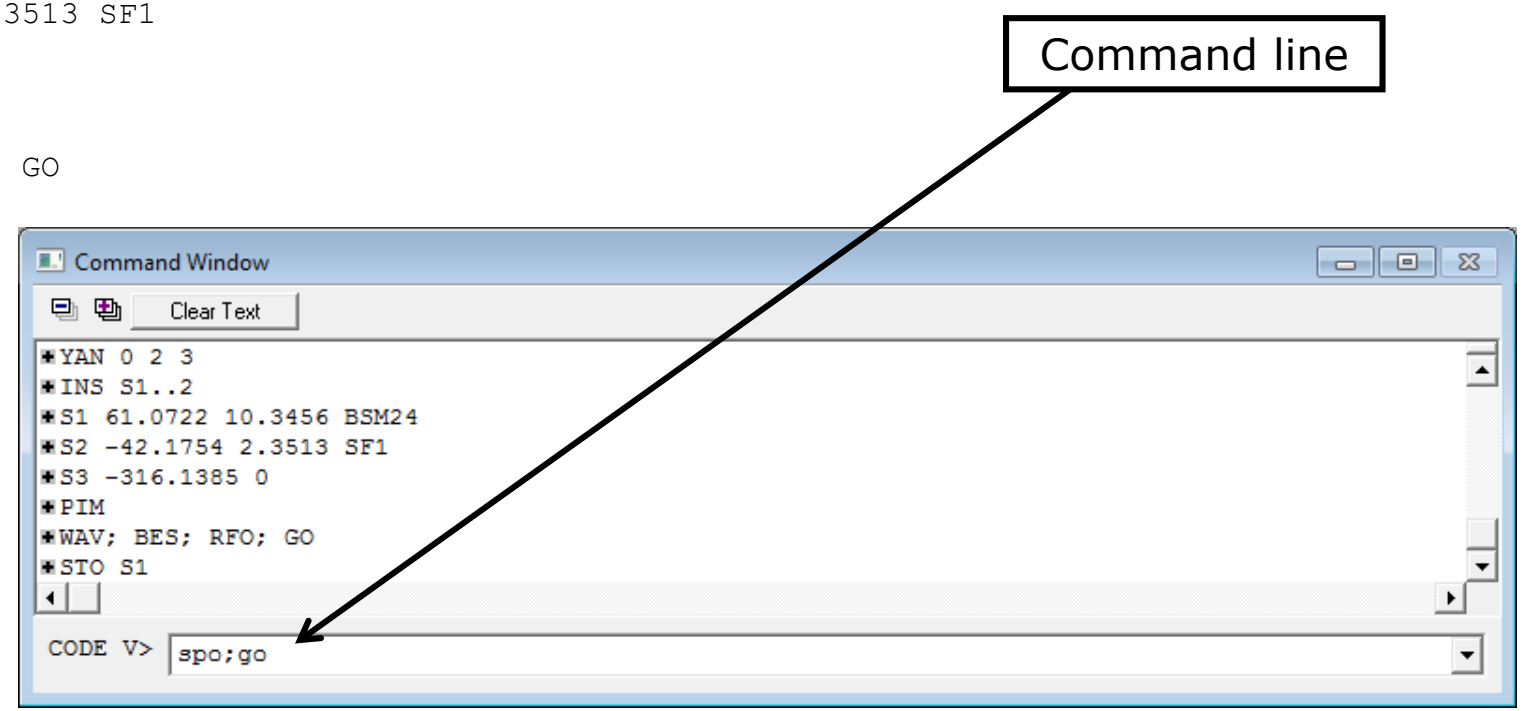


Grayed out cell is not directly editable; value is *computed* (by a solve, a pick up, or default value). Right click change to an editable quantity.

Data Entry – Ex. Doublet

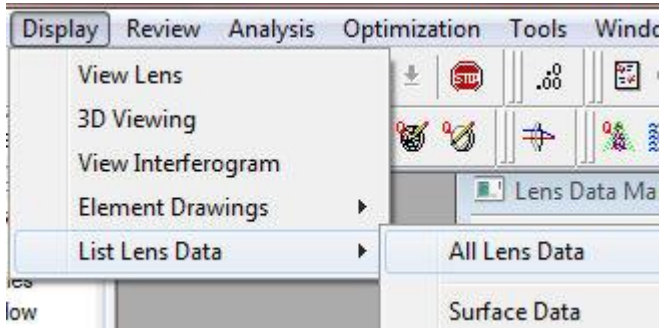
- Commands (copy and paste to the command line)

```
LEN NEW
EPD 33.3
WL 656.2725 587.5618 486.1327
YAN 0 2 3
INS S1..2
S1 61.0722 10.3456 BSM24
S2 -42.1754 2.3513 SF1
S3 -316.1385 0
PIM
STO S1
WAV; BES; RFO; GO
```



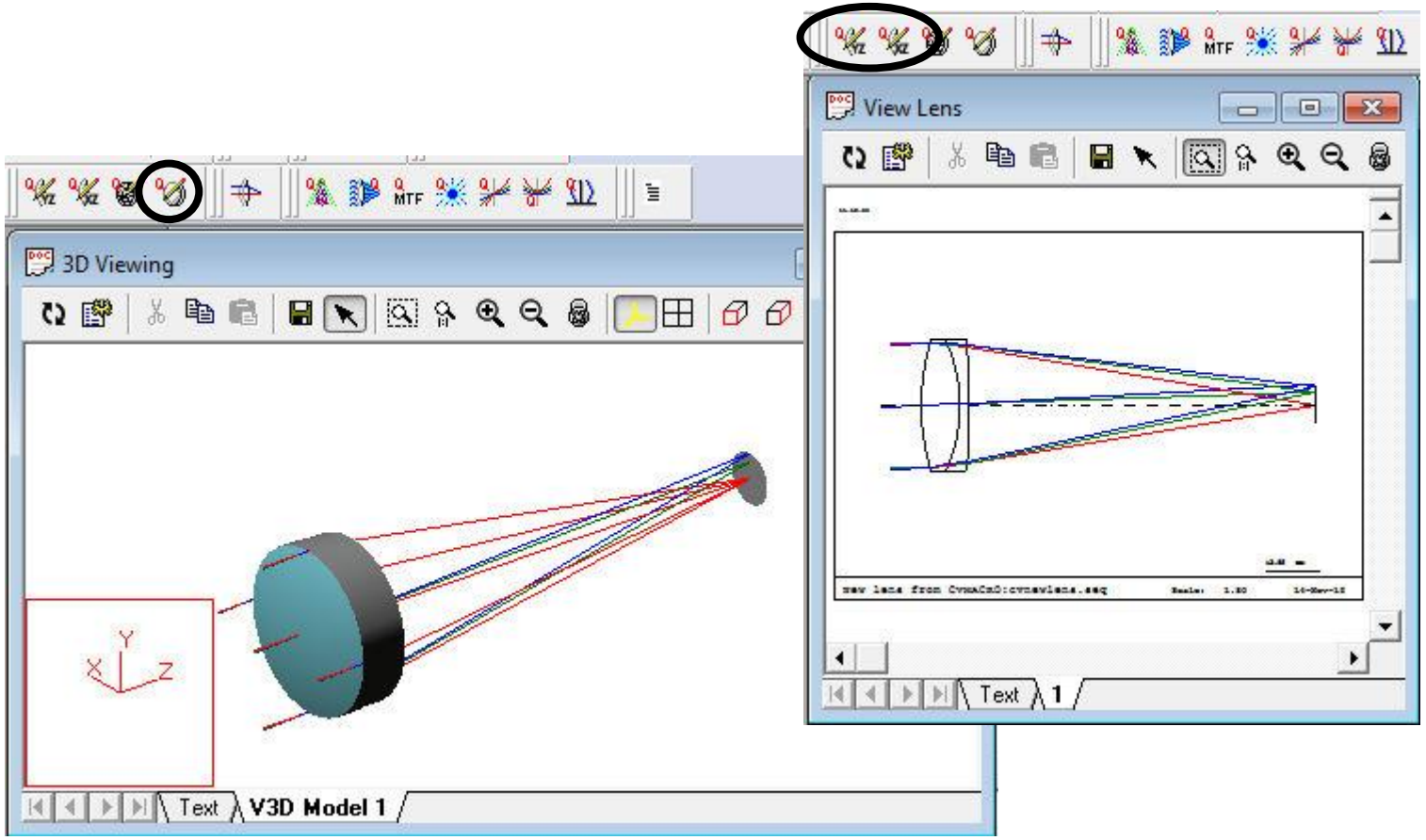
Analyses

- **Display>List Lens Data…**
  - –List surface data, system data, first order data, indices, etc.



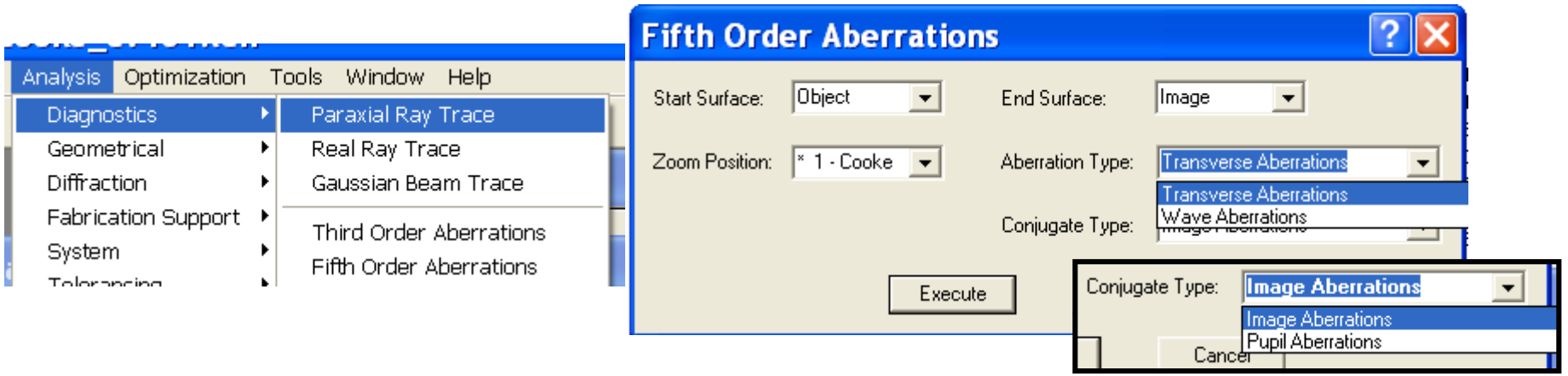
- **Display>View Lens**
  - –2D layout

- **Display>3D Viewing**
  - –Open-GL solid model, interactive rotation/zoom

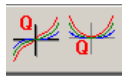


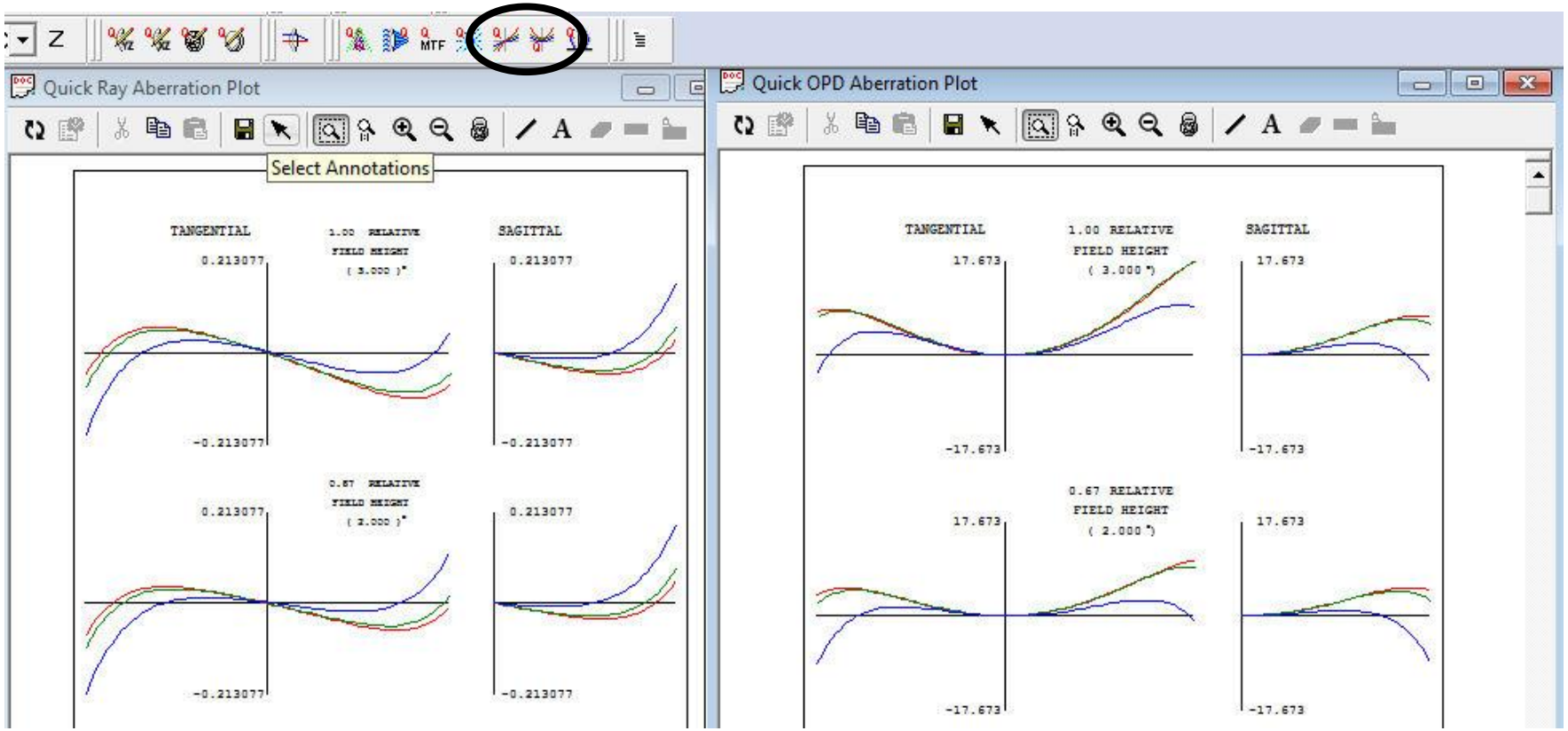
Analyses

- **Analysis>Diagnostics>Paraxial Ray Trace**
  - 1st order ray trace
- **Analysis>Diagnostics>Third Order Aberrations**
  - List the surface contributions and sum of the transverse third order aberrations for the system
- **Analysis>Diagnostics>Fifth Order Aberrations**
  - List the surface contributions and sum of the third and fifth order aberrations for the system (and elliptical coma)
  - Output can be in terms of transverse or wave aberrations
  - Output can be in terms of imaging or pupil aberrations



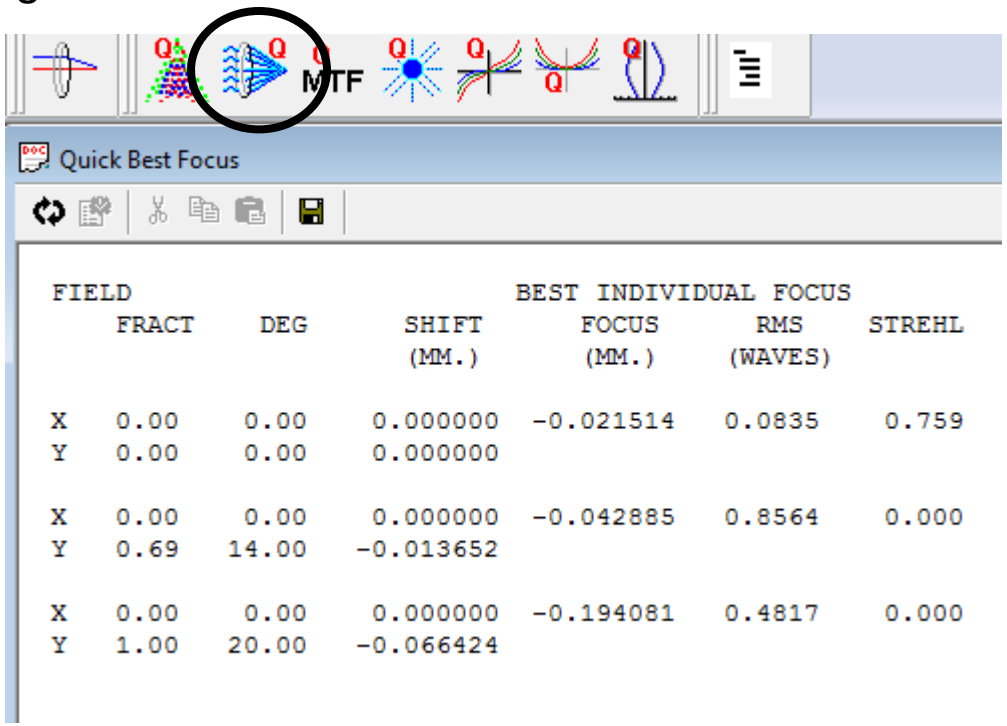
Analyses

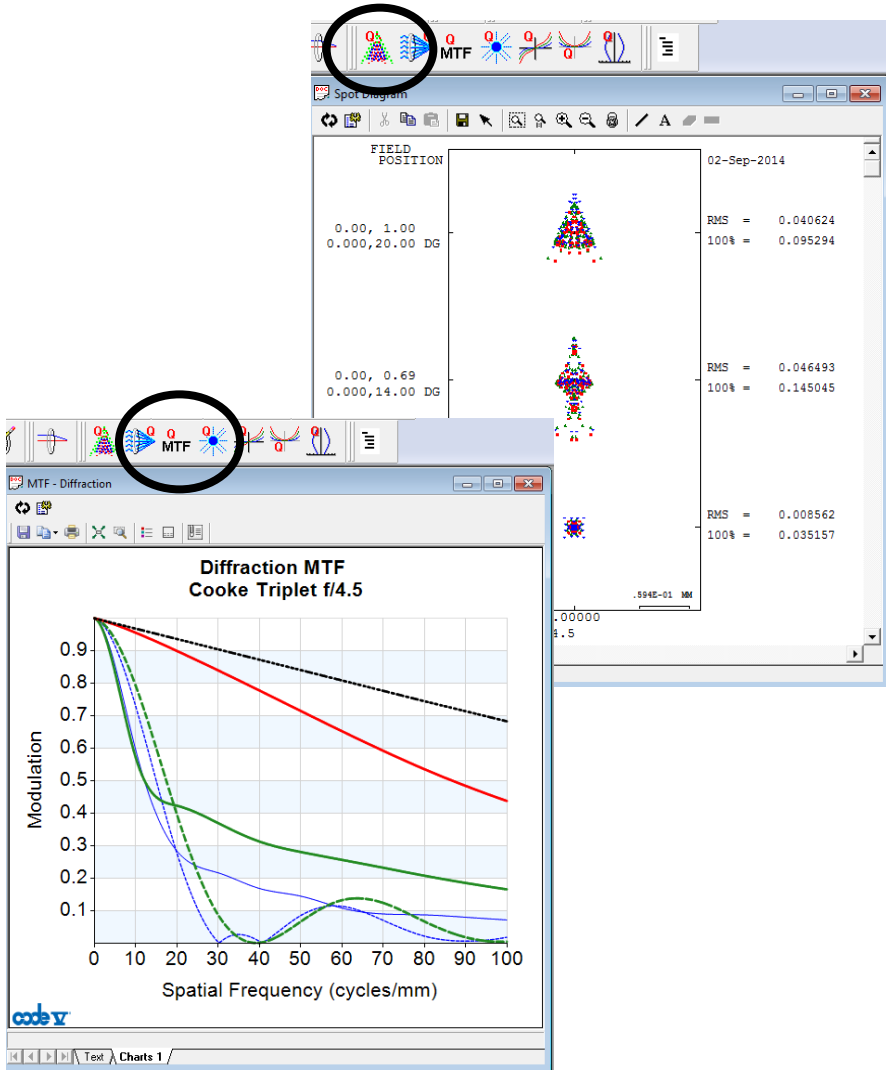
- **Analysis>Diagnostics>Ray Aberration Curves** or **OPD Aberration Curves**
  - –Useful for determining which aberrations are present in the lens
  - –Quick buttons actually run a macro which does auto-scaling 



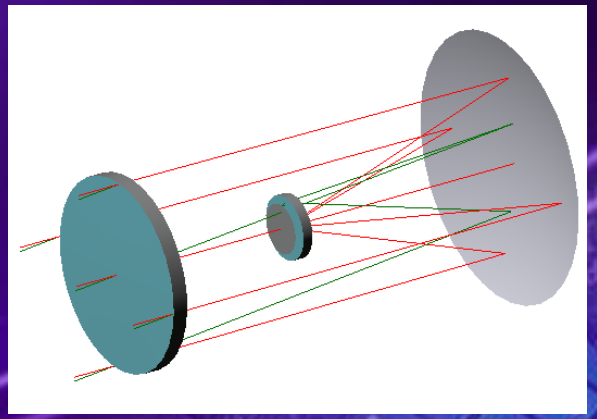
Analyses

- **Analysis>Geometrical>Spot Diagram**
  - Plots ray intercepts at the final surface for each field
- **Analysis>Diffraction>MTF**
  - Modulation Transfer Function values and plots
- **Analysis>Diffraction>Wavefront Analysis**
  - Listing of RMS Wavefront error





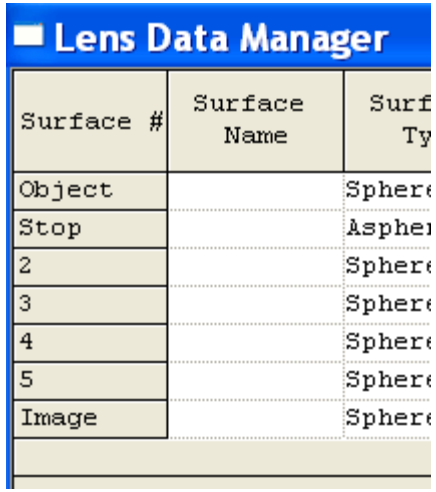
Demo: Entering a Reflective System



Data Entry – Ex. Reflective

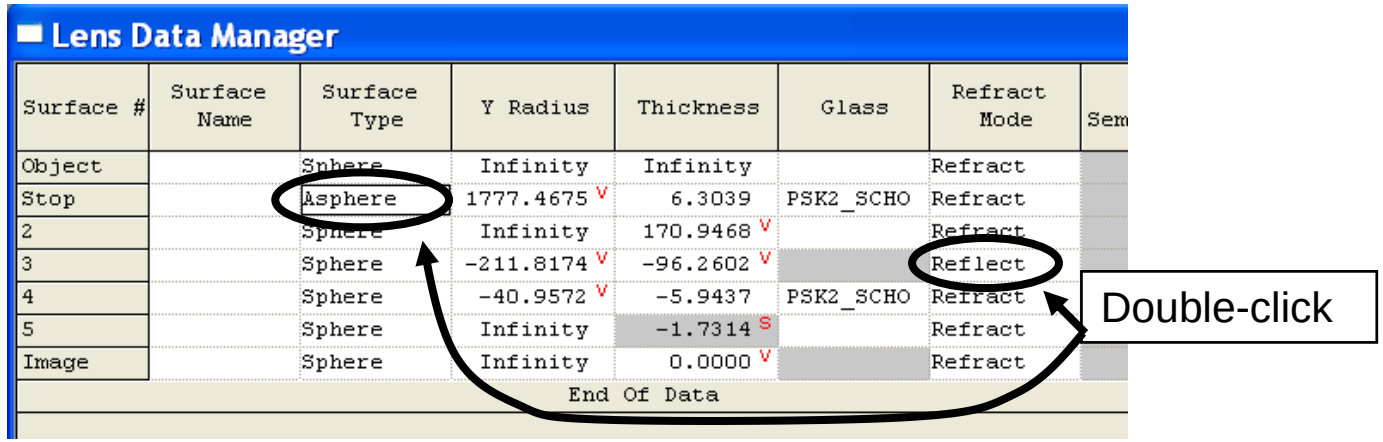
- Start with a new lens, and enter system and surface info same as the previous doublet example
  - –Entrance Pupil Diameter (EPD) 75
  - –Wavelengths d,F,c spectrum (656.3, 587.6, 486.1)
  - –Fields, Object angles 0 5.5 degrees
  - –Solves, Paraxial image solve

- Insert 4 surfaces, and make surface 1 the stop

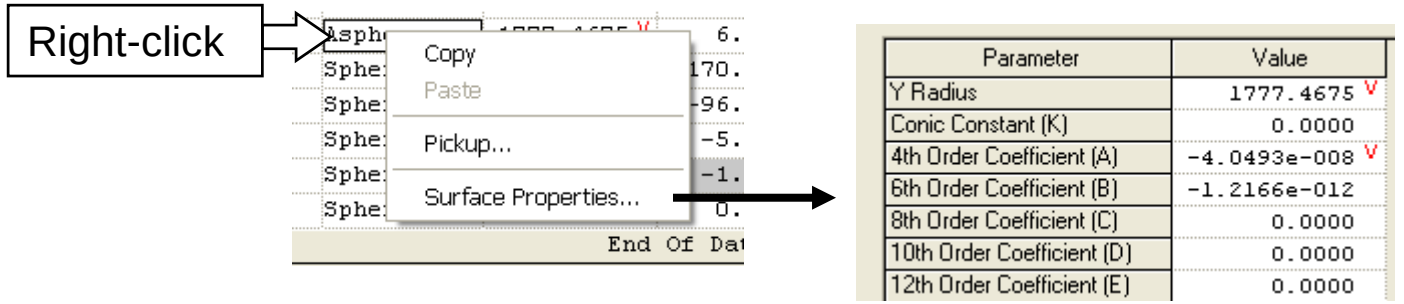


Data Entry – Ex. Reflective

- Note negative thicknesses. Rays travel in the opposite direction after each reflection. The coordinate system doesn't change



- Access Asphere coefficients in Surface Properties window



Data Entry – Ex. Reflective

- Commands (copy and paste to the command line)

```
LEN NEW
EPD   75.0
WL    656.3 587.6 486.1
YAN   0.0 5.5
PIM
INS S1..4
STO S1
S1     1777.467 6.304 PSK2_SCHOTT
  ASP
  K   0.0
  A -0.4049e-7
  B -0.1216e-11
S2     0.0 170.946
S3     -211.8173 -96.2601 REFL
S4     -40.9571 -5.9437 PSK2_SCHOTT
S5     0.0 -1.7313
```

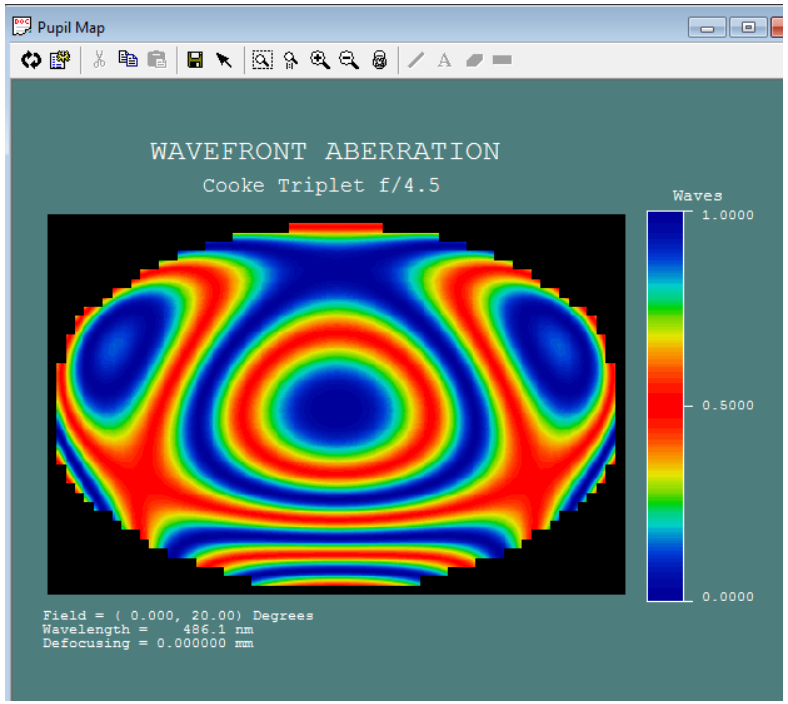
- More examples in New Lens Wizard, sample lenses (cassrc.len, maksutov.len, offner11, threemir, threemrc)

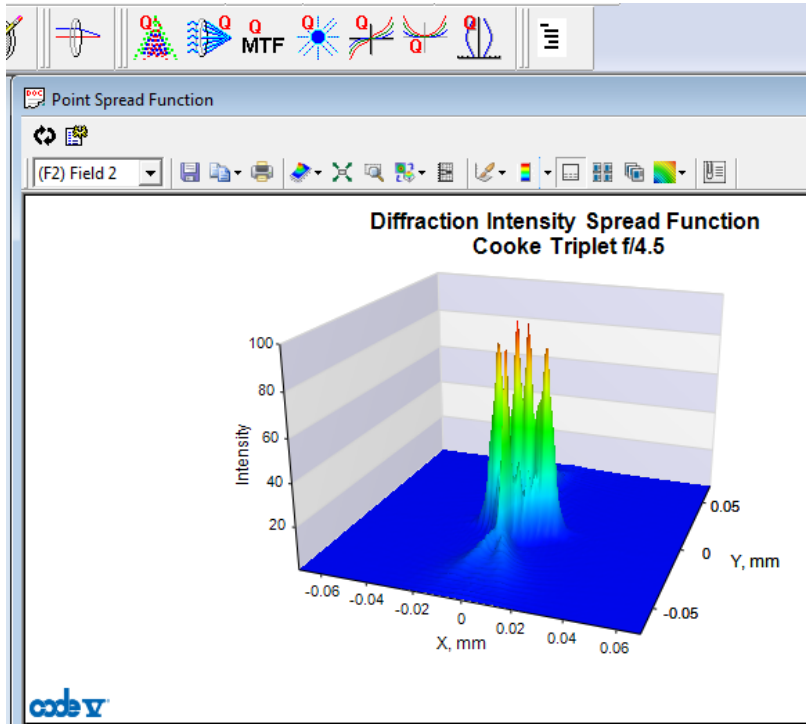
- For more info see Training Course Notes, Introduction, “Reflective Systems” (support.opticalres.com)

Analyses

- **Analysis > Diagnostics > Pupil Map**
  - OPD or intensity plot of wavefront at the exit pupil

- **Analysis > Diffraction > Point Spread Function**
  - Intensity plot of the PSF

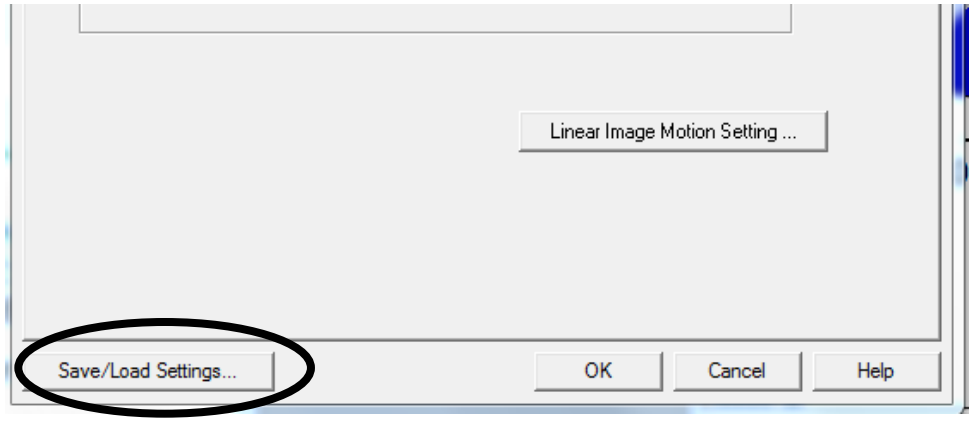




Analyses

- Settings button allows you to change options and re-run analysis

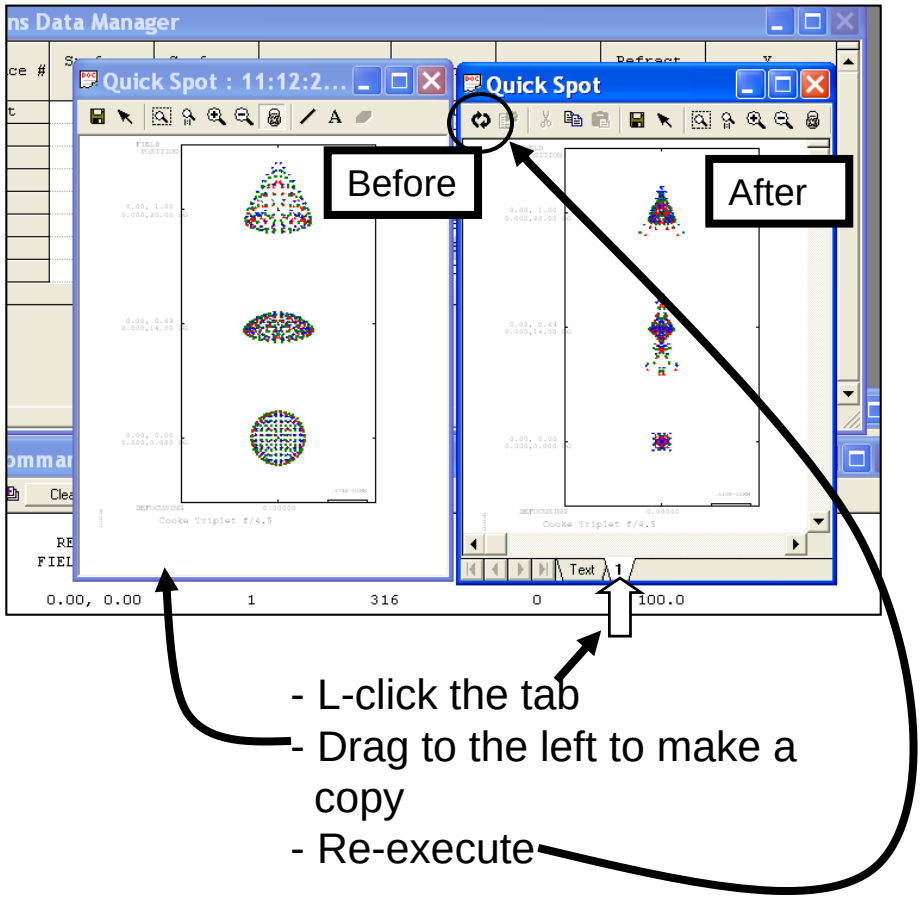
- Save/Load Settings… button allows you to save your options to apply in the future



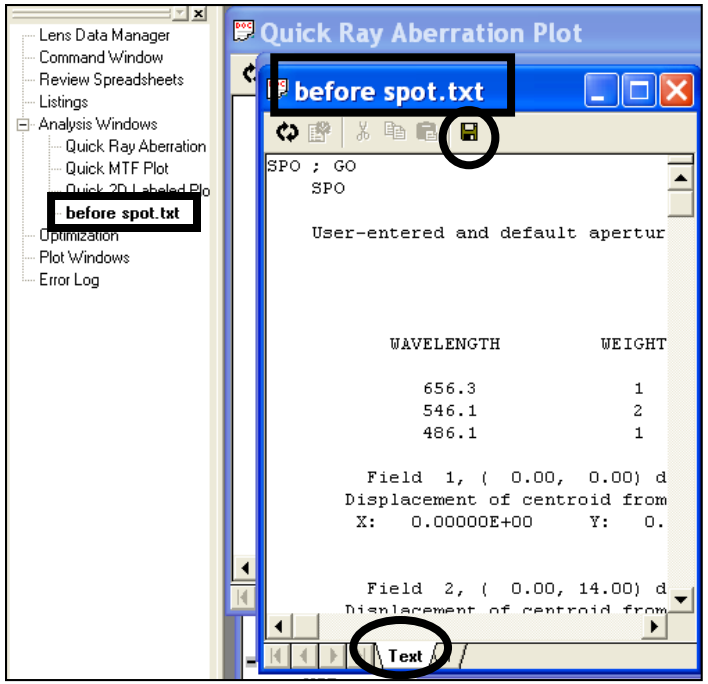
* Leave windows open so you can re-execute with the same options

Analyses

- Use tear-away feature to compare before and after analysis

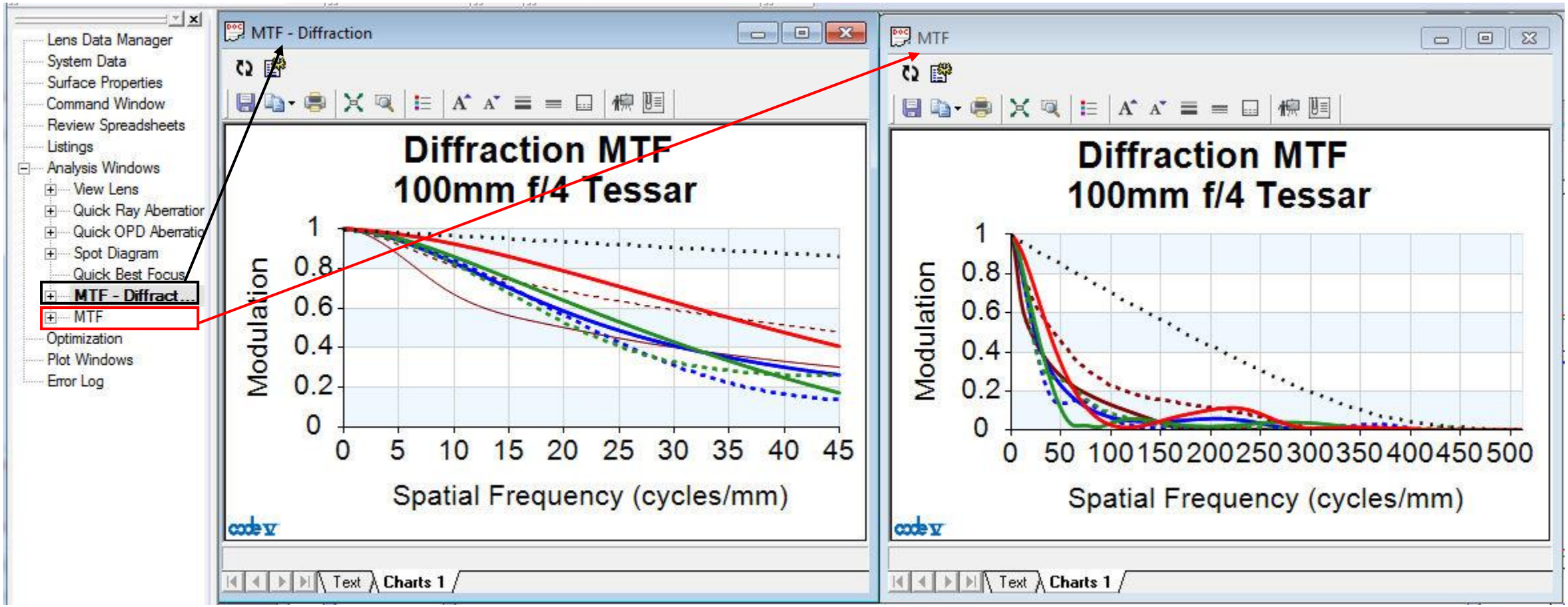


- Or save the text as a .txt file to see the name change in the navigation tree



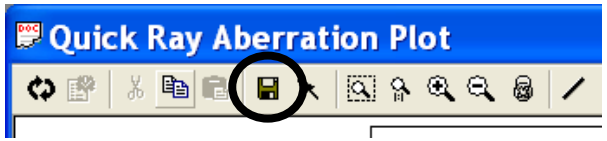
Analyses

- Can have multiple windows of same option
  - Each window has its own settings
  - Select desired window from System Navigator



Reports

- To save text or plotted output for your reports, use the **File > Save Window As …** choice

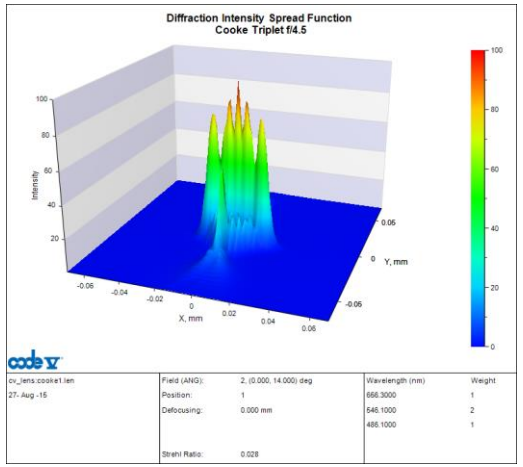


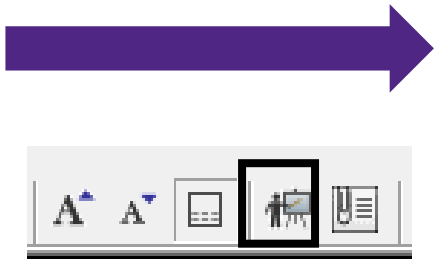
- For plotted output, you can also use Copy & Paste (CTRL-C, CTRL-V)

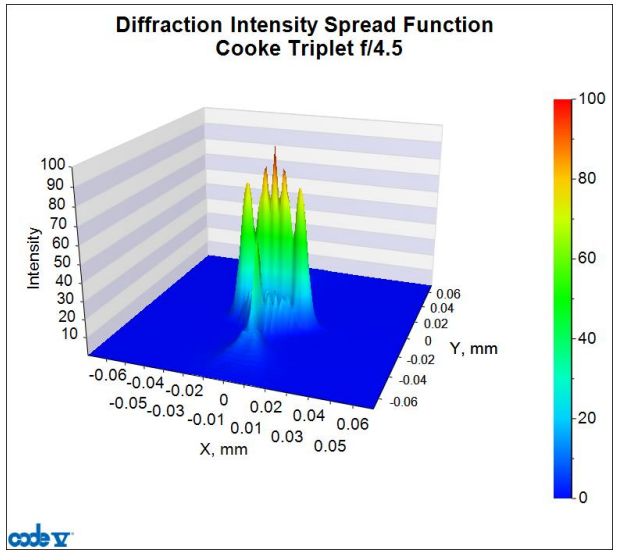
- The *LDM Spreadsheet* and *Review Spreadsheets* can also be printed directly
  - Verify the appearance with **File > Print Preview**

Use the Presentation/Report Template for clearer figures

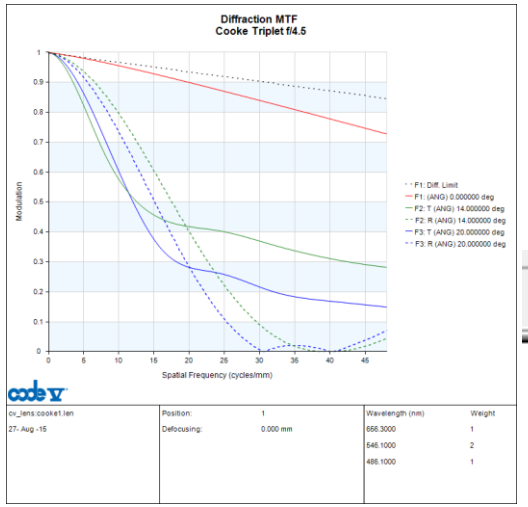
PSF

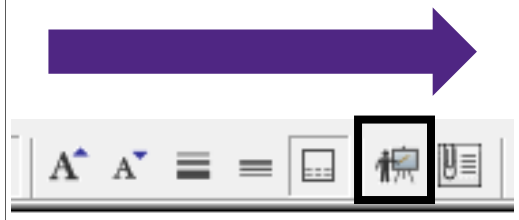


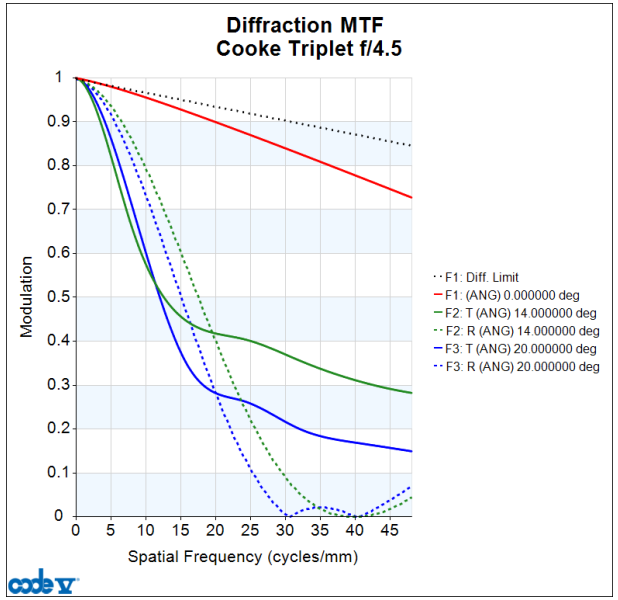




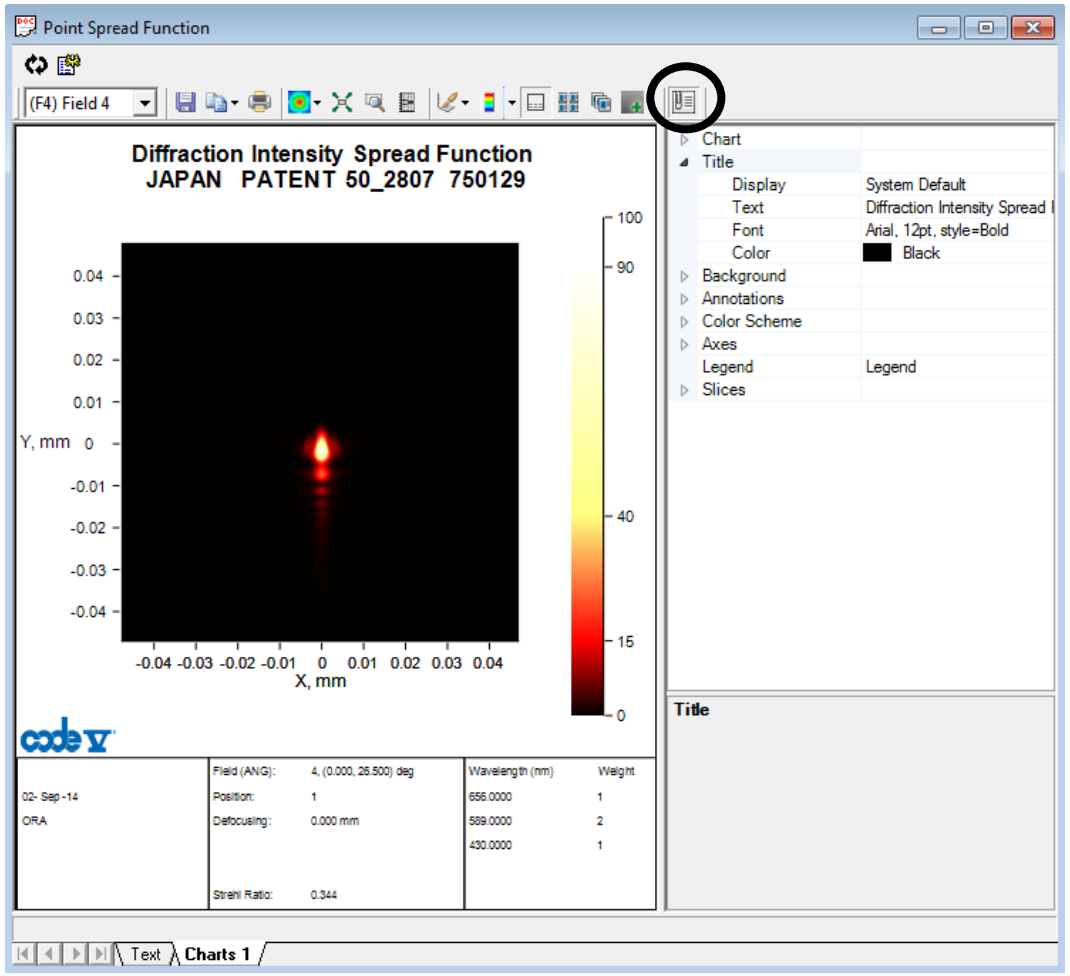
MTF





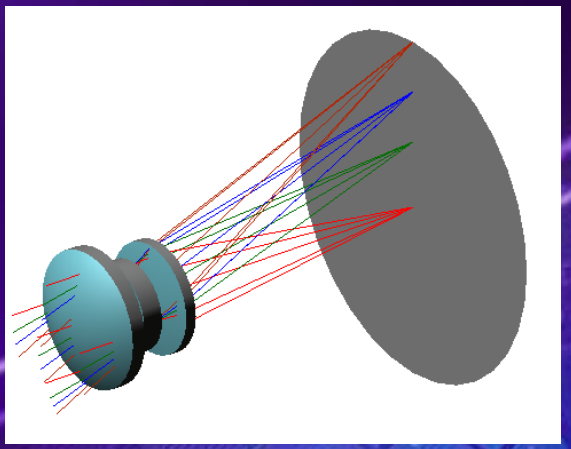


Click “Properties” to open full charting customization options



Demo: Designing a Digital Camera Lens

Introduction to SpecBuilder and Automatic Design



Example: Digital Camera Lens

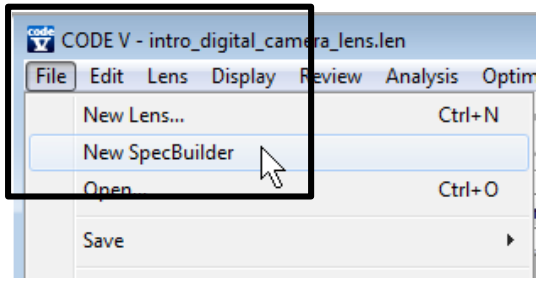
- Image sensor (baseline is Agilent FDCS-2020)
  a. Type CMOS
  b. Resolution 640 x 480 effective pixels
  c. Pixel size 7.4 x 7.4 microns (correspond to maximum spatial frequency of ~68 lp/mm)
  d. Sensitive area 4.74 x 3.55 mm (full diagonal 6-mm)

- Objective Lens
  e. Focal length Fixed, 6.0 mm
  f. f/number Fixed aperture, f/3.5
  g. Spectral Band 656, 546, 435 nm (~ C, e, g) with 1,2,1 weighting
  h. Semi-Field of View 26.5° (for 3-mm semi-diagonal and 6-mm EFL)
  i. Geometric Distortion < 4%
  j. Sharpness Radial & Tangential MTF

Low freq., 17 lp/mm	> 50%
High freq., 68 lp/mm	> 25%

  j. Vignetting Corner relative illumination > 60%
  k. Transmission Lens alone, > 80%
  l. Number of Elements (1-3) made from common glasses or plastics

Define the Specifications in SpecBuilder



SpecBuilder - digital_camera.sgt

SpecEvaluator

Specifications and Goals Table

	Label	Name	Goal Mode	Target	Value	Notes
☑	System Parameter	Effective Focal Length (mm): individual values over ZA F1; direction - mean of X & Y	equal to	6.0000		
☑	System Parameter	F-number (First Order): individual values over ZA F1; direction - mean of X & Y	equal to	3.5000		
☑	System Parameter	Field of View (Semi-FOV, deg): individual values over ZA; direction - Y	equal to	26.5000		
☑	Performance	Distortion (magnitude, percent): individual values over ZA FA; uncalibrated distortion	less than or equal to	4.0000		
☑		MTF (at 17.000 cycles/mm or cycles/afocal units): individual values over ZA FA DA; azimuth - 0 deg	greater than or equal to	0.5000		
☑	Performance	MTF (at 17.000 cycles/mm or cycles/afocal units): individual values over ZA FA DA; azimuth - 90 deg	greater than or equal to	0.5000		
☑		MTF (at 68.000 cycles/mm or cycles/afocal units): individual values over ZA FA DA; azimuth - 0 deg	greater than or equal to	0.2500		
☑	Performance	MTF (at 68.000 cycles/mm or cycles/afocal units): individual values over ZA FA DA; azimuth - 90 deg	greater than or equal to	0.2500		
☑	Performance	Relative Illumination (percent): individual values over ZA FA	greater than or equal to	60.0000		
☑	Performance	Transmission (percent): average over ZA FA; polychromatic	greater than or equal to	80.0000		
☑	User Specification	Number of Elements	less than or equal to	3.0000		
☑	Model Attribute	CODE V Model Attribute - Wavelength				
		Wavelength (nm): W1	equal to	656.0000		
		Wavelength (nm): W2	equal to	546.0000		
		Wavelength (nm): W3	equal to	435.0000		
		Wavelength Weight: W1 Z1	equal to	1		
		Wavelength Weight: W2 Z1	equal to	2		
		Wavelength Weight: W3 Z1	equal to	1		

Demo – Setup Lens

- File > New, click “Next”, choose patent lens, click “Next”, click “Filter…”, select F/# 1-4, Semi-Field of View 20-33, Number of elements 1-3
- Choose or02248, click “Finish”
  - This is a wider field, faster f/# than needed.
- Lens > System Data, select Pupil, chose Image F/# 3.5
- Select Wavelengths, change W2 weight to 2
- Select Fields, set type to object angle, define 4 fields: 0 11 19 26.5
- Select System Settings, change title to “CODE V Demo”
- Display > View Lens, note vignetting,
- System Data, select Fields, click “Set Vignetting…”
- Display > View Lens, note vignetting,
- Display > List lens data> First order data
- Edit > Scale, select Scale Effective Focal Length, surfaces 1 to 6, Scale Value = 6
- Re-run first order data, note change in EFL
- Re-draw lens

Demo – Run Analysis

- Analysis > Diffraction > MTF, maximum freq. 68, increment freq. 17
- Analysis > Geometrical > Spot Diagram, select Aberration Scaling, Value 0.02
- Analysis > Diagnostics > Ray Aberration Curves, change Scale to 0.02

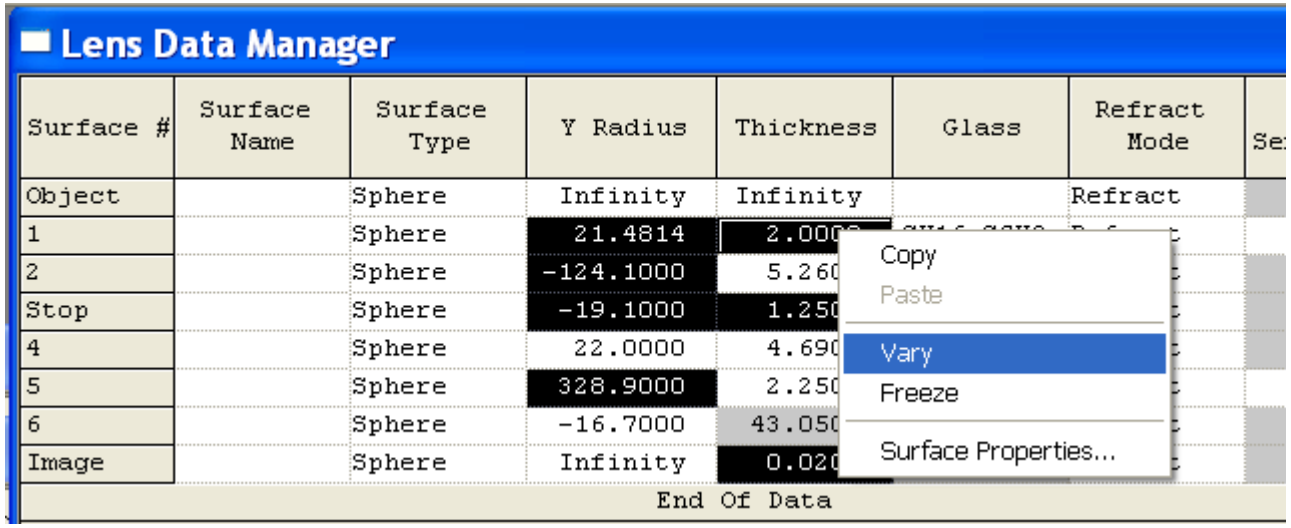
Optimizing a Lens

- One of CODE V's main strengths is the effectiveness of its optimization algorithms
  - In particular, CODE V's ability to control constraints exactly works better than any other commercial software

- CODE V optimization is easy to use, with very little input required by you in many cases
  - This is mainly achieved through CODE V's use of intelligent defaults
  - However, the **Automatic Design** feature is also flexible and you can control many details of the optimization if you wish to

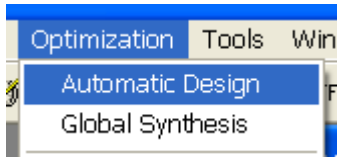
Optimizing a Lens

- Add variables to any desired parameter
  - Can select multiple cells by left-click and drag, or use CTRL+click
  - Right-click on any highlighted cell, choose “Vary”



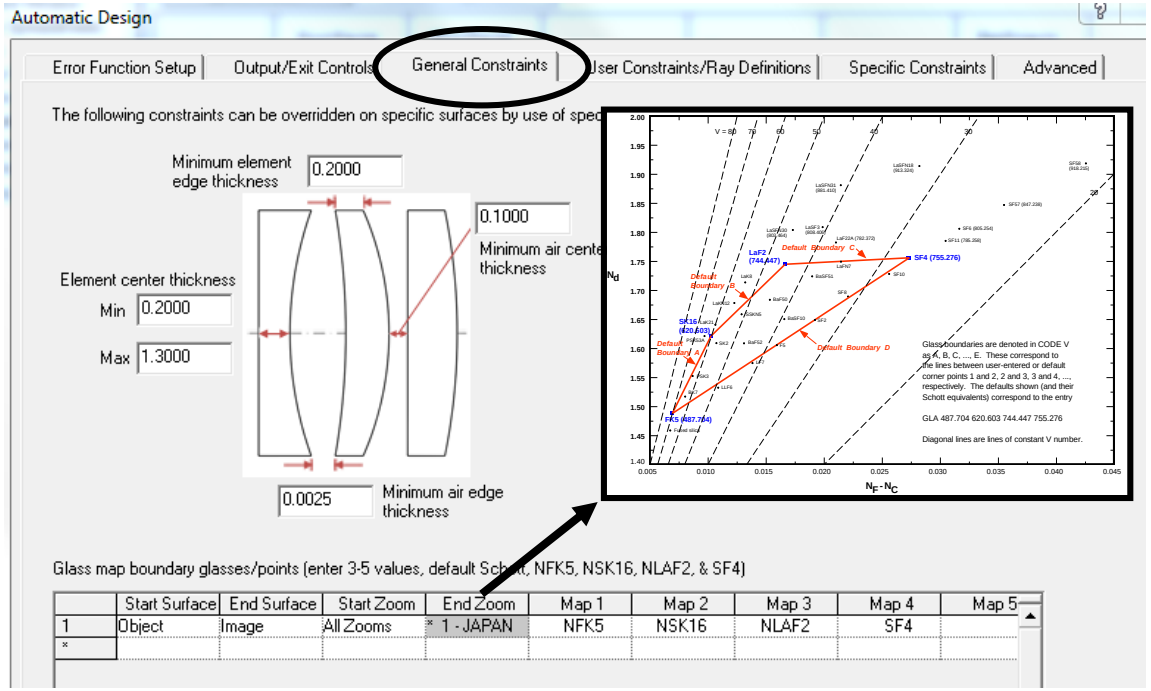
Optimizing a Lens

- Select **Optimization > Automatic Design**
- Check General Constraints
- Define glass map



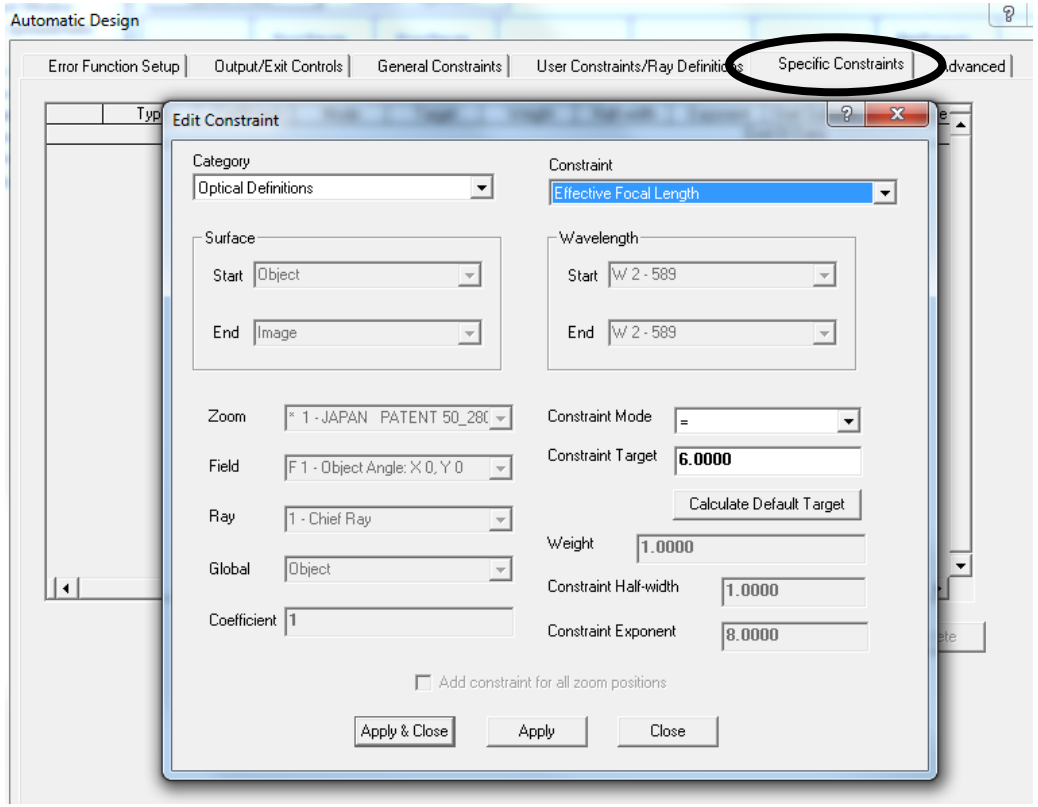
General constraints are limits placed on thicknesses for all surfaces.

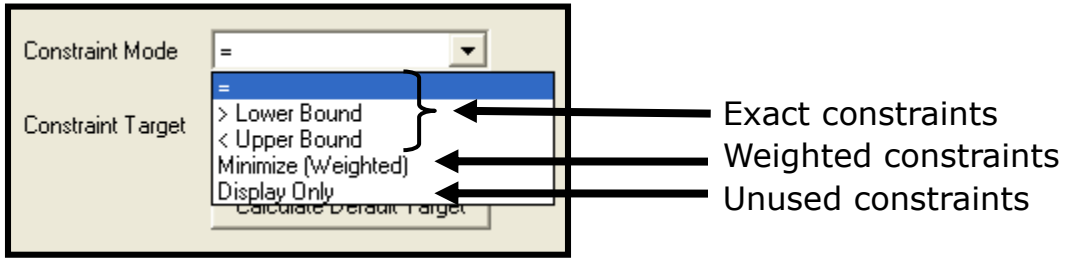
The glass map defines the boundary of glasses when varying the refractive index (**Tools > Macro Manager > Sample Macros > Materials Info > vp_plot.seq**)



Optimizing a Lens

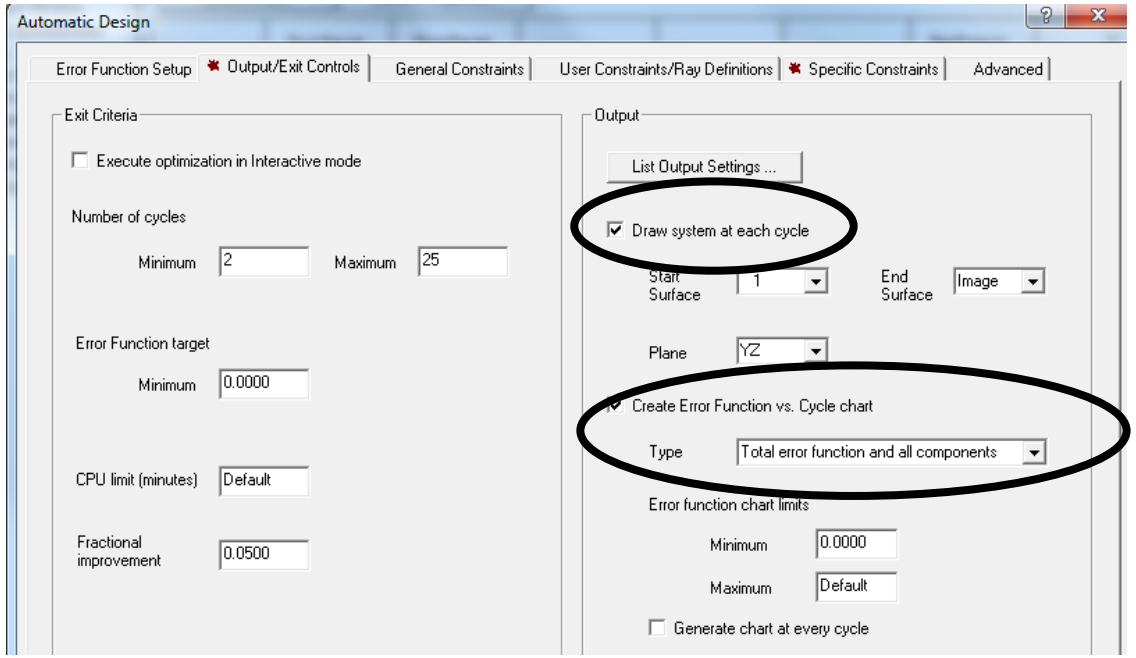
- Define any specific constraints (EFL, distortion, surface thicknesses, ray trace data, etc.). These may override general constraints.
- Note: exact constraints handled by linear algebra solutions (Lagrange multipliers) separate from error function, weighted constraints included in error function.





Optimizing a Lens

- Set output controls for drawing the lens at each cycle and printing text output.
- If desired, change exiting conditions (max cycles, improvement factor, interactive mode).
- Hit “OK” when finished, re-run any analyses.



Demo - Optimization

- Vary curvatures for surfaces 1-6
- Vary thickness for surfaces 1-5 and image. Leave the paraxial image solve on surface 6
- Vary all glasses
- Open Automatic Design window, under Output Controls select Draw system at each cycle, under Specific Constraints add EFL = 6, click OK
- Rerun analyses and compare before and after results (open new window or use tear-away feature)
  - Analysis > Diffraction > MTF, Maximum freq. 68, Increment freq. 17
  - Analysis > Geometrical > Spot Diagram, select Aberration Scaling, Value 0.02
  - Analysis > Diagnostics > Ray Aberration Curves, Scale 0.02
- Note that middle lens is too thin. Click settings button in Automatic Design window, under General Constraints change Minimum Center Thickness to 0.5, click OK
- Note thicker lenses. Rerun analyses and compare results.

Demo - Optimization

- Commands

```
in cv_macro:extlen 'or02248'     ! load patent lens
fno 3.5                          ! pupil spec for f/#
WTW W2  2                        ! wavelength weight
yan 0 11 19 26.5                 ! object field angles in Y
tit 'CODE V Demo'                ! set title
vie;go                           ! 2D plot
in cv_macro:setvig               ! set vignetting
vie;go                           ! 2D layout
fir                              ! list 1st order data
SCA EFL  S1..I-1 6               ! scale lens to EFL of 6
fir                              ! list 1st order data

mtf; mfr 68; ifr 17; go          ! run MTF, max freq. 68, increment 17
spo; ssi .02; go                 ! run spot diagram, plot scale .02
rim; ssi .02; go                 ! run ray aberration curves, plot scale .02

ccy s1..6 0                      ! vary curvatures
thc s1..5 0                      ! vary thicknesses
thc si 0
gc1 s1 0                         ! vary glasses
gc1 s3 0
gc1 s5 0
```

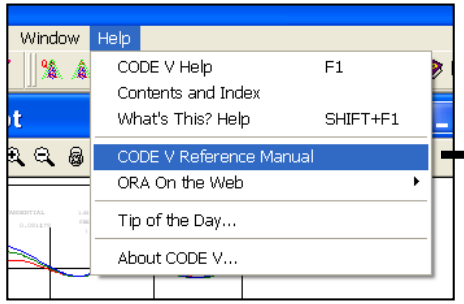

Demo - Optimization

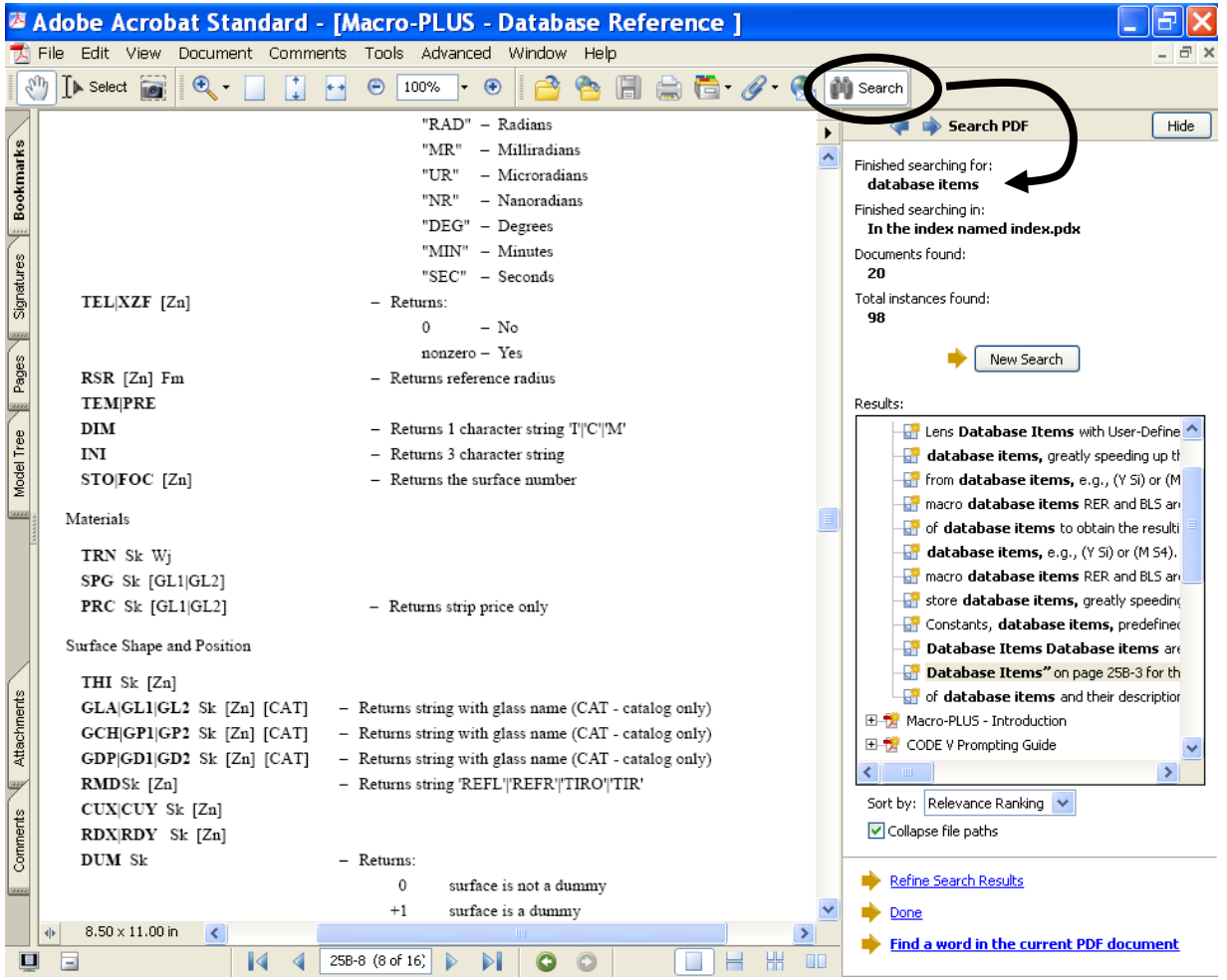
- Commands (cont'd)

```
aut;dra;efl=6;go                ! optimize, draw the system at each cycle

mtf; mfr 68; ifr 17; go         ! rerun analysis as before
spo; ssi .02; go
rim; ssi .02; go

aut;dra;efl=6;mnt .5;go         ! optimize, set min thickness of .5

mtf; mfr 68; ifr 17; go         ! rerun analysis as before
spo; ssi .02; go
rim; ssi .02; go
```

CODE V Help

- CODE V reference manual (PDF) has the most info





e.g. Search on “database items” provides links to syntax for various database info (curvatures, thicknesses, pupil size… any CODE V info)

Welcome to CODE V!