

# CODE V<sup>®</sup> New User Orientation

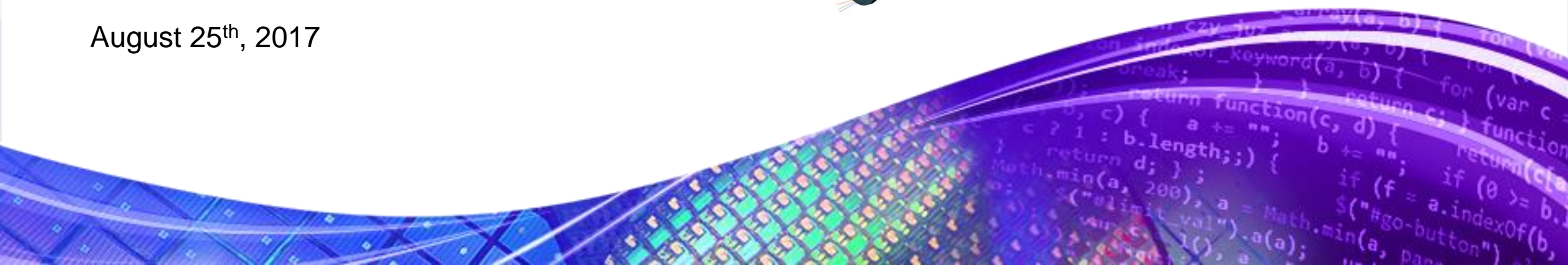
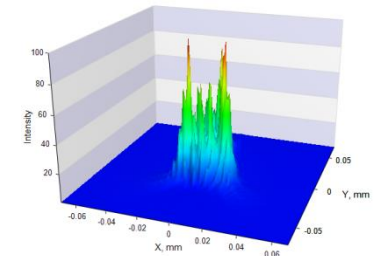
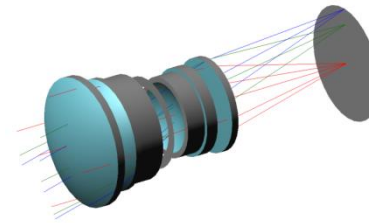
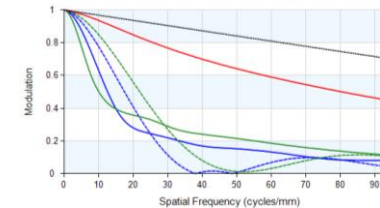
## A Brief Introduction to CODE V

### Design and Analysis Software for Imaging Systems

### For OPTI517

Craig Pansing: [cpansing@synopsys.com](mailto:cpansing@synopsys.com)

August 25<sup>th</sup>, 2017

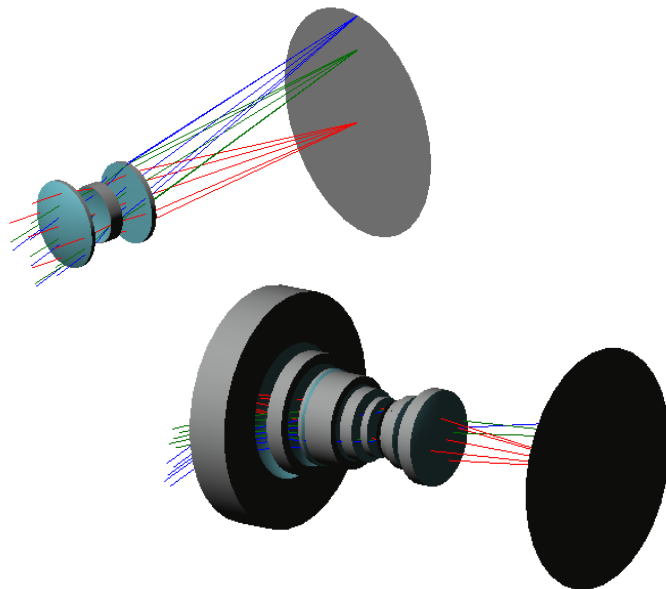


# Purpose

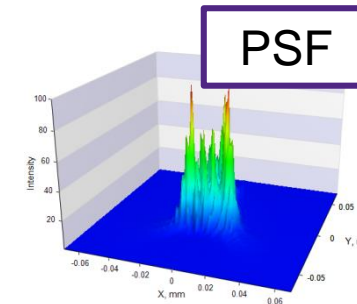
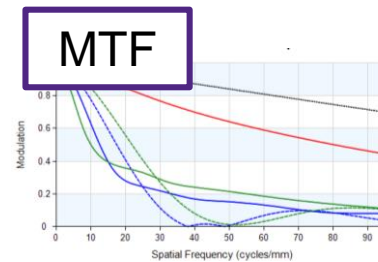


- Provide you with an overview of CODE V structure, interface, and capabilities for optical system:

Modeling



Analysis



Optimization

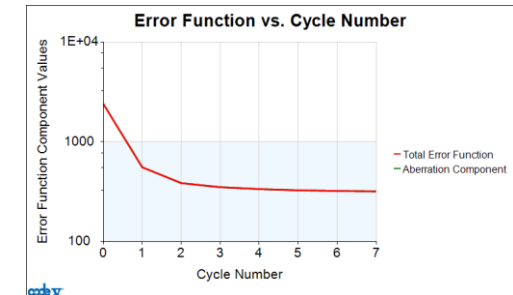


Image Simulation

# 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](mailto: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](mailto:rcorcoran@optics.arizona.edu)) in the academic office

# Education for CODE V Users

*Customer Support Portal, and Training*

# Resources for Learning CODE V

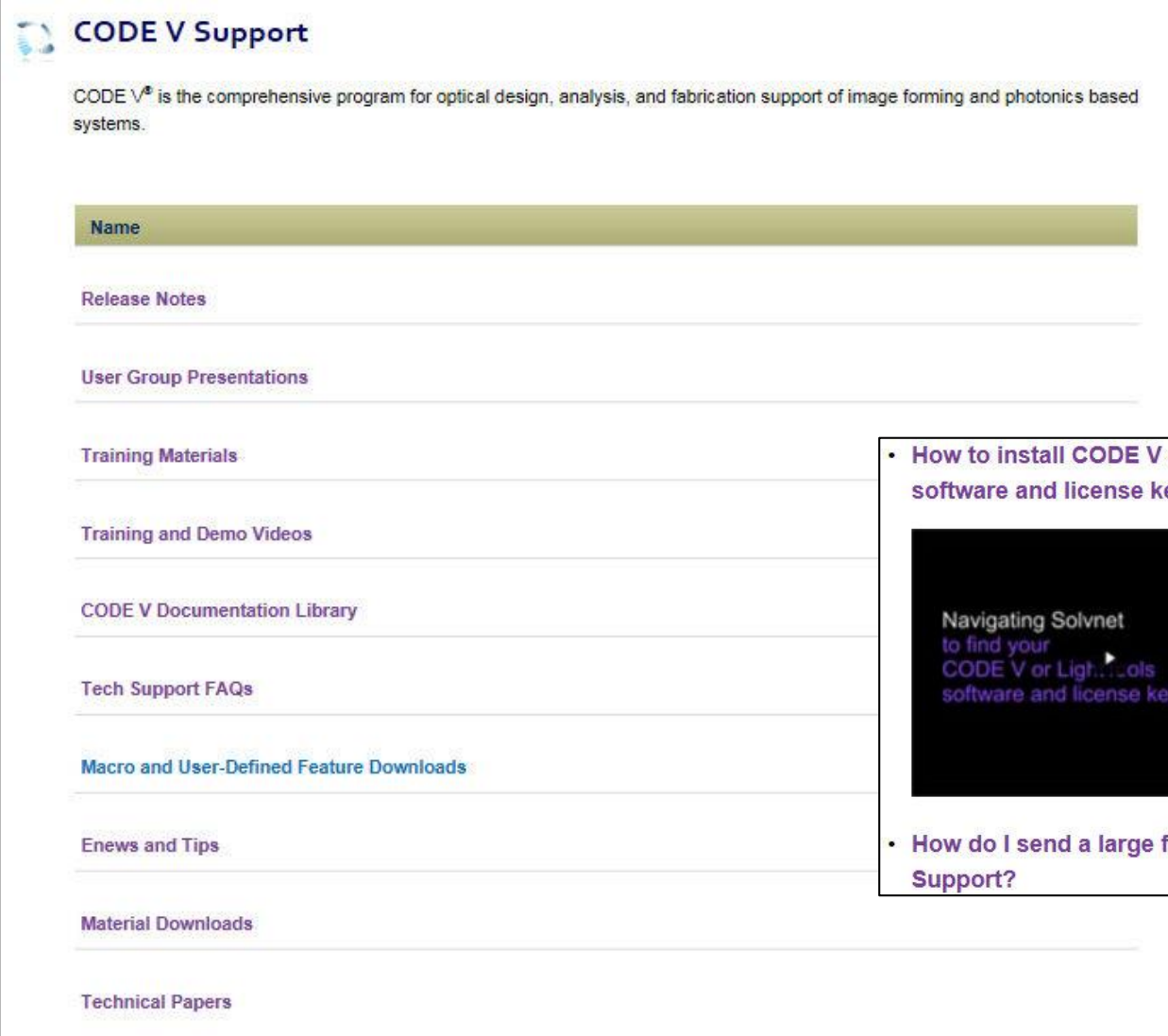
- Various CODE V Help Choices (**HELP** > ... )
- The Customer area of the ORA website: [support.opticalres.com](http://support.opticalres.com)
  - **Introductory & Advanced Training presentations**
  - CODE V User Group meeting presentations
  - CODE V Webinar recordings
  - Release notes
  - E-news 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



The screenshot shows the 'CODE V Support' portal. At the top, it says 'CODE V® is the comprehensive program for optical design, analysis, and fabrication support of image forming and photonics based systems.' Below this is a search bar labeled 'Name'. A list of navigation links follows: 'Release Notes', 'User Group Presentations', 'Training Materials', 'Training and Demo Videos', 'CODE V Documentation Library', 'Tech Support FAQs', 'Macro and User-Defined Feature Downloads', 'Enews and Tips', 'Material Downloads', and 'Technical Papers'.

- How to install CODE V or LightTools software and license key



- How do I send a large file to Tech Support?

# Training Courses and User Group Meetings

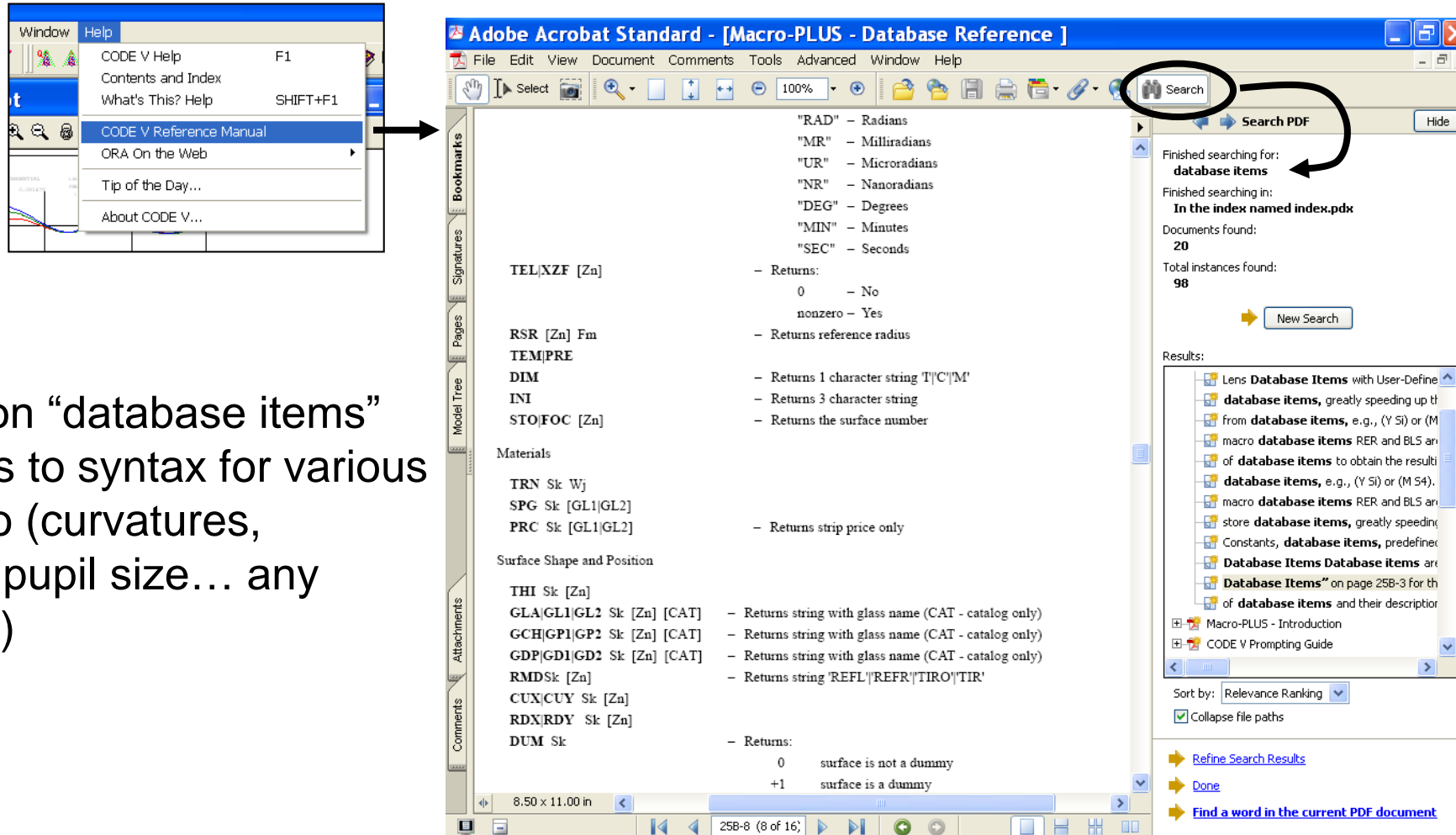
- Introduction to CODE V:
  - September 25-29, 2017, in Pasadena, CA (Los Angeles area)
- Advanced Topics in CODE V:
  - October 23-25, 2017, in Mt. View, CA (San Jose area)
- CODE V User Group Meetings, typically held in June
  - Free, 1-day meetings held in Mountain View, CA (San Jose area), Pasadena, 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



The screenshot shows the Adobe Acrobat Standard interface with a search for "database items" in a PDF document. The search results are displayed on the right side of the window, showing 20 documents found and 98 total instances. The search results list various "database items" and their descriptions.

Finished searching for:  
**database items**

Finished searching in:  
**In the index named index.pdx**

Documents found:  
**20**

Total instances found:  
**98**

Results:

- Lens Database Items with User-Define
- database items, greatly speeding up th
- from database items, e.g., (Y 5i) or (M
- macro database items RER and BLS an
- of database items to obtain the result
- database items, e.g., (Y 5i) or (M 54).
- macro database items RER and BLS an
- store database items, greatly speedin
- Constants, database items, predefined
- Database Items Database items are
- Database Items" on page 25B-3 for th
- of database items and their descriptor

Sort by: Relevance Ranking

Collapse file paths

Refine Search Results

Done

Find a word in the current PDF document

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](http://optics.synopsys.com))
  - \$4,000 in prizes awarded each year

## ANNOUNCING THE 2008 WINNERS

### 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 \(FAQs\)](#).

### 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.

### 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](mailto:service@opticalres.com)

### COMPETITION RULES

#### FAQS

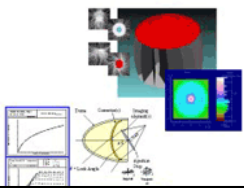
#### ENTRY FORM

**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](#)

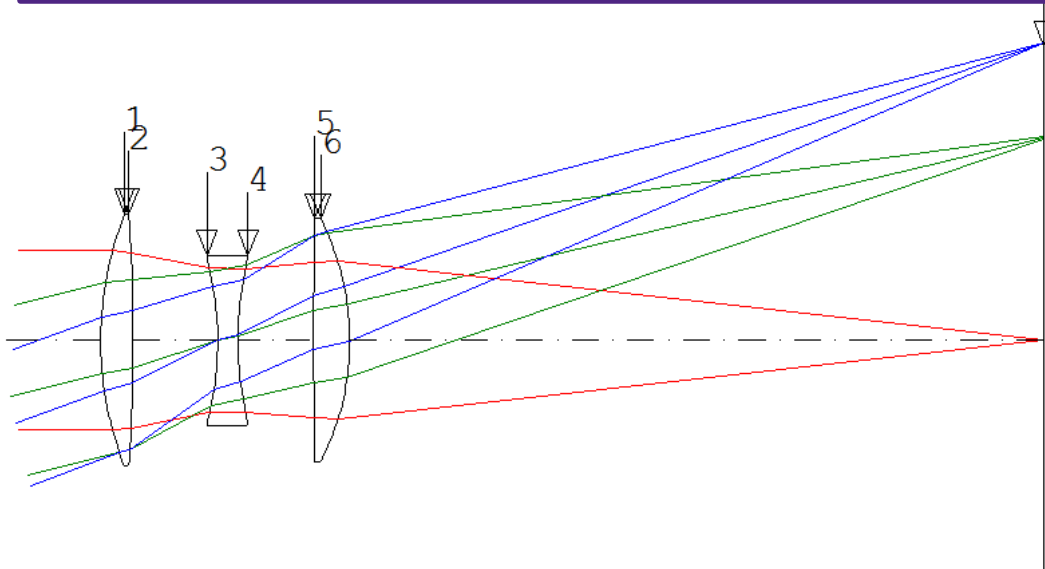
#### Illustrations of CODE V and LightTools model and analysis output.



# 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



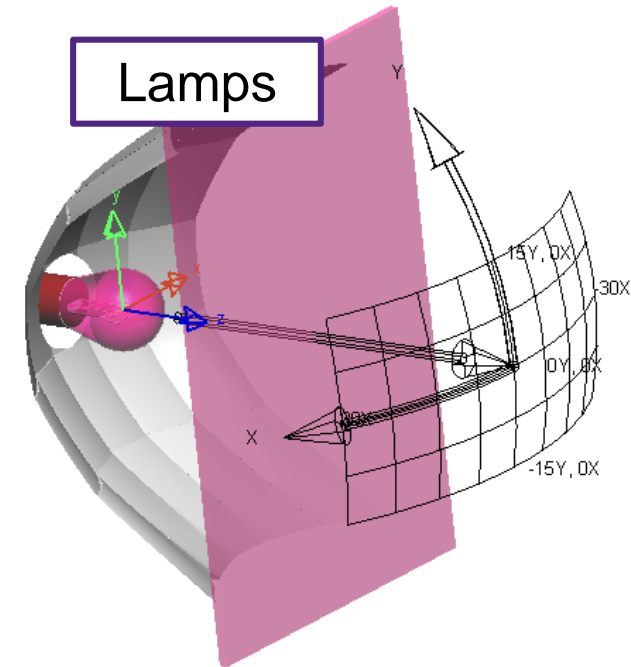
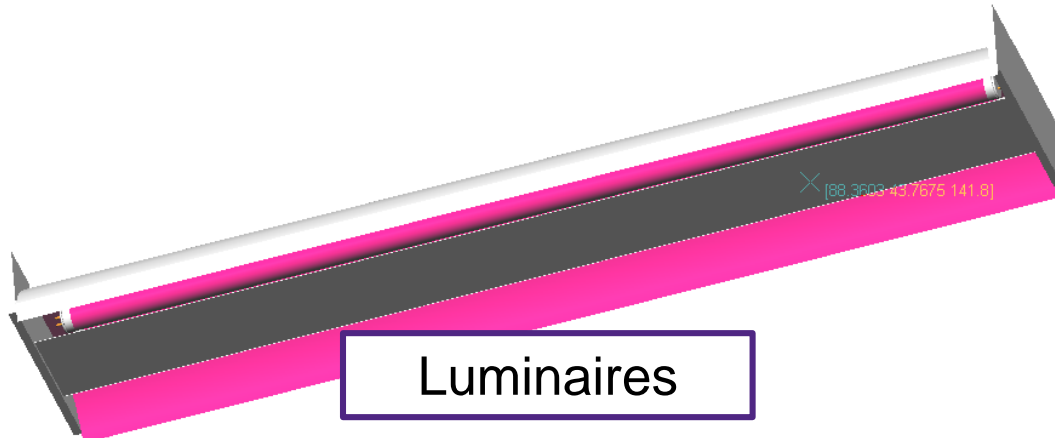
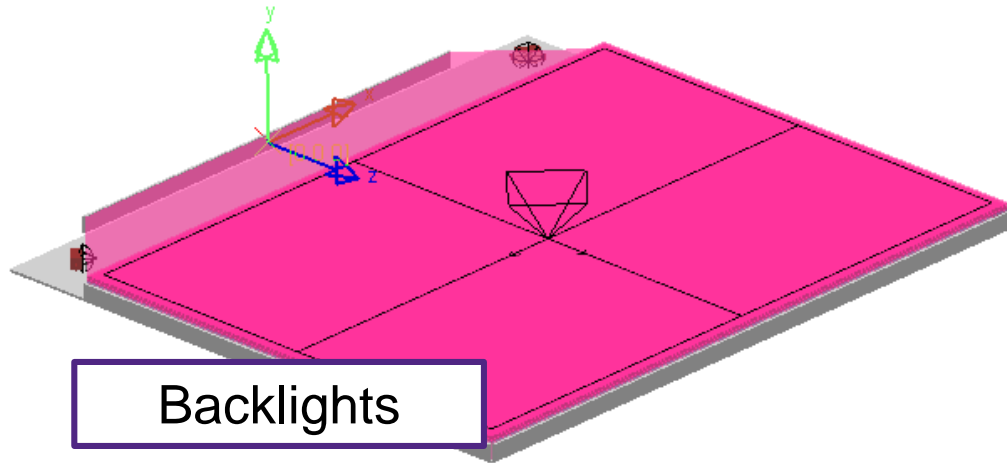
Used for imaging systems

Surface #	Surface Name	Surface Type	Y Radius	Thickness	Glass	Refract Mode	Y Semi-Aperture
Object			Infinity	Infinity			0
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

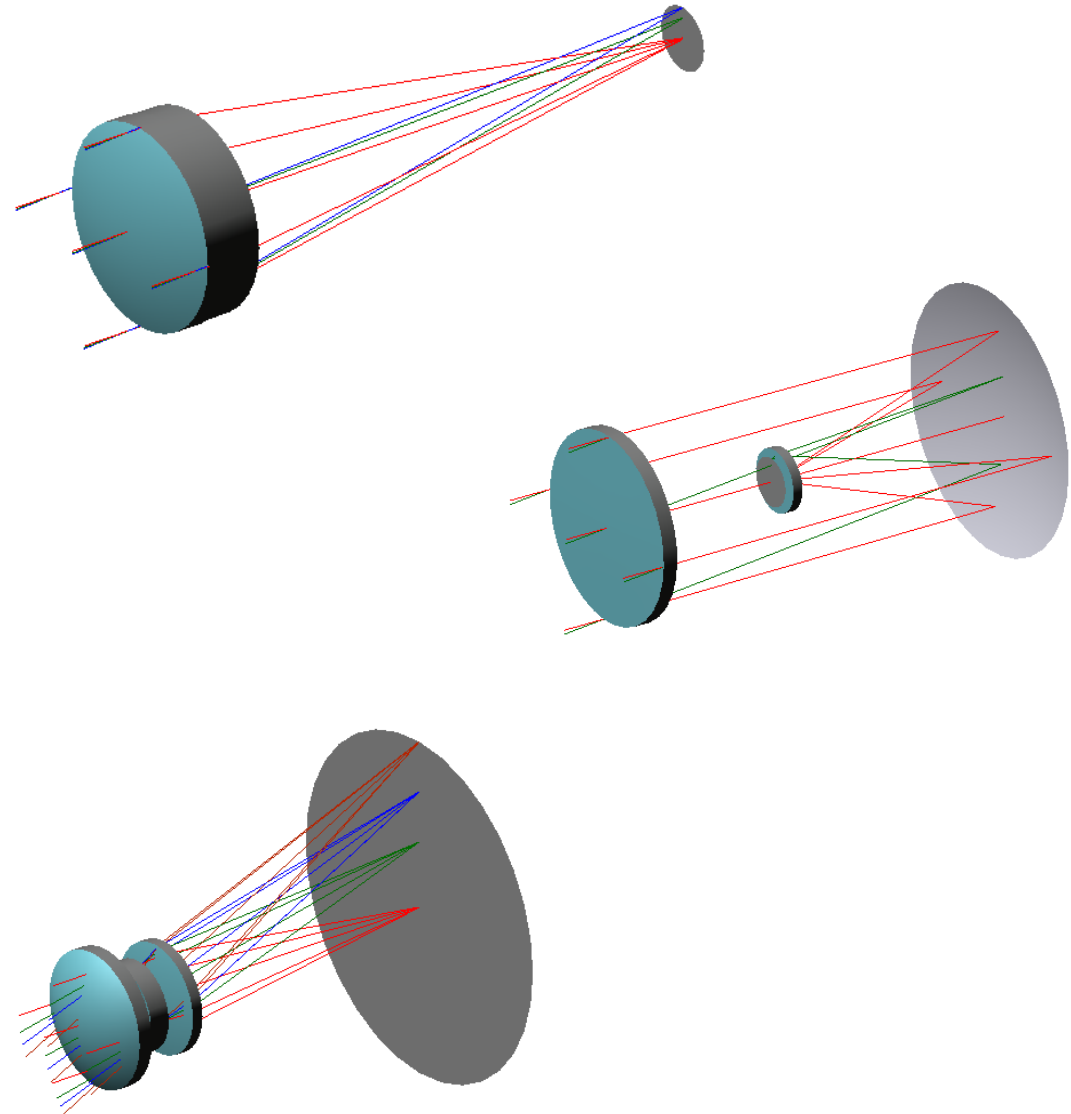
Rays start from source(s) ->bounce around geometry -> Measure illumination pattern on receiver(s)



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

The screenshot shows the CODE V software interface with several key components labeled:

- Title Bar:** Located at the top of the main window, displaying the file name "CODE V - wideangle\_sgt.Len".
- Menu Bar:** A horizontal bar below the title bar containing standard application menus: File, Edit, Lens, Display, Review, Analysis, Optimization, Tools, Window, and Help.
- Toolbars:** A row of icons below the menu bar for various functions like file operations, editing, and analysis.
- Navigation Toolbar:** A vertical toolbar on the left side of the interface.
- Command Window:** A small window at the bottom left showing a list of surface numbers (211-216).
- Command Line:** A text input field at the bottom left of the command window.
- LDM Spreadsheet:** A central window titled "Lens Data Manager" containing a table of lens parameters.
- Interactive 3D Visualization window:** A window on the right showing a 3D model of a lens system with light rays and a "Diffraction Intensity Spread Function" plot.
- Tabbed Output Window:** A window at the bottom right showing a "Diffraction MTF" plot.
- Status Bar:** A horizontal bar at the very bottom of the interface displaying system information like "CVW: 11.0", "CD: C:\CVUSER", "DIM: Millimeters", "FFL: 10.8916", "CA: User-Defined and Defaults", "XZF: No", and "POL: Inactive".

# CODE V Interface (GUI Components)

**Title Bar**

**Menu Bar**

**Toolbar(s)**

**Navigation Window**

**Re-execute & Modify Settings**

**Text Window Splitter**

**Status Bar**

The screenshot shows the CODE V interface with the following components labeled:

- Title Bar:** CODE V - movie.len
- Menu Bar:** File, Edit, Lens, Display, Review, Analysis, Optimization, Tools, Window, Help
- Toolbar(s):** Multiple toolbars containing icons for file operations, navigation, and analysis.
- Navigation Window:** A tree view on the left showing the project structure, including SpecBuilder Windows, Review Spreadsheets, Listings, Analysis Windows, Optimization, Plot Windows, and Error Log.
- Central Workspace:** Contains several windows, including 'MTF - Diffraction' and 'MTF - Diffraction : 10:15:05 AM'. The 'MTF - Diffraction' window displays a table of diffraction limit data.
- Status Bar:** Located at the bottom, displaying various system and project parameters.

The 'MTF - Diffraction' window displays the following data:

DIFFRACTION LIMIT				FOCUS POSITI	
L/MM	f/2.000	RAD	TAN	RAD	TAN
0	.999	.999	.999	.999	.999
5	.993	.993	.987	.983	.970
10	.986	.986	.965	.950	.913
15	.979	.979	.935		

The status bar displays the following information:

CODE V CVV: 11.0 EFL: 9.3838 RED: 9.3838e-010 THI SO: 1.0000e+010 IMD: 15.3276 BFL: 15.3596 OAL: 92.1950 Infinity f/ 2.0000 1/2 FOV: 20.9887  
 Used f/ 2.0000 NAO: 2.3460e-010 NA: 0.2500 DIM: Millimeters EPD: 4.6919 EXD: 23.2688 CA: User-Defined and Defaults POL: Inactive  
 TIT: 9MM - 36 MM F/2 ZOOM U.S. PAT. 3,464,763 ERF: 35.2085 MPP: 4 CD: C:\backup\CVUSER



# CODE V Interface (SpecBuilder™)

SpecBuilder Window

SpecEvaluator™ Button

The screenshot shows the CODE V software interface. The main window displays the 'Specifications and Goals Table' with the following data:

Label	Name	Goal Mode	Target	Value	Notes
	Spectral Range				
	Short Wavelength (um): individual values over ZA	display only		0.4861	
	Long Wavelength (um): individual values over ZA	display only		0.6563	
	Effective Focal Length (mm): individual values over ZA F1; direction - mean of X & Y	equal to	28.5000	28.5000	
	F-number (First Order): individual values over ZA F1; direction - mean of X & Y	equal to	4.0000	4.0000	
	F-number (PSA-Based): individual values over ZA F1	display only		3.9757	
	Field of View (Semi-FOV, deg): maximum over ZA;	display only		36.0000	

An 'F-number (PSA-Based) Specification' dialog is open, showing a diagram of a lens system and the formula: 
$$F\text{-Number} = \frac{1}{n'} \sqrt{\frac{\pi}{4 \Omega_{proj}}}$$

The 'Evaluation Information Window' displays the following data:

```

Table format:
-----
FldNum  AZI    Value
1       0     0.728
        90    0.728
2       0     0.250
        90    0.405
3       0     0.499
        90    0.225
-----
Aggregation results:
-----
AVG     0.473
MIN     0.328
MAX     0.728
(Default) = 0.472813
    
```

Insert/Edit Specification dialog

Evaluation Information Window

# CODE V Interface (Input)

The screenshot displays the CODE V software interface with several key windows and data tables:

- System Data Window:** Located at the top right, it contains a table of Wavelengths and a section for Reference Wavelength and Coating Wavelength.
- Surface Properties Window:** Located at the bottom right, it shows detailed parameters for the selected surface (1 - Crown Singlet), including Y Radius, Normalization Radius, and various Qcon coefficients.
- Lens Data Manager (LDM) Spreadsheet:** A central table listing lens surfaces with their properties.
- Review Spreadsheet(s):** A table below the LDM showing aperture details for surfaces 1 and 8.
- Command Line:** A window at the bottom left showing the current command 'CYCLE NUMBER 2:' and 'CODE V>'.

Surface #	Surface Name	Surface Type	Y Radius	Thickness	Glass	Refract Mode	Y Semi-Aperture
Object		Sphere	Infinity	Infinity		Refract	
1	Crown Singlet	Qcon Asp	35.0000	8.0000	NLAF2_SCHOTT	Refract	14.0000
2		Sphere	458.0000	5.4000		Refract	12.5415
3	Flint Singlet	Sphere	-100.2000	4.0000	NSF10_SCHOTT	Refract	10.4813
4		Sphere	31.0000	2.0000		Refract	9.6754
Stop		Sphere	Infinity	6.6000		Refract	9.7015
6	Doublet	Sphere	Infinity	3.0000	LF5_SCHOTT	Refract	11.8000
7		Sphere	38.5000	6.9000	NLAF2_SCHOTT	Refract	13.3921
8		Sphere	-57.0000	80.6497		Refract	14.0000
Image		Sphere	Infinity	-0.1374		Refract	36.0936

Surface #	Aperture #	OR	Shape	Type	Label
1 - Cr	CLR A1	<input type="checkbox"/>	Circular	Clear	
8	CLR A1	<input type="checkbox"/>	Circular	Clear	

Parameter	Value
Y Radius	35.0000
Normalization Radius	14.0000
Conic Constant (SCO K   C1)	0.0000
4th Order Qcon Coefficient (SCO QC4   C4)	-0.0015
6th Order Qcon Coefficient (SCO QC6   C5)	0.0005
8th Order Qcon Coefficient (SCO QC8   C6)	3.1370e-005
10th Order Qcon Coefficient (SCO QC10   C7)	0.0000
12th Order Qcon Coefficient (SCO QC12   C8)	0.0000
14th Order Qcon Coefficient (SCO QC14   C9)	0.0000
16th Order Qcon Coefficient (SCO QC16   C10)	0.0000
18th Order Qcon Coefficient (SCO QC18   C11)	0.0000
20th Order Qcon Coefficient (SCO QC20   C12)	0.0000
22th Order Qcon Coefficient (SCO QC22   C13)	0.0000
24th Order Qcon Coefficient (SCO QC24   C14)	0.0000
26th Order Qcon Coefficient (SCO QC26   C15)	0.0000
28th Order Qcon Coefficient (SCO QC28   C16)	0.0000
30th Order Qcon Coefficient (SCO QC30   C17)	0.0000
X Half-width of Bounding Box	0.0000
Y Half-width of Bounding Box	0.0000
Z Half-width of Bounding Box	0.0000

System Data Window

Surface Properties Window

LDM Spreadsheet

Review Spreadsheet(s)

Command Line

# CODE V Interface (Output)

Plot Window

The screenshot displays the CODE V software interface with the following components:

- View Lens:** Shows a 2D schematic of a lens system with light rays passing through multiple elements.
- Quick Ray Aberration Plot:** A grid of plots showing aberrations for different lens elements.
- MTF - Diffraction:** A graph titled "Diffraction MTF 9MM - 36 MM F/2 ZOOM U.S. PAT. 3,464,763" showing Modulation vs. Spatial Frequency. It includes curves for F1 (Diff. Limit), F1 (IMG) 0.000 mm, F2: T (IMG) 2.400 mm, and F2: R (IMG) 2.400 mm.
- List First Order Data:** A table with columns POS 1, POS 2, and POS 3.
 

	POS 1	POS 2	POS 3
INFINITE CONJUGATES			
EFL	9.3838	20.3072	35.6
BFL	15.3596	15.3473	15.34
FFL	40.6238	92.8330	132.6
FNO	2.0000	2.0000	2.00
IMG DIS	15.3276	15.3733	15.3
QAT	92.1950	92.1950	92.1
- 3D Viewing:** A 3D perspective view of the lens assembly.
- Pupil Map:** A color-coded wavefront aberration map showing a circular pattern.
- Command Window:** Displays text such as "Active zoom positions are : 1, 2, 3" and "CODE V>".
- Error Log:** Shows a warning message: "Warning: There are energy levels as great as 0.8% at the PSF grid for field 3, defocus = 0.000000. This may give inaccurate results. Increase TGR or GRI if possible."

Display > View Lens

Display > List Lens Data (text window)

Command Output Window

Tabbed Output Windows

Display > 3D Visualization

CODE V® Error Log

# CODE V Interface (Tabbed Output Window Components):

The screenshot displays the CODE V interface with three main components highlighted by arrows:

- Input Dialog:** A dialog box titled "Beam Synthesis Propagation" with tabs for "Input Beam", "Output", "Pre-Analysis", "Propagation Controls", and "Output Grid Definitions/Time Estimate". It includes a table for "Generate 2D charts" and various control buttons.
- Graphical Output:** A window titled "Beam Synthesis Propagation -- Intensity Ball lens fiber coupler" showing a 2D intensity plot. The x and y axes are labeled "X, mm" and "Y, mm" respectively, ranging from -0.04 to 0.04. A central peak is visible, surrounded by a color gradient from blue to red.
- Text Output:** A window showing a table of parameters for the beam synthesis process. The table includes columns for SURF NUM, GRID LOC, THRESH, X-RAD (mm), Y-RAD (mm), X-SHIFT (mm), Y-SHIFT (mm), ROTATION ANGLE (deg.), and PEAK INTENSITY.



Additional graphical output windows are visible in the background, including one titled "Beamlet footprints at reference wavelength" showing a circular pattern of red dots.

# SpecBuilder Features at a Glance

Select All  and copy & paste the table into another application

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

User-Specified Notes, with double-byte character support

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

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

Re-orderable rows

Label	Name	Goal Mode	Target	Value	Notes
<input checked="" type="checkbox"/> ユーザー定義ラベル	Spectral Range				ユーザー定義ノート
	Short Wavelength (um): individual values over ZA	display only		0.4861	
	Long Wavelength (um): individual values over ZA	display only		0.6563	
<input checked="" type="checkbox"/> 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
<input checked="" type="checkbox"/> 1st Order	F-number (First Order): individual values over ZA F1; direction -	equal to	3.9000	4.0000	
<input type="checkbox"/>	F-number (PSA-Based): individual values over ZA F1	display only			Monitor delta between 1st order and PSA f/#
<input checked="" type="checkbox"/> 1st Order	Field of View (Semi-FOV, deg): maximum over ZA; direction - Y	display only		36.0000	
<input checked="" type="checkbox"/> Mechanical	Overall Length to Image (mm): individual values over ZA	less than or equal to	85.0000	85.0000	
<input checked="" type="checkbox"/> Mechanical	Image Clearance (lens units)	greater than or equal to	37.5000	37.5000	
<input checked="" type="checkbox"/> Performance	Distortion (magnitude, percent): individual values over ZA FA; un	less than or equal to	1.5000	[0.0000, 1.1786]	
<input checked="" type="checkbox"/> UserSpec	Chief Ray Distortion (%; in Y)	display only		[-1.1786, 0.0000]	
<input checked="" type="checkbox"/> Performance	Relative Illumination (percent): individual values over ZA FA	greater than or equal to	60.0000	[64.1159, 100.0000]	
<input checked="" type="checkbox"/> 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
<input checked="" type="checkbox"/> Performance	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
<input checked="" type="checkbox"/> As-built Perf.	RMS Wavefront Error, As-Built (waves RMS, Mean + 2-sigma pro	less than or equal to	0.7500		
<input checked="" type="checkbox"/> LDM	CODE V Model Attribute - System Units	equal to	Millimeters	Millimeters	
<input checked="" type="checkbox"/> LDM	CODE V Model Attribute - Field				
	Number of Fields	equal to	3	3	

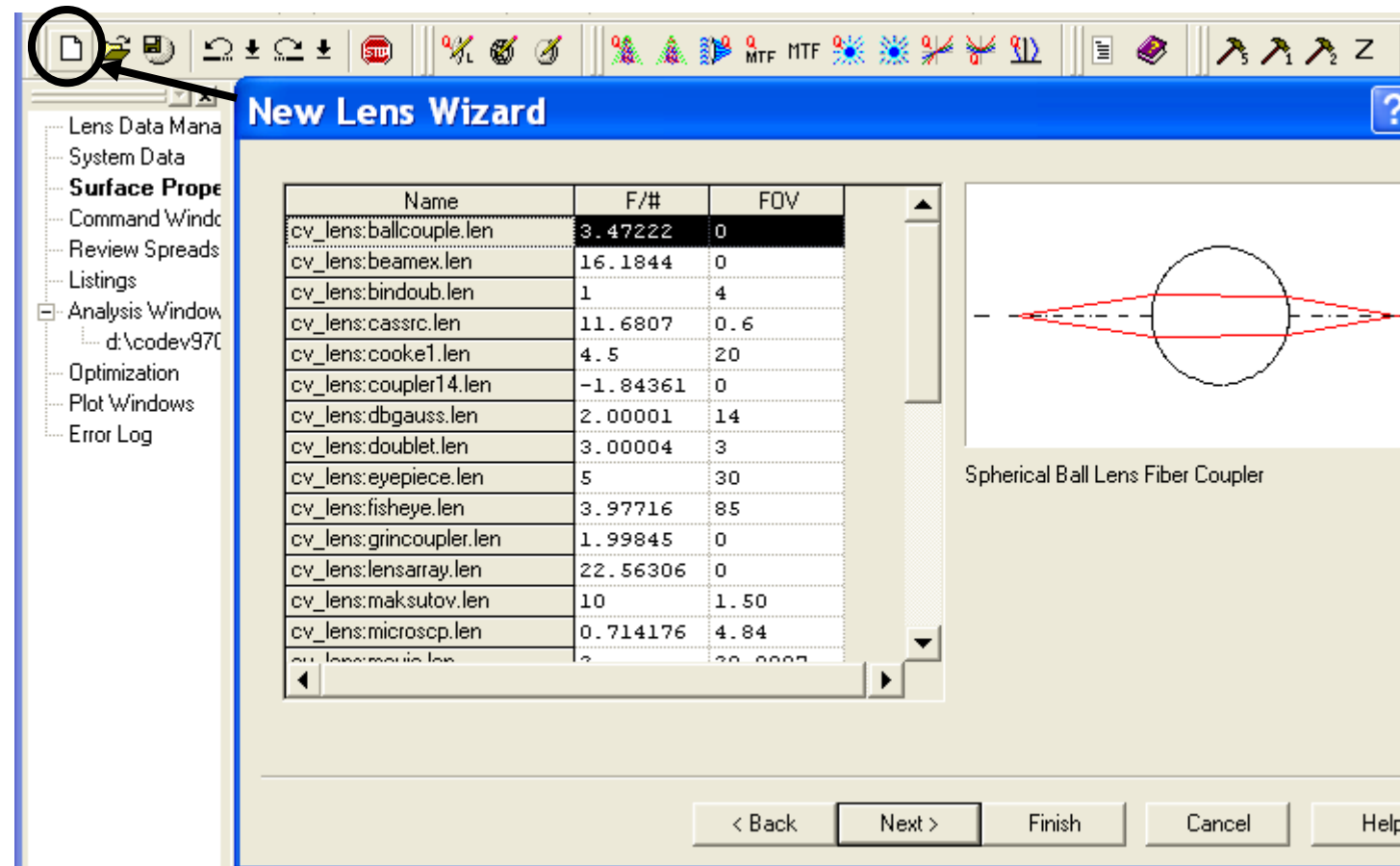
User-Specified labels, with double-byte character support

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

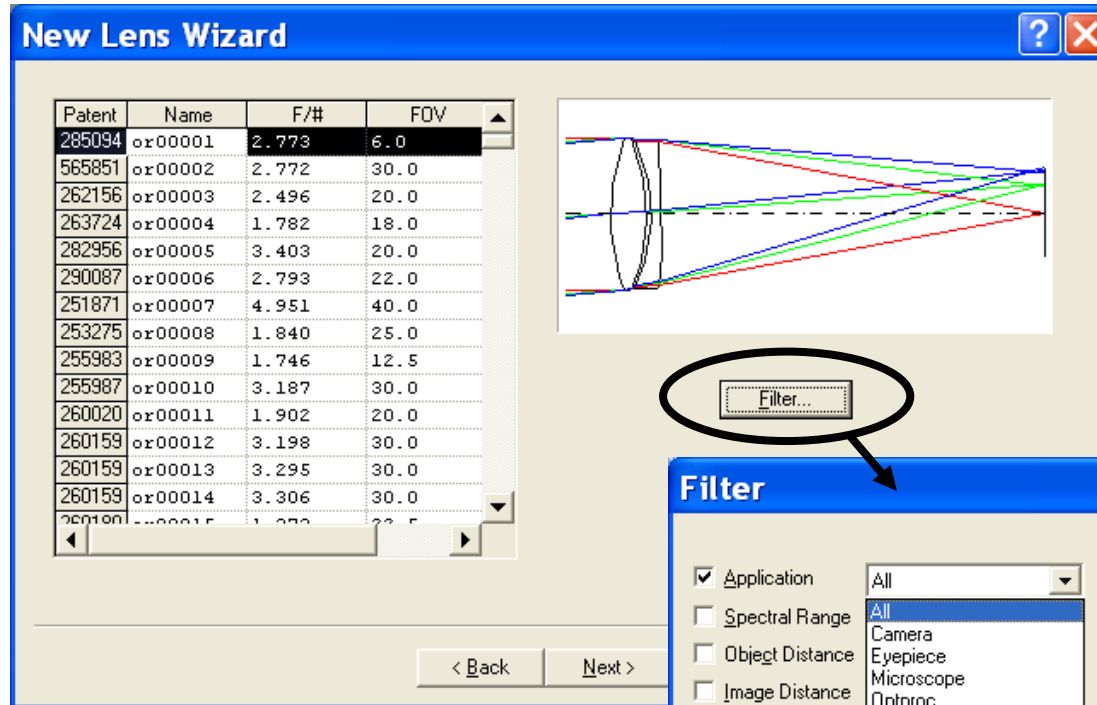
User-specified Target & the current, or min/max Values. Highlighted cells for “Values” out of “spec”

# Opening a Lens

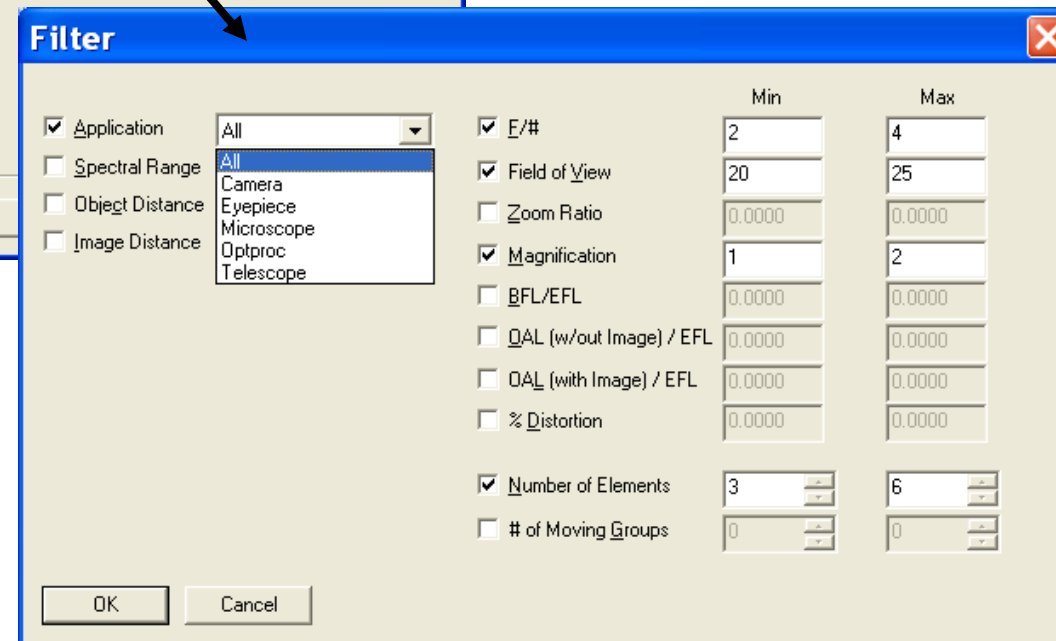
- **New Lens Wizard** can open a blank lens, CODE V sample lens, or a patent lens



# Opening a Lens

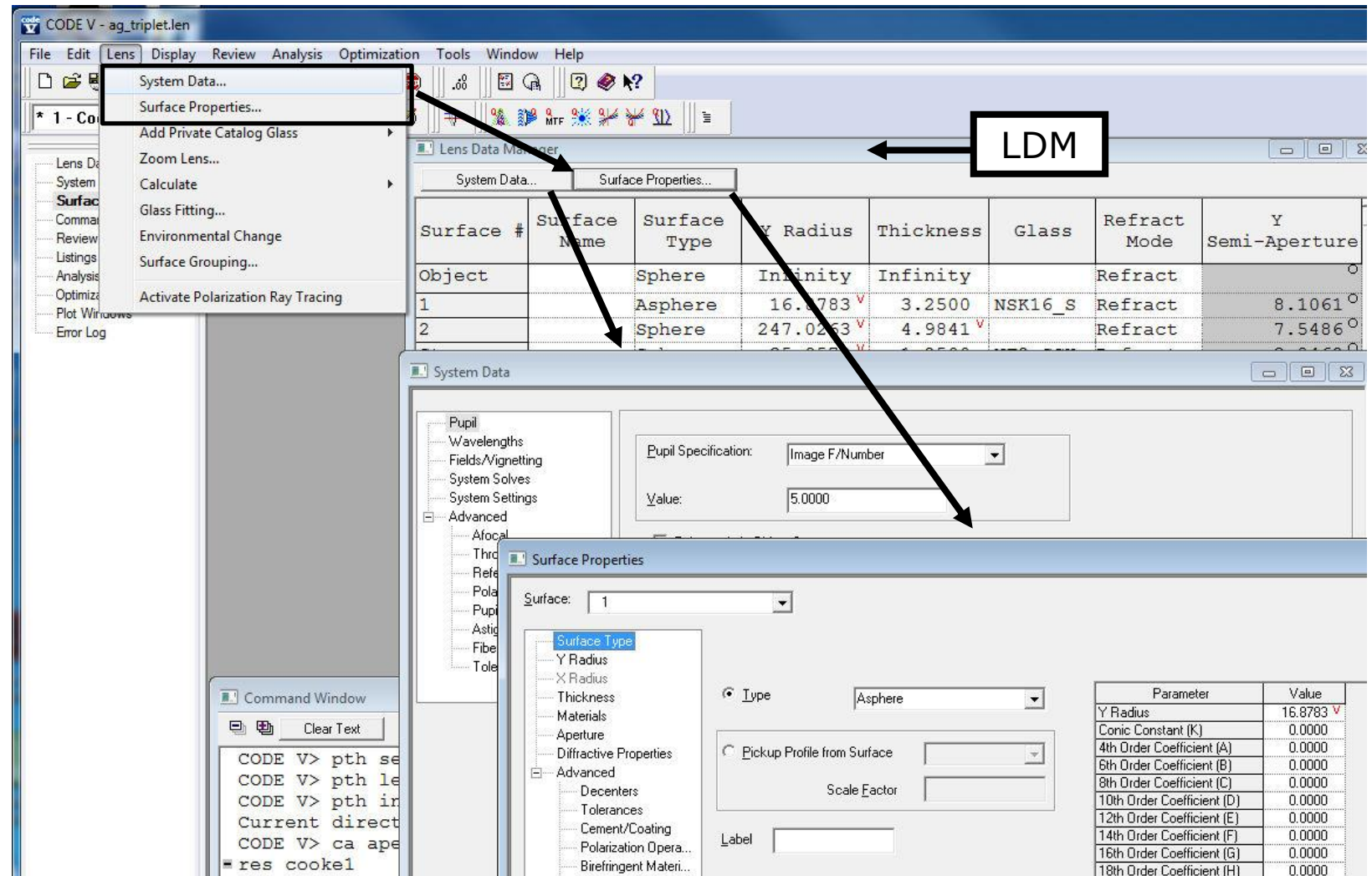


- Filter list of 2,400 patent lenses for desired criteria



# 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

Object	Surface Type	Y Radius	Thickness
1	Sphere	Infinity	Infinity
2	Sphere	2.2686	0.9918
3	Sphere	6.0211	0.1387
4	Sphere	-5.1764	0.2000
5	Sphere	2.4142	0.2622
6	Sphere	5.7637	0.4571
7	Sphere	-3.3584	4.8063
8	Sphere	Infinity	-0.0511
End Of Data			

Surface Type	Y Radius	Thickness	Glass	Refract Mode	Semi-
Sphere	Infinity	Infinity		Refract	
Sphere	2.2686	0.9918	743972.44	Refract	
Sphere	6.0211	0.1387	727063.28	Refract	
Sphere			743972.44	Reflect	
Sphere				Only TIR	
Sphere				Refract	

- 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

Surface Type	Y Radius	Thickness	Glass	Refract Mode	Semi-
Sphere	Infinity	Infinity		Refract	
Sphere	2.2686	0.9918	743972.44	Refract	
Sphere	6.0211	0.1387	727063.28	Refract	
Sphere			743972.44	Reflect	
Sphere				Only TIR	
Sphere				Refract	
Cylinder				Refract	
Conic				Refract	
Asphere				Refract	
X Toroid				Refract	
Y Toroid				Refract	
Thermal Gradient				Refract	
Spline				Refract	
Anamorphic Asphere				Refract	
Lens Module				Refract	
User Defined				Refract	

# Data Entry

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

nfinity	3.7770	F15_SCHOT	Refre
21.4692 V	15.1079 V		Refre
nfinity	15.1079 V		Refre
27.0349 V	3.7770		
nfinity	10.8339		
34.9867 V	0.2982 V		
86.7405 V	6.8582		

Copy  
Paste  
Vary  
-

- Allows use of expressions in cells

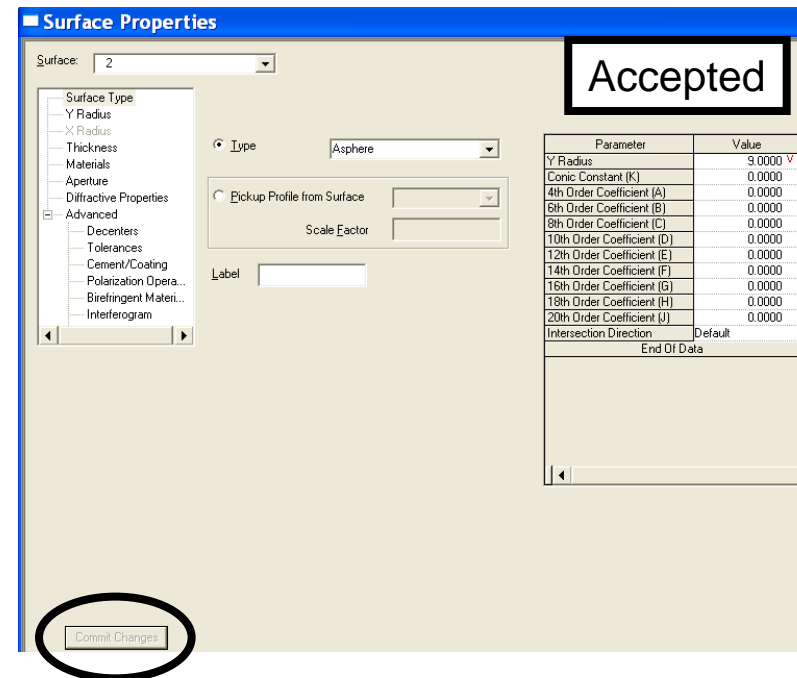
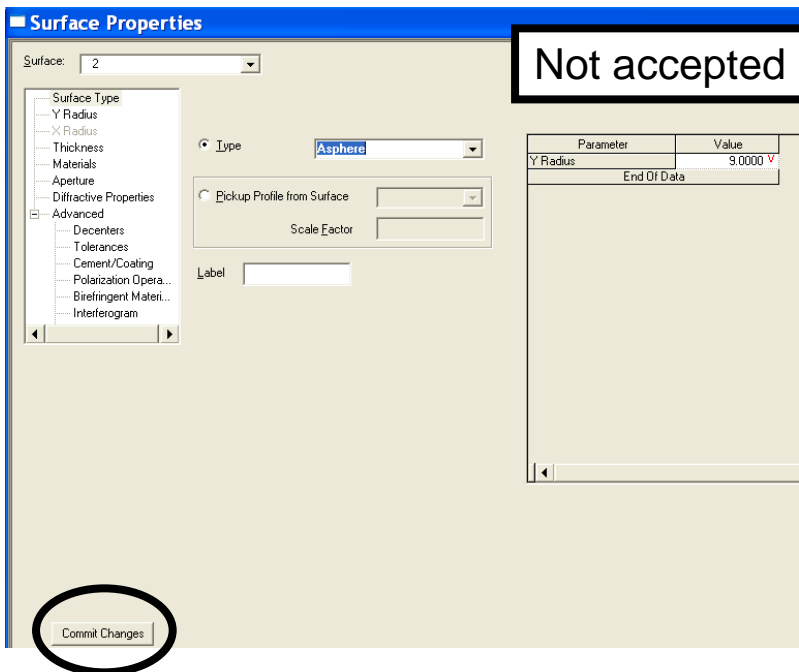
.4692 V	15.1079 V		
nfinity	$=(thi s5)/2$ V		
.0349 V	3.7770	F15 SCH	

→

.4692 V	15.1079 V		
nfinity	7.5539 V		
.0349 V	3.7770	F1	

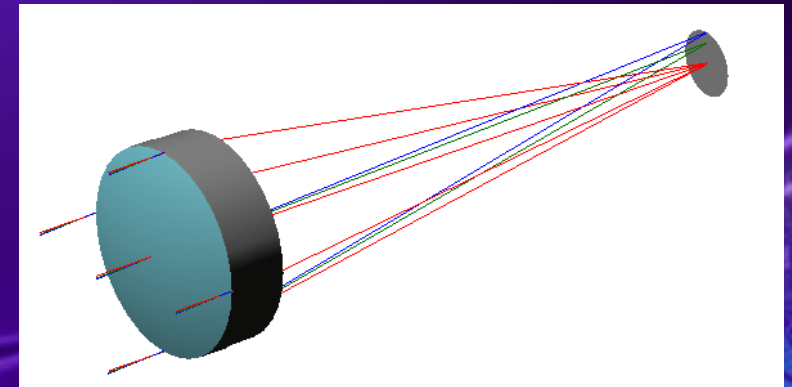
# Data Entry

- 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



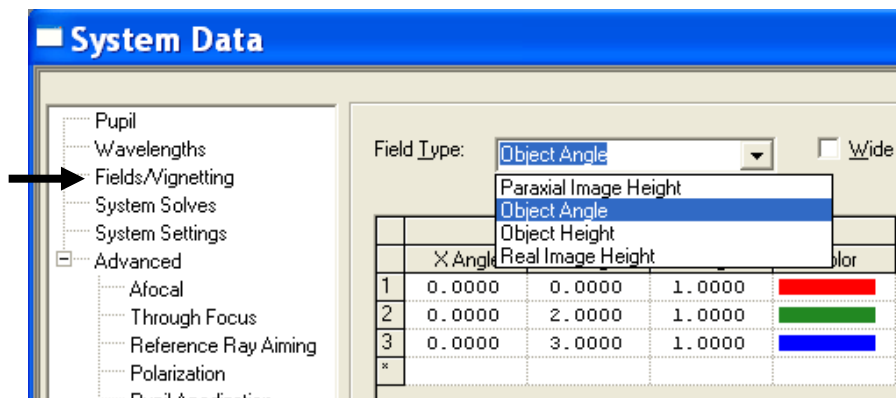
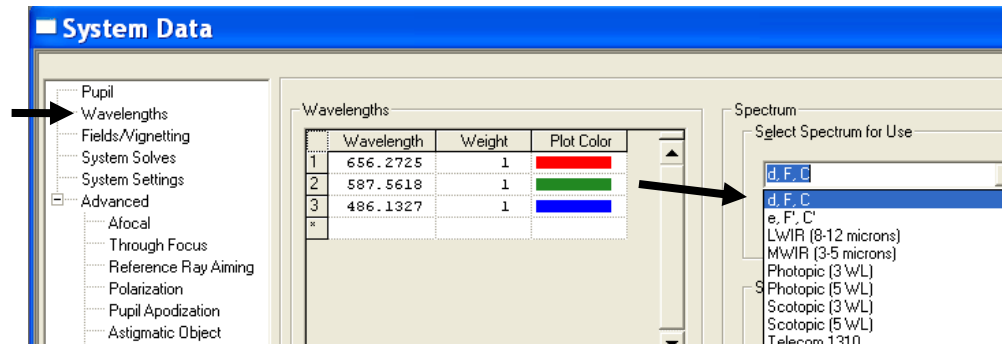
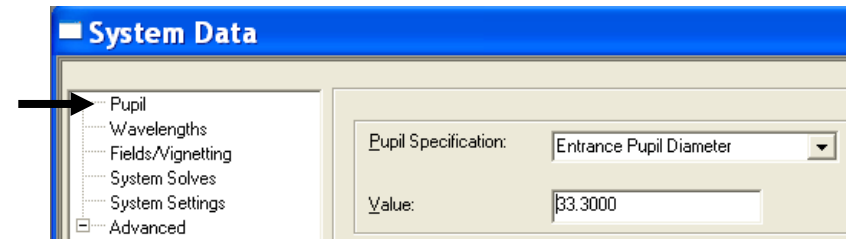
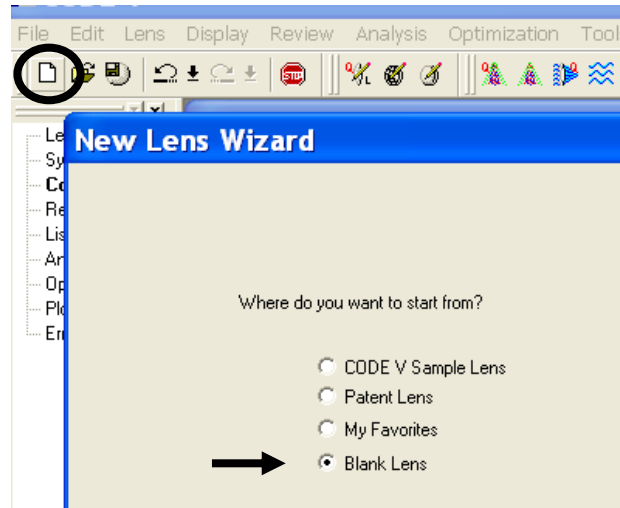
# Demo: Lens Data Entry

*Getting to know the Lens Data Manager*



# Data Entry – Ex. Doublet

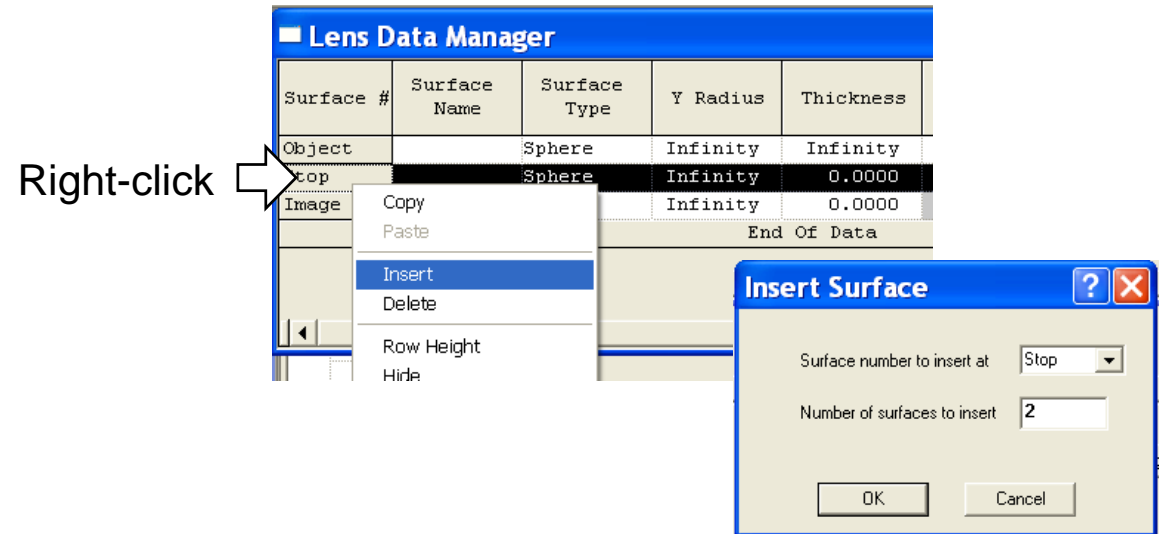
- Open a blank lens from New Lens Wizard
- From menus open **Lens > System Data**
- Set pupil size, Entrance Pupil Diameter = 33.3
- Use F,d,c wavelengths (can use a pre-stored spectrum)
- Define fields as Object Angle, 0, 2, and 3 degrees



# Data Entry – Ex. Doublet

- Insert 2 surfaces

(Or press “Insert” button twice)



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

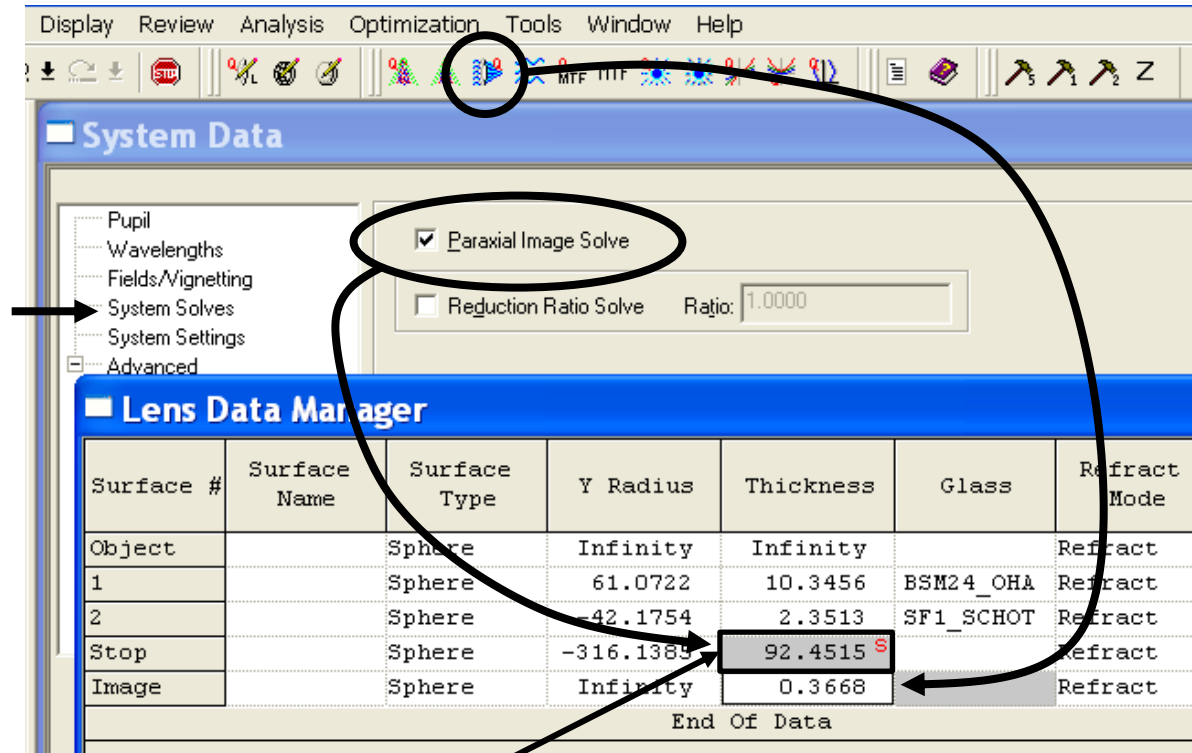
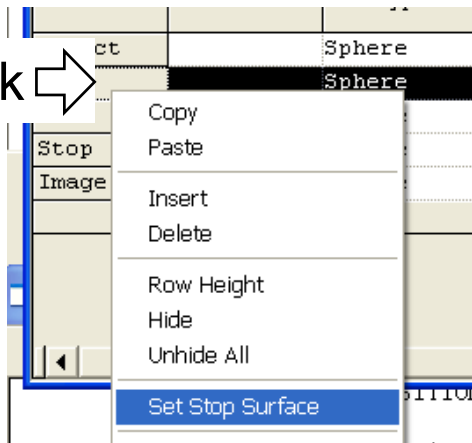
The image shows the 'Lens Data Manager' window with the completed lens data table. The table includes columns for Surface #, Surface Name, Surface Type, Y Radius, Thickness, Glass, Refract Mode, and Y Semi-Aperture.

Surface #	Surface Name	Surface Type	Y Radius	Thickness	Glass	Refract Mode	Y Semi-Aperture
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



Surface #	Surface Name	Surface Type	Y Radius	Thickness	Glass	Refract Mode
Object		Sphere	Infinity	Infinity		Refract
1		Sphere	61.0722	10.3456	BSM24_OHA	Refract
2		Sphere	-42.1754	2.3513	SF1_SCHOT	Refract
Stop		Sphere	-316.1389	92.4515 S		Refract
Image		Sphere	Infinity	0.3668		Refract

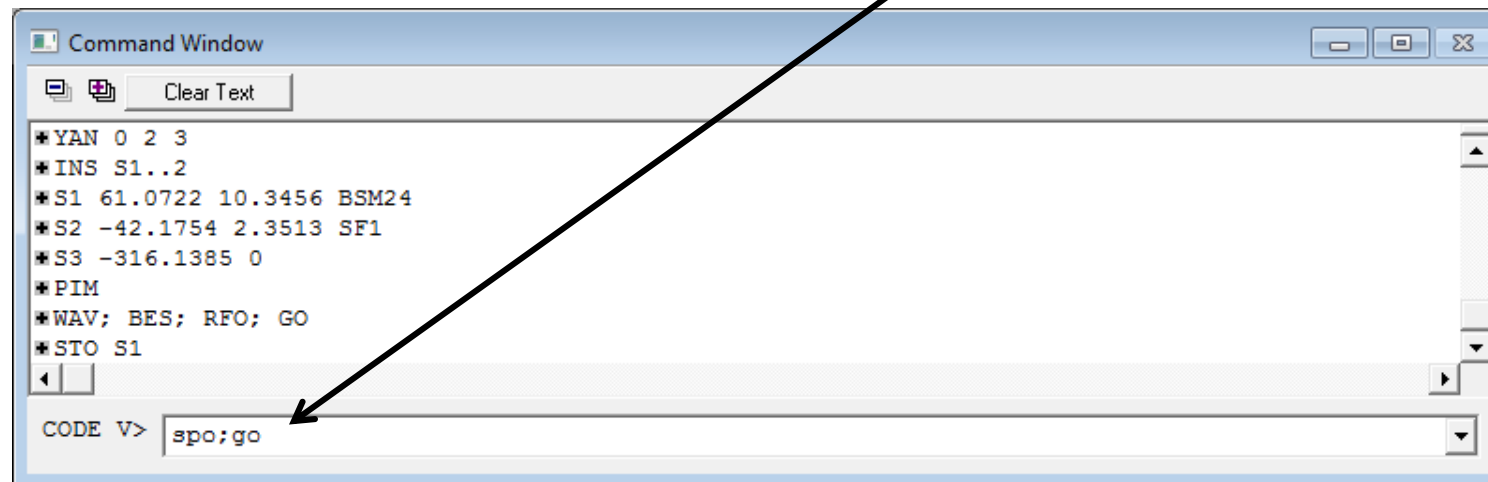
Grayed out cell is not directly editable; value is *computed* (by a solve, a pick up, or default value). Right click change to an editable quantity.

# 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
```

Command line

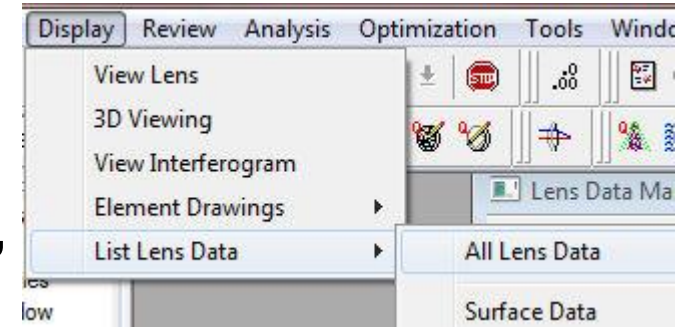




# Analyses

- **Display>List Lens Data...**

- List surface data, system data, first order data, indices, etc.

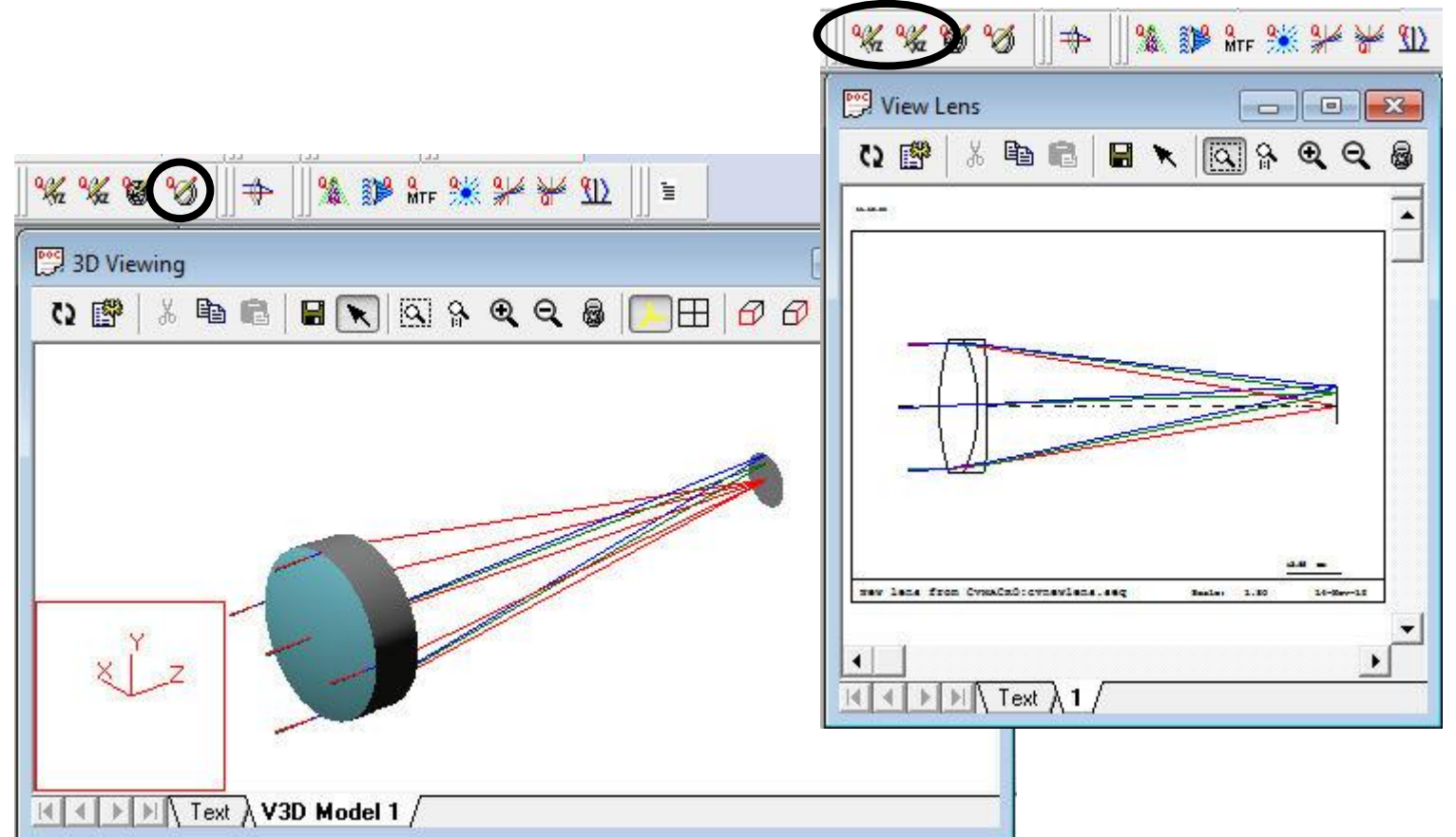


- **Display>View Lens**

- 2D layout

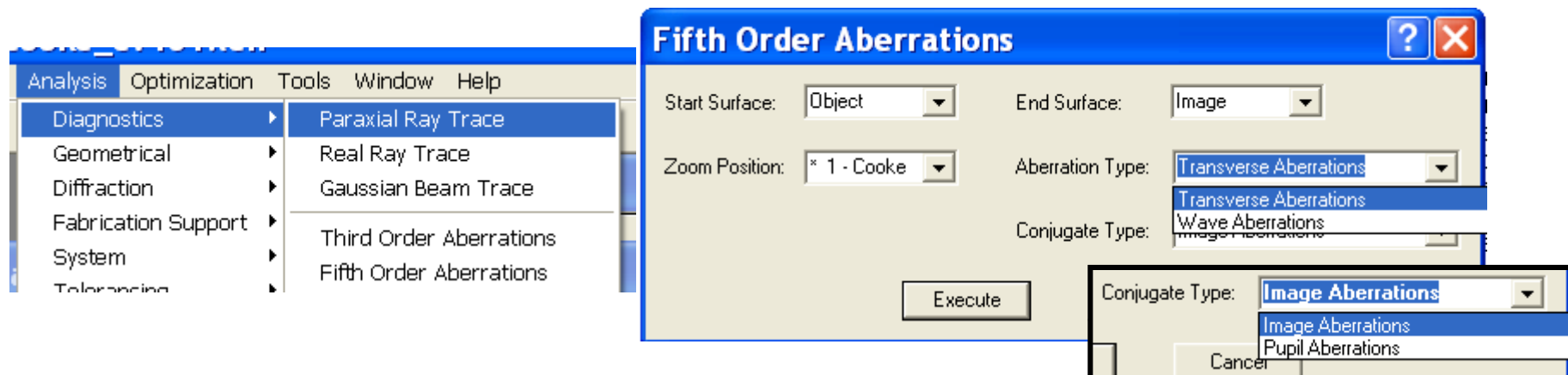
- **Display>3D Viewing**

- Open-GL solid model, interactive rotation/zoom

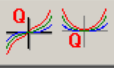


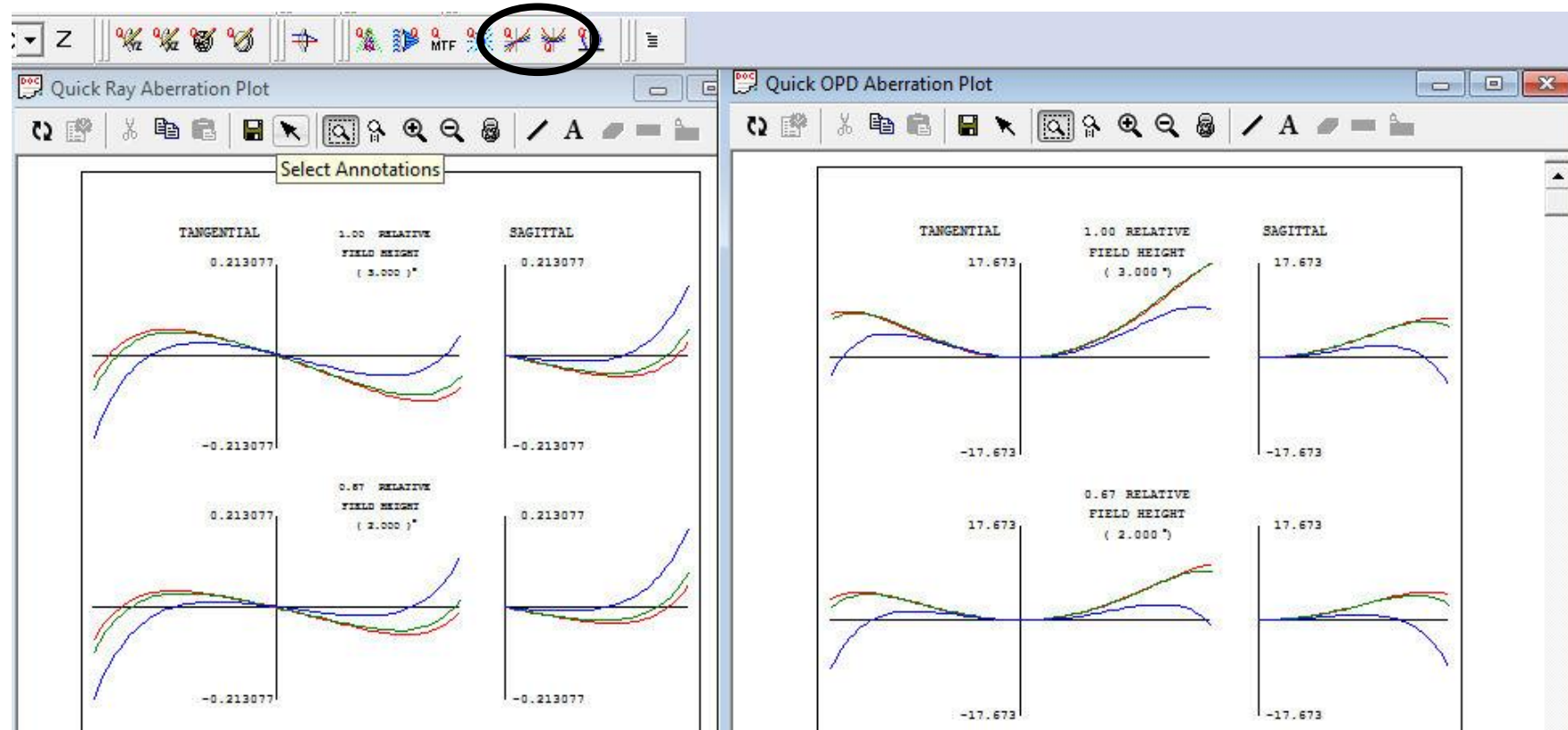
# Analyses

- **Analysis>Diagnostics>Paraxial Ray Trace**
  - 1<sup>st</sup> 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



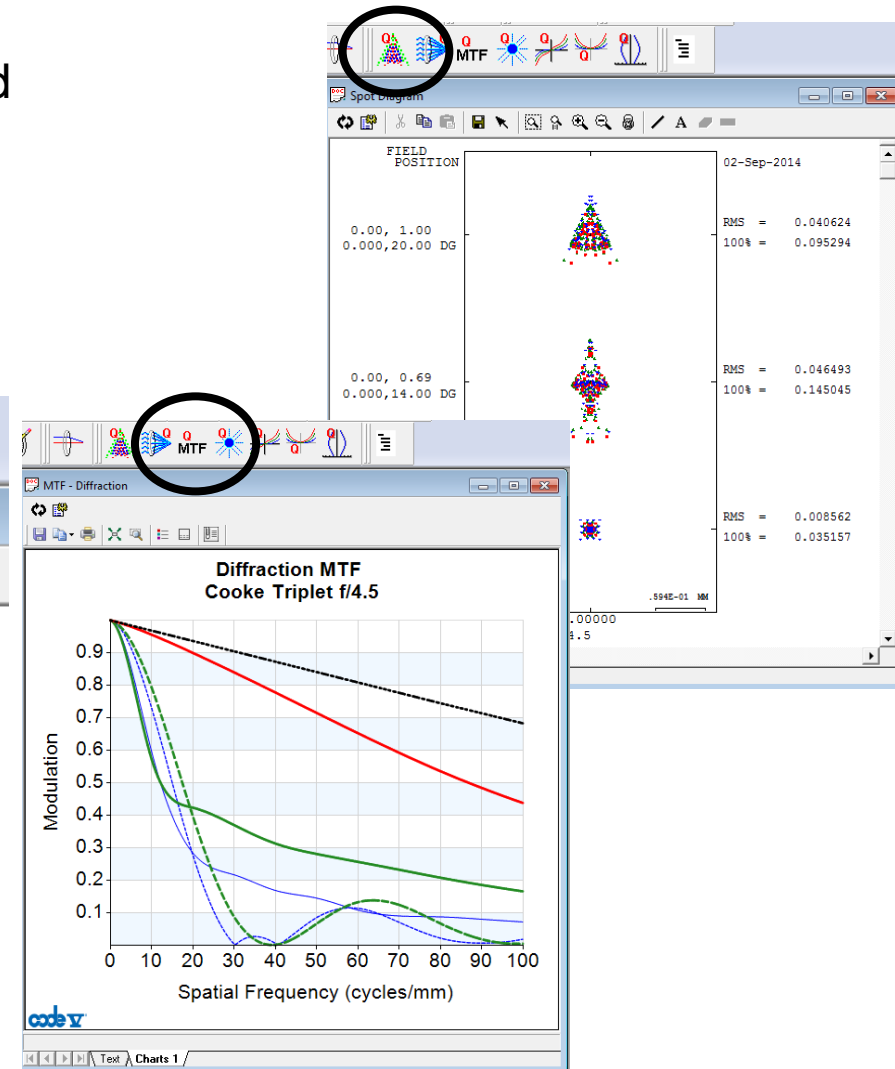
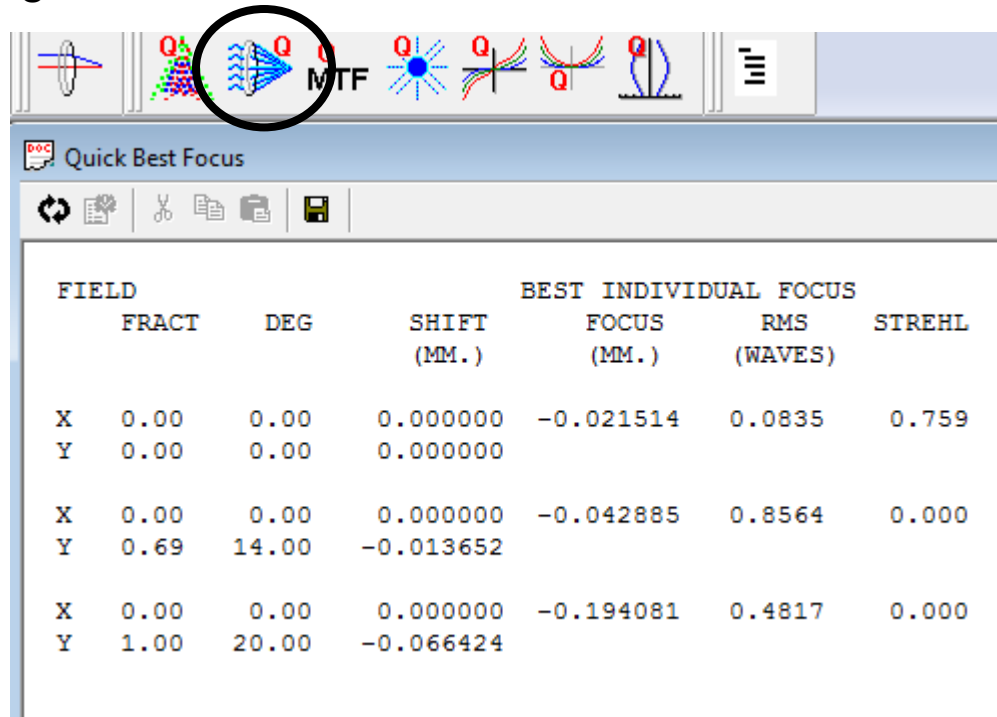
# Analyses

- **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 

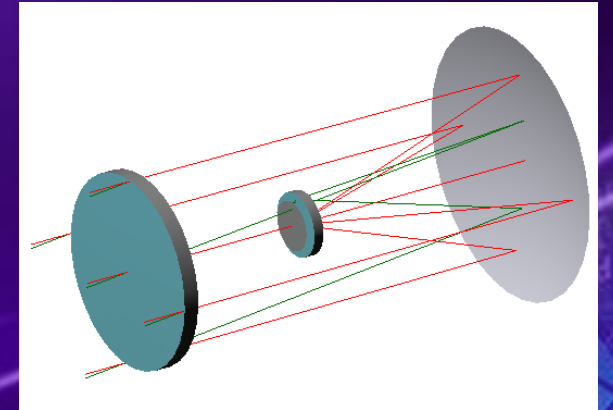


# Analyses

- **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

Lens Data Manager		
Surface #	Surface Name	Surface Type
Object		Sphere
Stop		Aspher
2		Sphere
3		Sphere
4		Sphere
5		Sphere
Image		Sphere

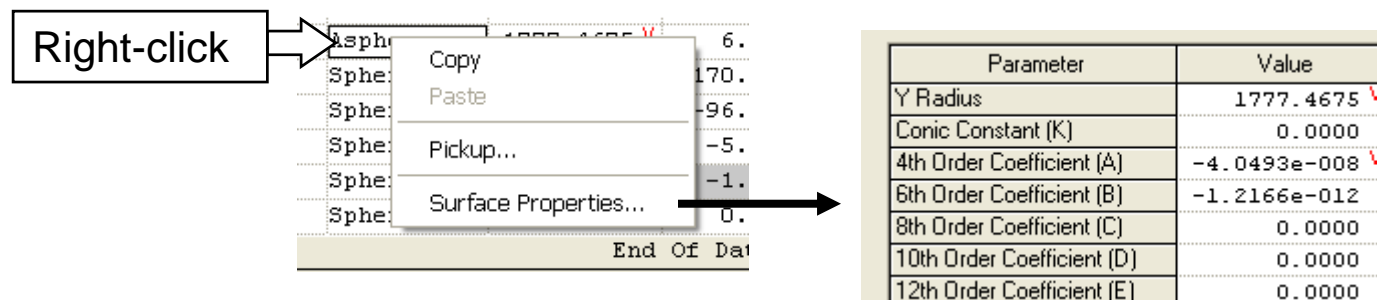
# Data Entry – Ex. Reflective

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

Lens Data Manager							
Surface #	Surface Name	Surface Type	Y Radius	Thickness	Glass	Refract Mode	Sem
Object		Sphere	Infinity	Infinity		Refract	
Stop		Asphere	1777.4675 V	6.3039	PSK2_SCHO	Refract	
2		Sphere	Infinity	170.9468 V		Refract	
3		Sphere	-211.8174 V	-96.2602 V		Reflect	
4		Sphere	-40.9572 V	-5.9437	PSK2_SCHO	Refract	
5		Sphere	Infinity	-1.7314 S		Refract	
Image		Sphere	Infinity	0.0000 V		Refract	
End Of Data							

Diagram illustrating the Lens Data Manager table. A callout box labeled "Double-click" points to the "Reflect" mode for surface 3. Another callout box labeled "Double-click" points to the "Asphere" surface name for surface 2.

- Access Asphere coefficients in Surface Properties window



# Data Entry – Ex. Reflective

- Commands (copy and paste to the command line)

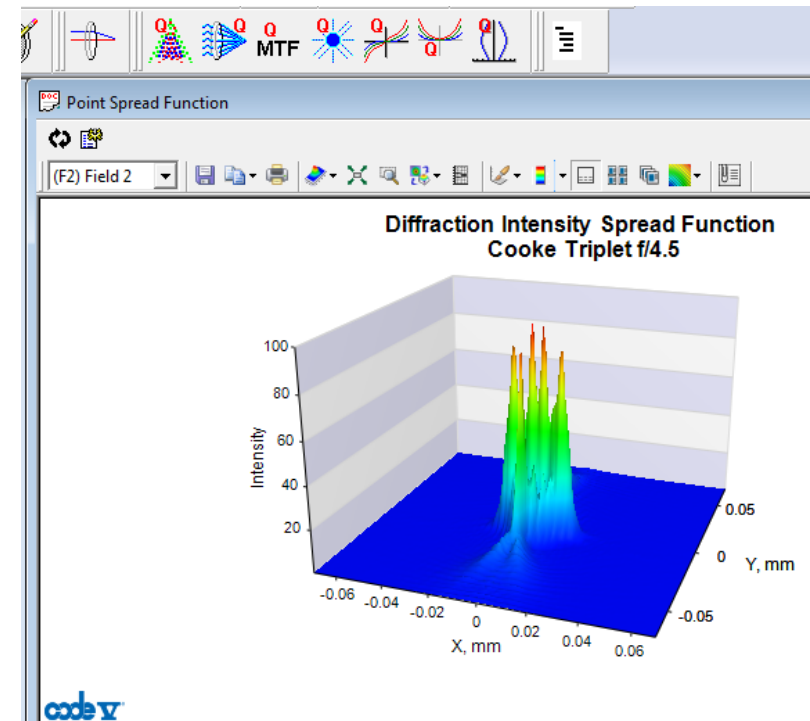
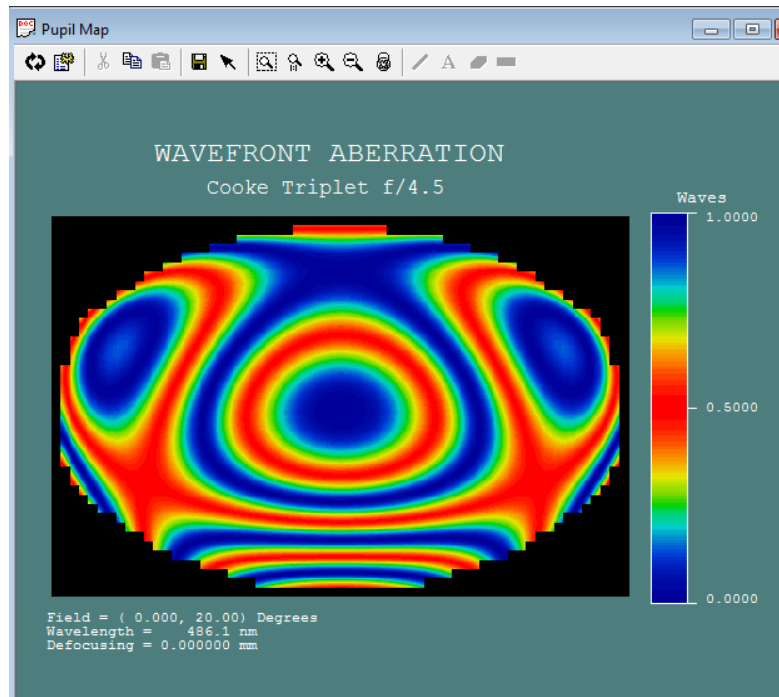
```
LEN NEW
EPD 75.0
WL 656.3 587.6 486.1
YAN 0.0 5.5
PIM
INS S1..4
STO S1
S1 1777.467 6.304 PSK2_SCHOTT
ASP
K 0.0
A -0.4049e-7
B -0.1216e-11
S2 0.0 170.946
S3 -211.8173 -96.2601 REFL
S4 -40.9571 -5.9437 PSK2_SCHOTT
S5 0.0 -1.7313
```

- 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](http://support.opticalres.com))



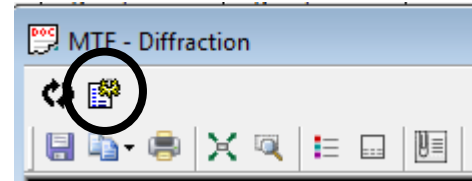
# Analyses

- **Analysis > Diagnostics > Pupil Map**
  - OPD or intensity plot of wavefront at the exit pupil
- **Analysis > Diffraction > Point Spread Function**
  - Intensity plot of the PSF

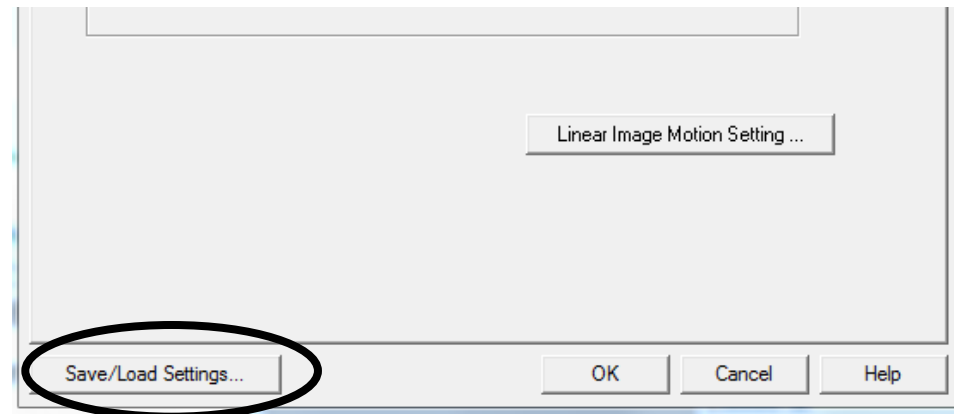


# Analyses

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



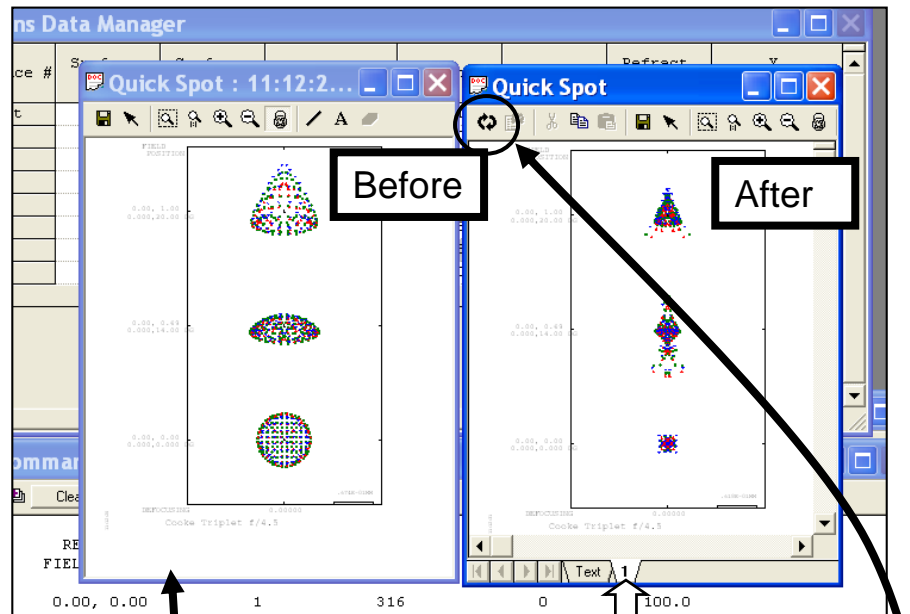
- **Save/Load Settings... button allows you to save your options to apply in the future**



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

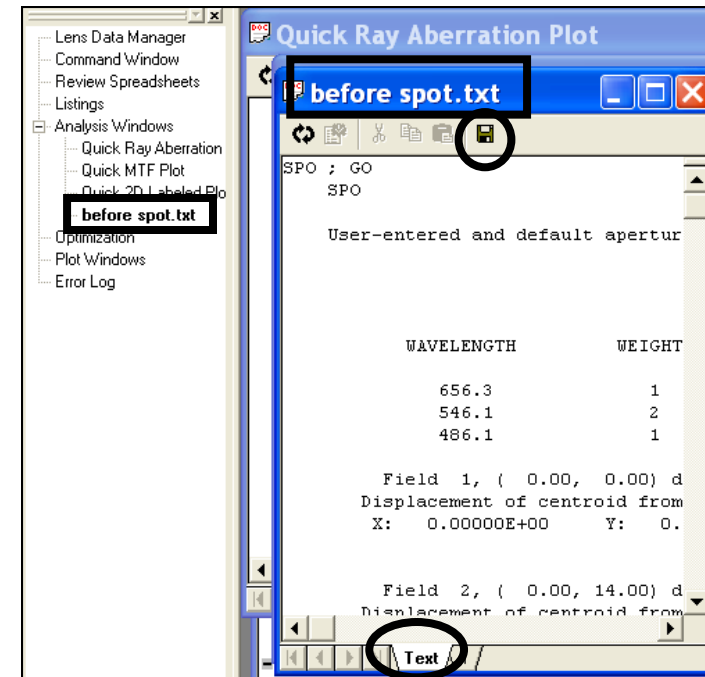
# Analyses

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



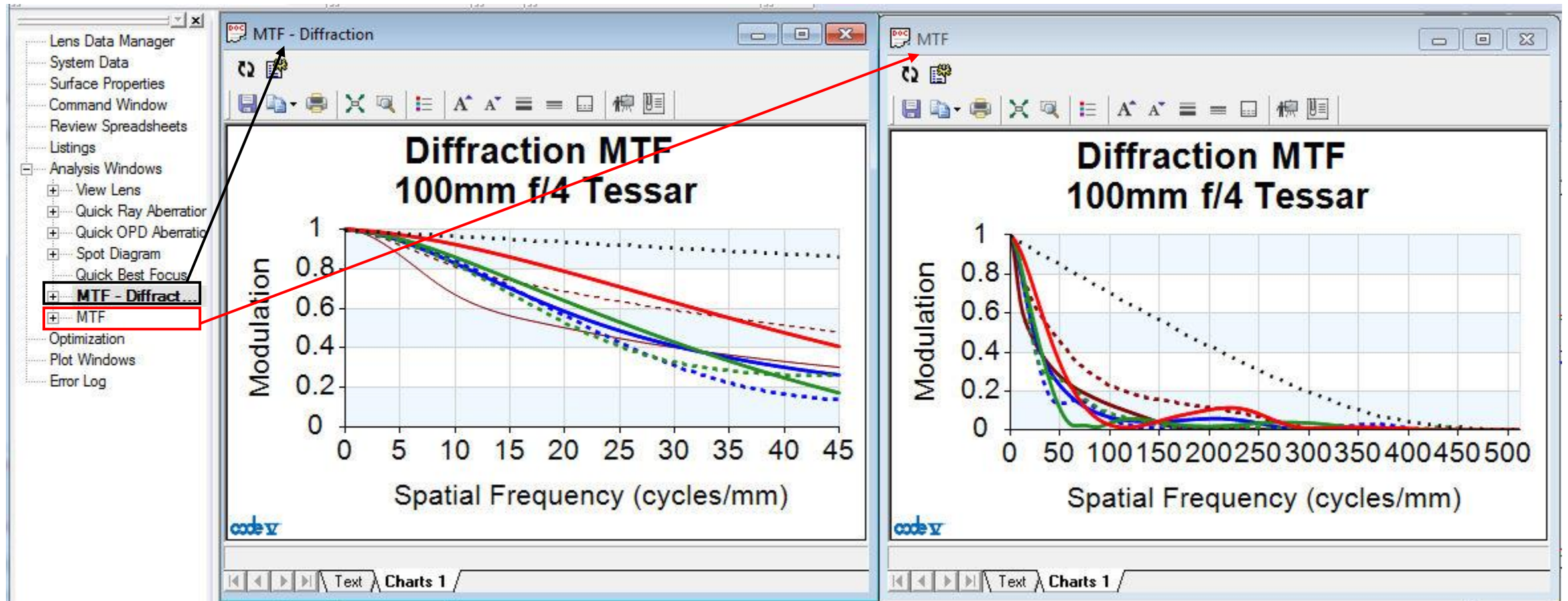
- L-click the tab
- Drag to the left to make a copy
- Re-execute

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



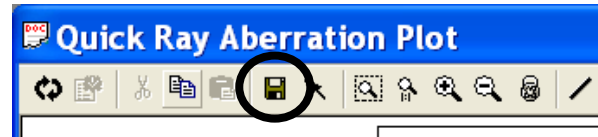
# Analyses

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



# Reports

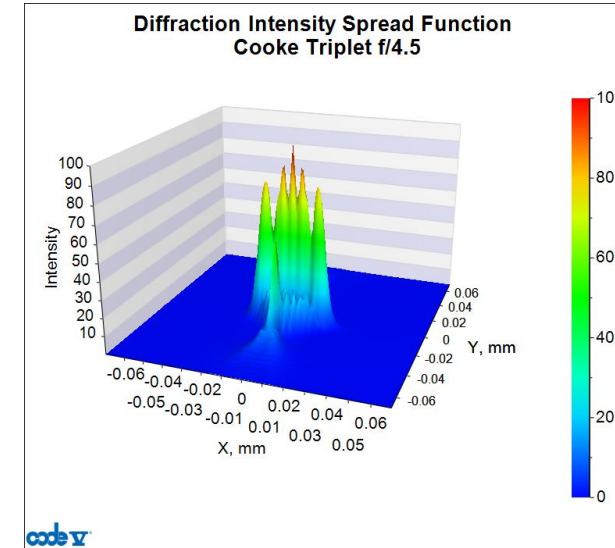
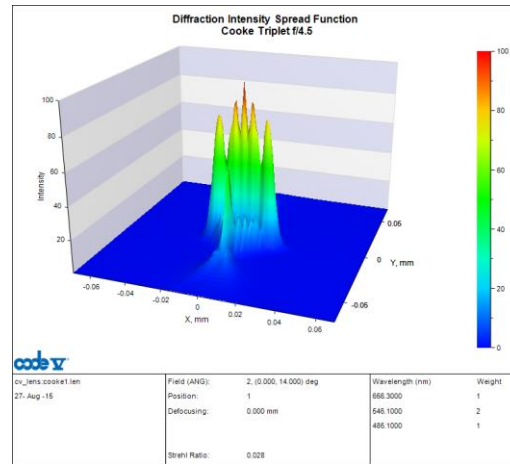
- To save text or plotted output for your reports, use the **File > Save Window As ...** choice



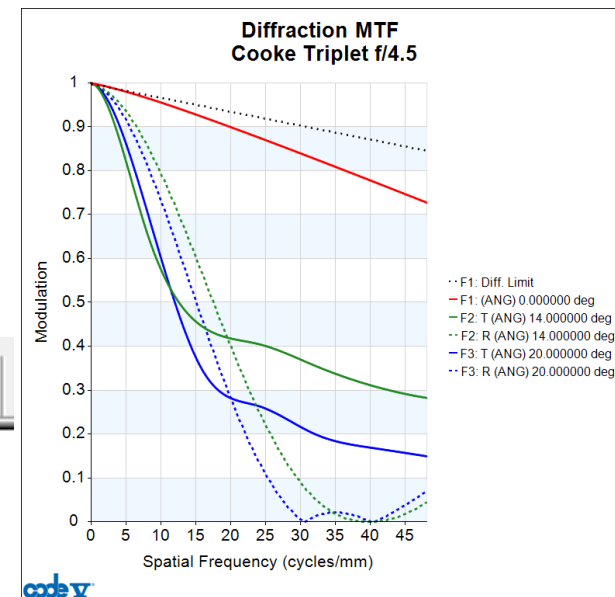
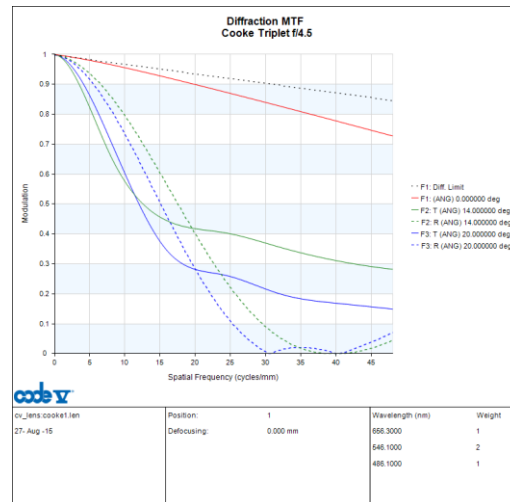
- For plotted output, you can also use Copy & Paste (CTRL-C, CTRL-V)
- The *LDM Spreadsheet* and *Review Spreadsheets* can also be printed directly
  - Verify the appearance with **File > Print Preview**

# Use the Presentation/Report Template for clearer figures

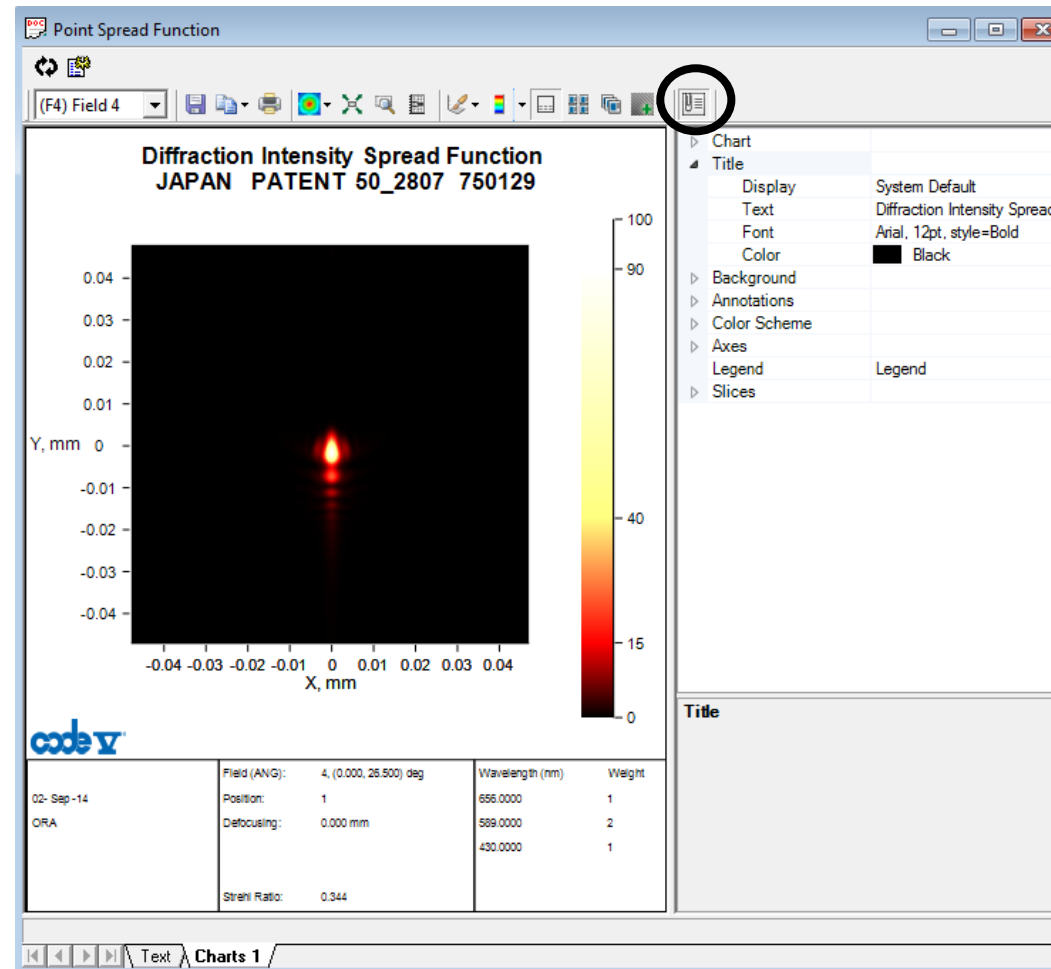
PSF



MTF

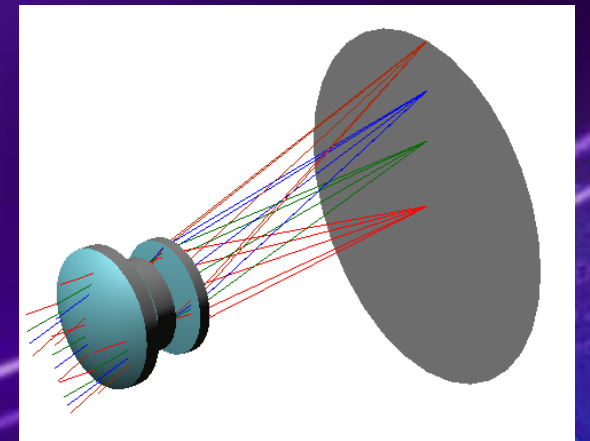


# Click “Properties” to open full charting customization options



# Demo: Designing a Digital Camera Lens

*Introduction to SpecBuilder and Automatic Design*



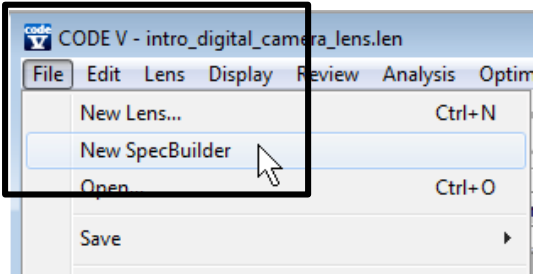


# Example: Digital Camera Lens

- 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		
Performance	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		
Performance	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

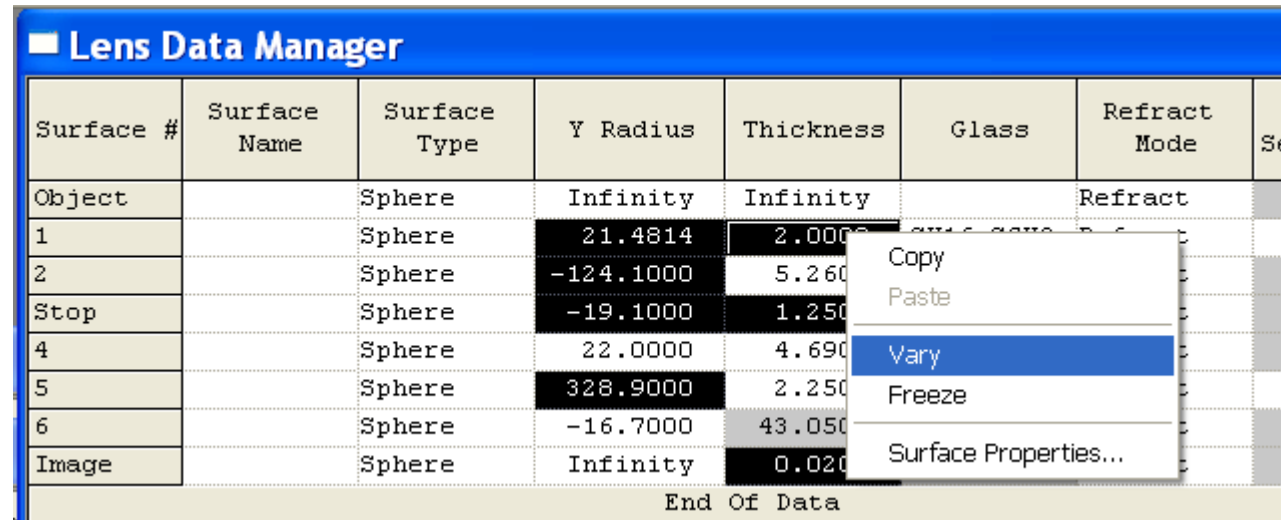
- Analysis > Diffraction > MTF, maximum freq. 68, increment freq. 17
- Analysis > Geometrical > Spot Diagram, select Aberration Scaling, Value 0.02
- Analysis > Diagnostics > Ray Aberration Curves, change Scale to 0.02

# 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”

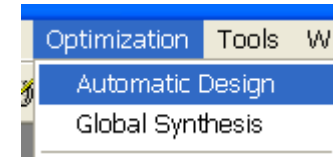


The screenshot shows the 'Lens Data Manager' window with a table of lens parameters. The table has columns for Surface #, Surface Name, Surface Type, Y Radius, Thickness, Glass, and Refract Mode. The 'Y Radius' column is highlighted, and a context menu is open over it, showing options: Copy, Paste, Vary (selected), Freeze, and Surface Properties... The 'End Of Data' text is visible at the bottom of the table.

Surface #	Surface Name	Surface Type	Y Radius	Thickness	Glass	Refract Mode	Se
Object		Sphere	Infinity	Infinity		Refract	
1		Sphere	21.4814	2.0000			
2		Sphere	-124.1000	5.2600			
Stop		Sphere	-19.1000	1.2500			
4		Sphere	22.0000	4.6900			
5		Sphere	328.9000	2.2500			
6		Sphere	-16.7000	43.0500			
Image		Sphere	Infinity	0.0200			

# 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**)

Automatic Design

Error Function Setup | Output/Exit Controls | **General Constraints** | User Constraints/Ray Definitions | Specific Constraints | Advanced

The following constraints can be overridden on specific surfaces by use of spec

Minimum element edge thickness: 0.2000

Element center thickness: Min 0.2000, Max 1.3000

Minimum air center thickness: 0.1000

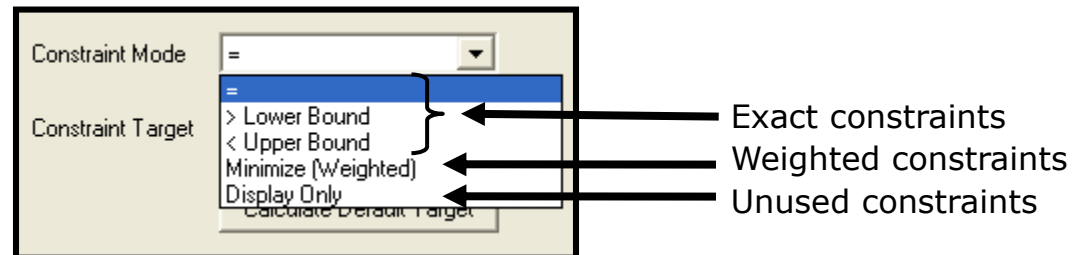
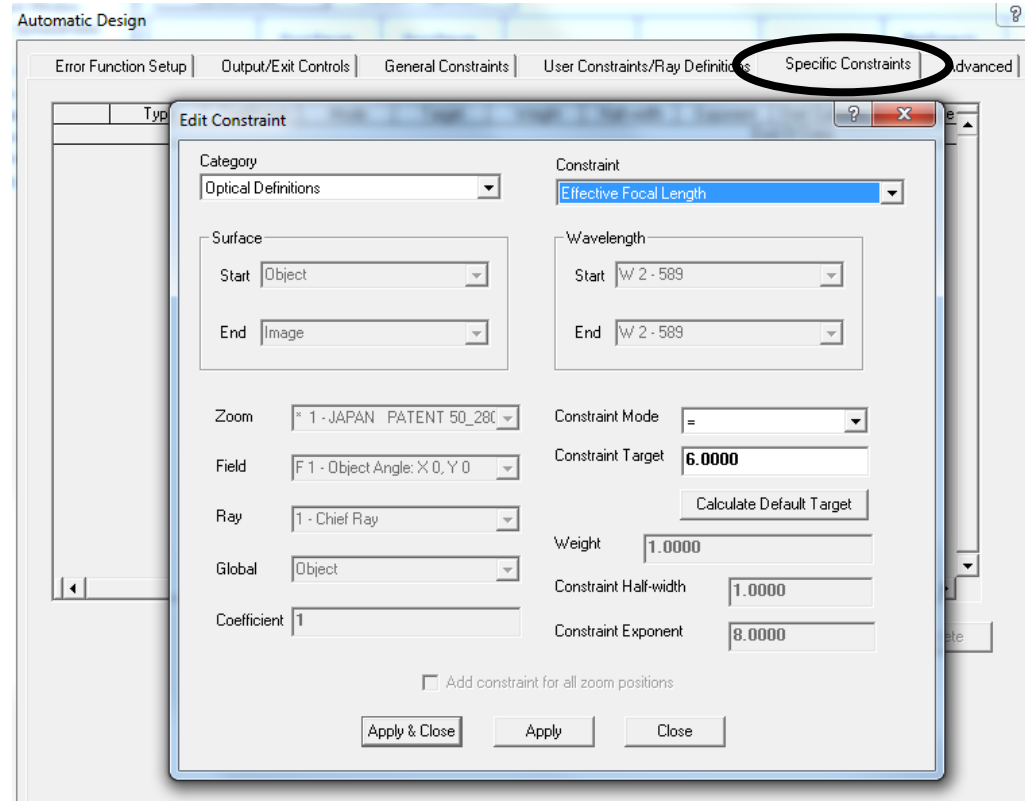
Minimum air edge thickness: 0.0025

Glass map boundary glasses/points (enter 3-5 values, default Schott, NFK5, NSK16, NLAf2, & SF4)

	Start Surface	End Surface	Start Zoom	End Zoom	Map 1	Map 2	Map 3	Map 4	Map 5
1	Object	Image	All Zooms	* 1 - JAPAN	NFK5	NSK16	NLAf2	SF4	
x									

# Optimizing a Lens

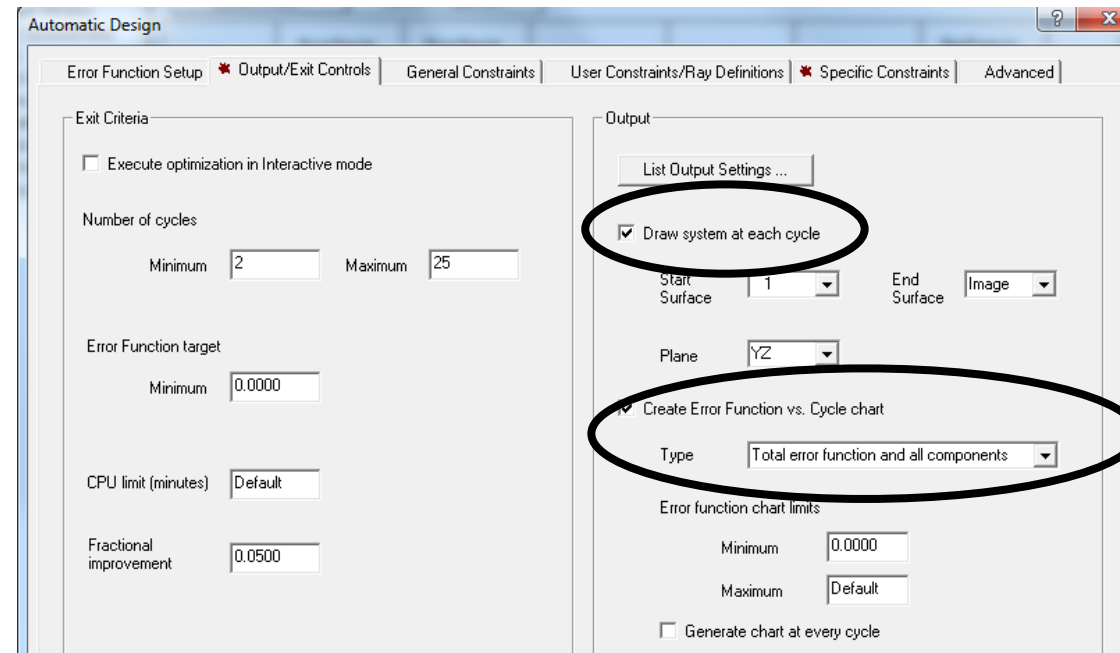
- Define any specific constraints (EFL, distortion, surface thicknesses, ray trace data, etc.). These may override general constraints.
- Note: exact constraints handled by linear algebra solutions (Lagrange multipliers) separate from error function, weighted constraints included in error function.





# 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
gcl s1 0                          ! vary glasses
gcl s3 0
gcl 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

The screenshot shows the Adobe Acrobat Standard interface with the search results for 'database items' in the 'index.pdx' file. The search results are displayed in a list format, showing the number of documents found (20) and total instances found (98). The search results are sorted by Relevance Ranking and are collapsed to show file paths. The search results include links to 'Database Items Database items' and 'Database Items' on page 258-3 for the 'database items' and their descriptor.

The search results are as follows:

- Finished searching for: **database items**
- Finished searching in: **In the index named index.pdx**
- Documents found: **20**
- Total instances found: **98**
- Results:
  - Lens **Database Items** with User-Define
  - database items**, greatly speeding up th
  - from **database items**, e.g., (Y 5i) or (M
  - macro **database items** RER and BLS an
  - of **database items** to obtain the result
  - database items**, e.g., (Y 5i) or (M 54).
  - macro **database items** RER and BLS an
  - store **database items**, greatly speedin
  - Constants, **database items**, predefin
  - Database Items Database items** are
  - Database Items**" on page 258-3 for th
  - of **database items** and their descrip

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!