

CODE V[®] 101

A Brief Introduction to CODE V Design and Analysis Software for Imaging Systems

OPTICAL RESEARCH ASSOCIATES

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CODE V Access for Distance Students

- Send email to sales@opticalres.com, indicate you need CODE V for your distance learning class, include your full contact info
- We ship you all installation materials

Purpose

- The purpose of this presentation is to provide you with an overview of CODE V structure, interface, and capabilities for optical system modeling, analysis, and optimization
 - This will be done both via this presentation and via CODE V demonstrations

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CODE V 101, Slide 3

Presentation Topics

- Structure of CODE V
- Interface elements
- The Basics
 - How to enter a lens
 - How to analyze a lens
 - How to optimize a lens
- Resources for learning CODE V
- Frequently used analyses for homework
- *Useful supplied macros*
- *CODE V odds-&-ends*
- Conclusions

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Interface Elements

Title Bar

Menu Bar

Toolbars

Navigation Toolbar

Tabbed Output Window

LDM Spreadsheet

Interactive 3D Visualization window

Tear-away Window

Command Window

Command Line

Status Bar

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CODE V 101, Slide 5

Opening a Lens

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

New Lens Wizard

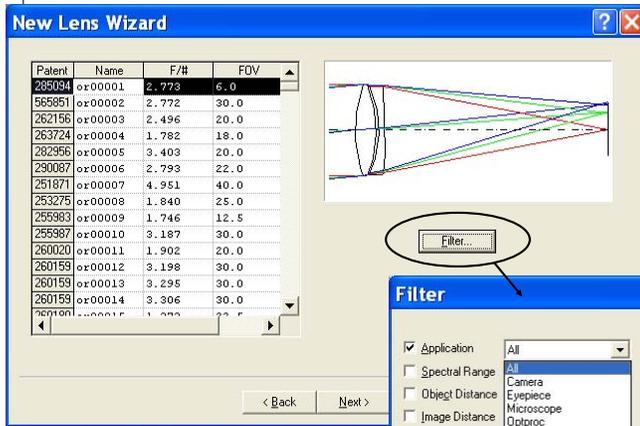
Name	F/R	FOV
cv_lens:ballcouple.len	3.47222	0
cv_lens:beamex.len	16.1844	0
cv_lens:bindoub.len	1	4
cv_lens:cassrc.len	11.6807	0.6
cv_lens:cooke1.len	4.5	20
cv_lens:couple14.len	-1.84361	0
cv_lens:dbgauss.len	2.00001	14
cv_lens:doublet.len	3.00004	3
cv_lens:eyepiece.len	5	30
cv_lens:fisheye.len	3.97716	85
cv_lens:grincoupler.len	1.99845	0
cv_lens:lensarray.len	22.56306	0
cv_lens:maksutov.len	10	1.50
cv_lens:microscpl.len	0.714176	4.84

Spherical Ball Lens Fiber Coupler

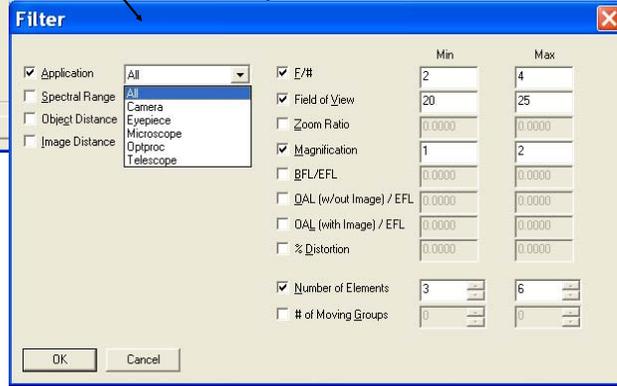
< Back Next > Finish Cancel Help

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Opening a Lens



- Filter list of 2400 patent lenses for desired criteria

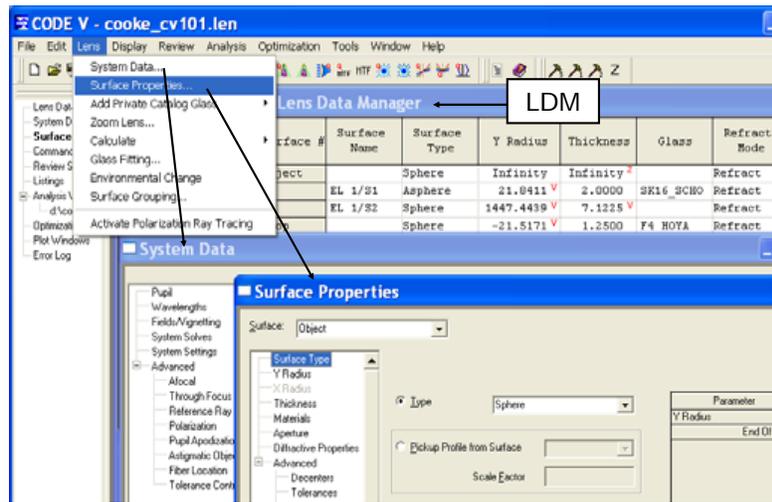


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Data Entry

- 3 main windows for entering data
 - Lens Data Manager
 - System Data
 - Surface Properties



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CODE V 101, Slide 8

Data Entry

- Right-click for context sensitive menus

Object	Sphere	Infinity	Infinity
1	Sphere	2.2686	0.9918
2	Sphere	6.0211	0.1387
3	Sphere	-8.1764	0.2000
4	Sphere	2.4142	0.2622
5	Sphere	5.7637	0.4571
6	Sphere	-3.3584	4.8063
Image	Image	Infinity	-0.0511

Surface Type	Y Radius	Thickness
Sphere	Infinity	Infinity
Sphere	2.2686	0.9918
Sphere	6.0211	0.1387
Sphere	-8.1764	0.2000
Sphere	2.4142	0.2622
Sphere	5.7637	0.4571
Sphere	-3.3584	4.8063
Sphere	Infinity	-0.0511

- 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		Refract	
Sphere			727063.28	Refract	
Cylinder				Refract	
Conic			743972.44	Refract	
Asphere				Only TIR	
X Toroid				Refract	
Y Toroid					
Thermal Gradient					
Spine					
Anamorphic Asphere					
Lens Module					
User Defined					

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Data Entry

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

nfinity	3.7770	F15_SCHOT	Refre
21.4692	15.1079		Refre
nfinity	15.1079		Refre
27.0349	3.7770		Copy
nfinity	10.8339		Paste
34.9867	0.2982		Vary
86.7405	6.8582		-

- Allows use of expressions in cells

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

→

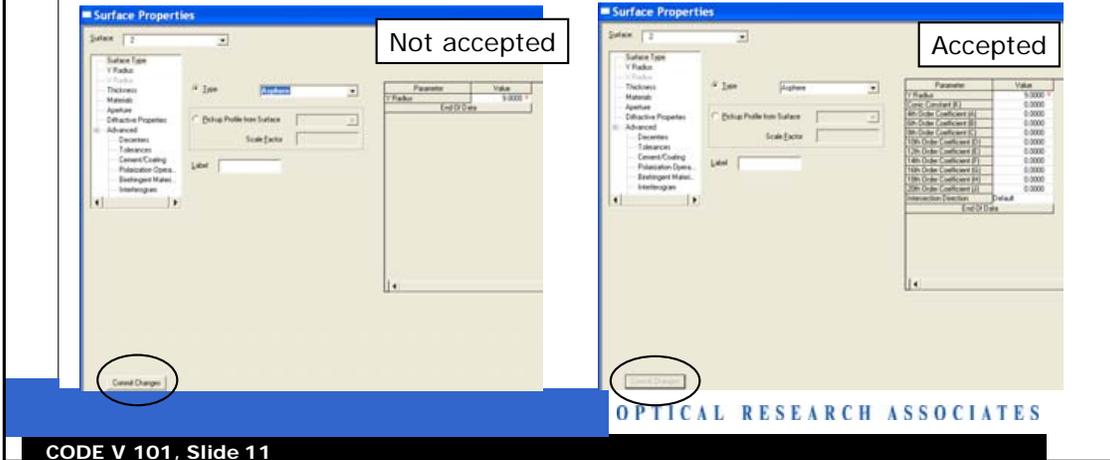
.4692	15.1079		
inity	7.5539		
.0349	3.7770	F1	

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CODE V 101, Slide 10

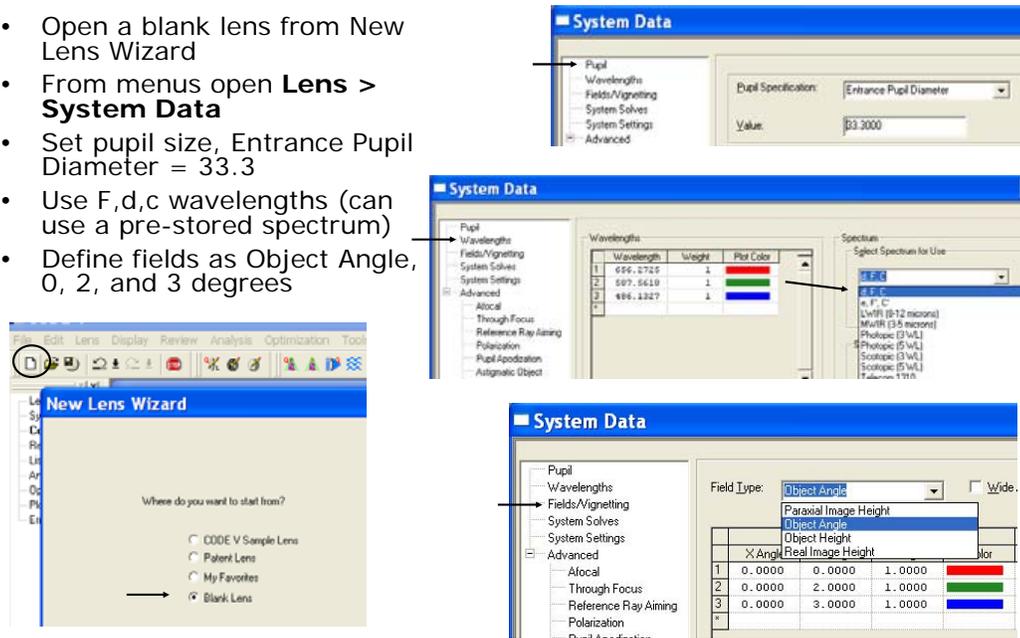
Data Entry

- 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



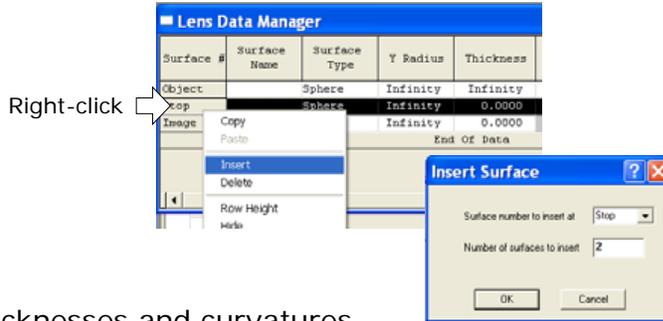
Data Entry – Ex. Doublet

- Open a blank lens from New Lens Wizard
- From menu 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



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

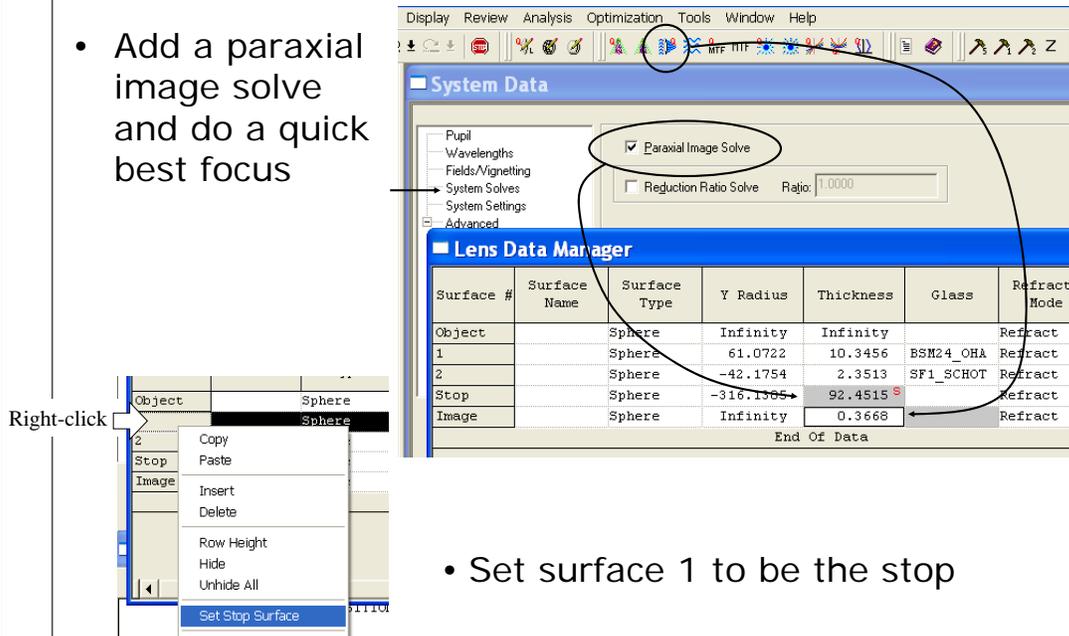
Surface #	Surface Name	Surface Type	Y Radius	Thickness	Glass	Refract Mode	Y Semi-Aperture
Object		Sphere	Infinity	Infinity		Refract	
1		Sphere	61.0722	10.3456	BSM24_OHA	Refract	16.9651
2		Sphere	-42.1754	2.3513	SF1_SCHOT	Refract	16.3051
Stop		Sphere	-316.1385	0.0000		Refract	15.7427
Image		Sphere	Infinity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

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Data Entry – Ex. Doublet

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



- Set surface 1 to be the stop

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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
WAV; BES; RFO; GO
STO S1
```

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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

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Data Entry – Ex. Reflective

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

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							

- Access Asphere coefficients in Surface Properties window

Parameter	Value
Y Radius	1777.4675 V
Conic Constant (K)	0.0000
4th Order Coefficient (A)	-4.0493e-008 V
6th Order Coefficient (B)	-1.2166e-012
8th Order Coefficient (C)	0.0000
10th Order Coefficient (D)	0.0000
12th Order Coefficient (E)	0.0000

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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" (www.oraservice.com)

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Homework Analyses

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

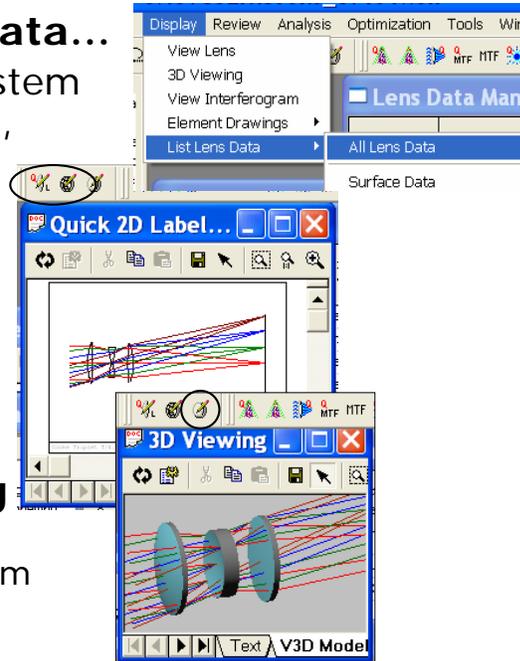
- List surface data, system data, first order data, indices, etc.

- **Display>View Lens**

- 2D layout

- **Display>3D Viewing**

- Open-GL solid model, interactive rotation/zoom



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Homework 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

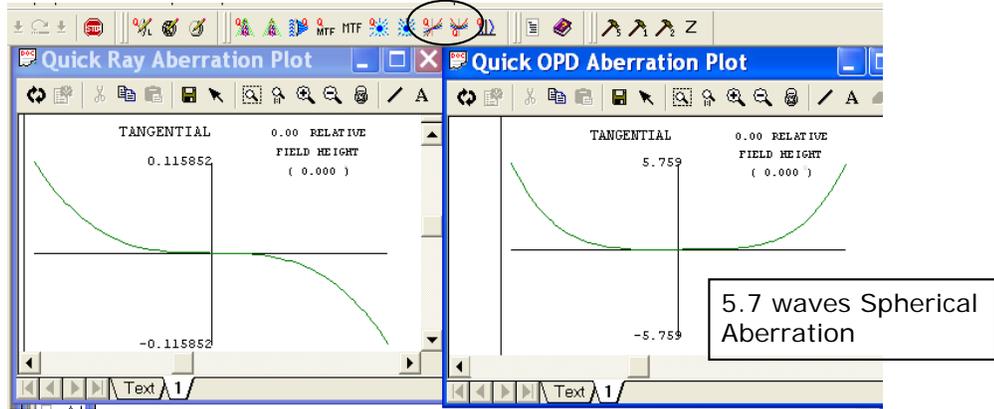


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Homework Analyses

- **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 autoscaling

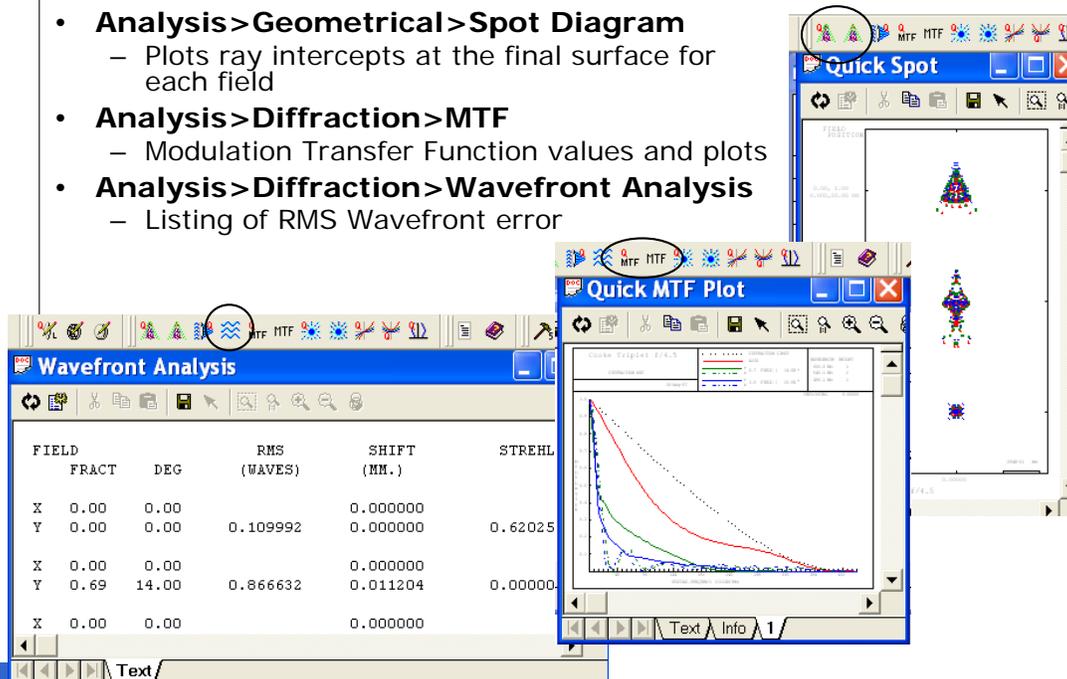


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Homework Analyses

- **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

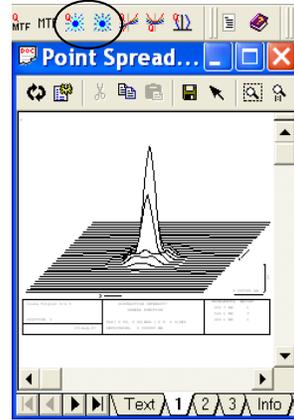
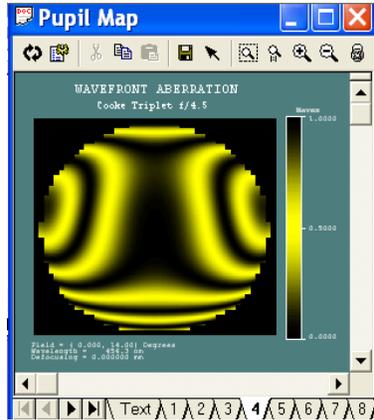


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Homework Analyses

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

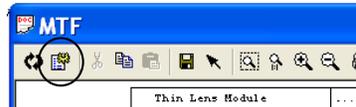


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Homework Analyses

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



(quick options don't allow this)

- **Option Set... button allows you to save your options to apply in the future**



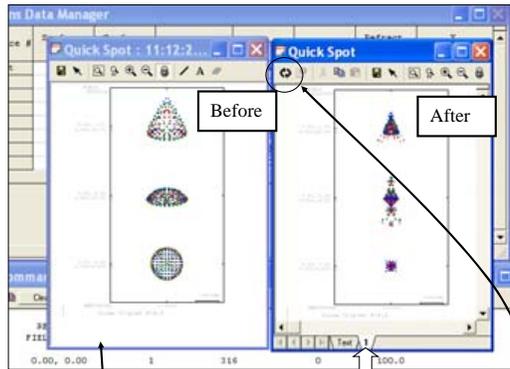
- * **Leave windows open so you can re-execute with the same options**

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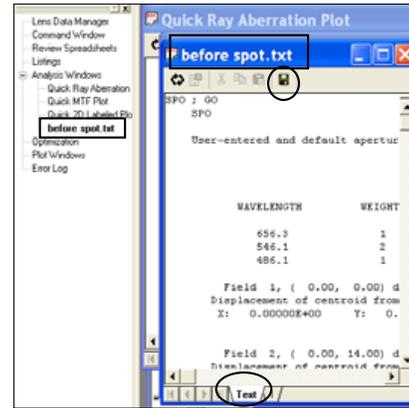
Homework Analyses

- 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



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Homework 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**

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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

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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

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Optimizing a Lens

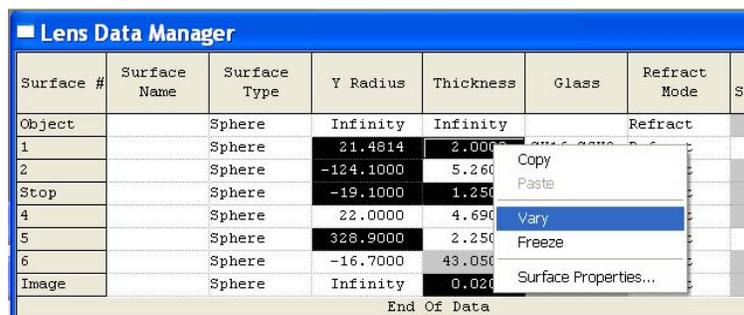
- One of CODE V's main strengths is the effectiveness of its optimization algorithms
 - In particular, CODE V's ability to control constraints exactly works better than any other commercial software
- CODE V optimization is easy to use, with very little input required by you in many cases
 - This is 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

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CODE V 101, Slide 29

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"



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			

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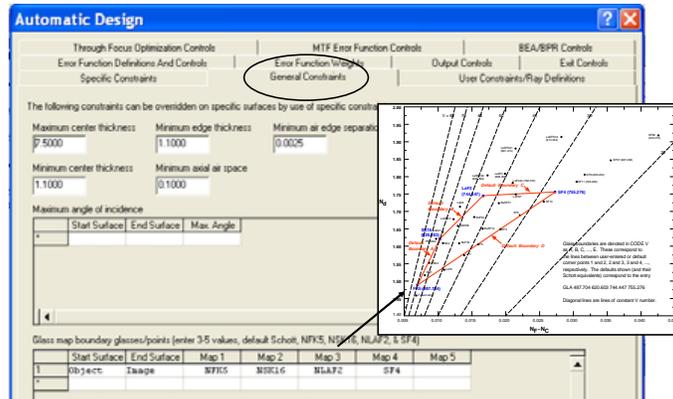
Optimizing a Lens

- 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**)

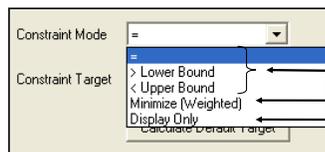
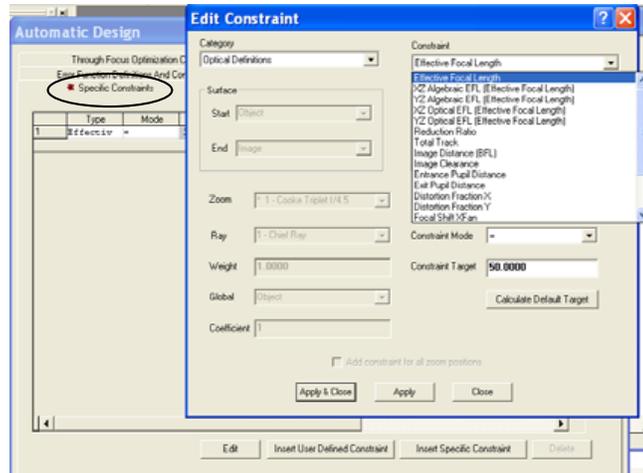


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Optimizing a Lens

- 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.



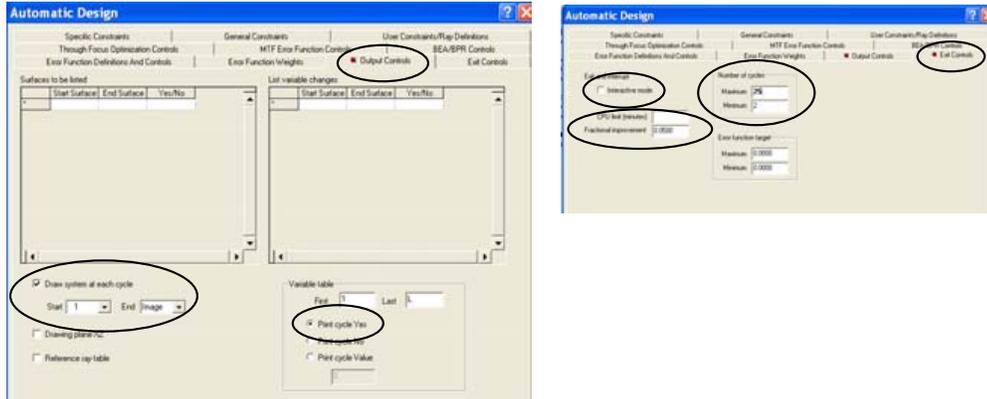
Exact constraints
Weighted constraints
Unused constraints

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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.



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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.

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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
```

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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
```

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Resources for Learning CODE V

- Various CODE V Help Choices (**HELP** > ...)
- The Customer area of the ORA website: www.oraservice.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

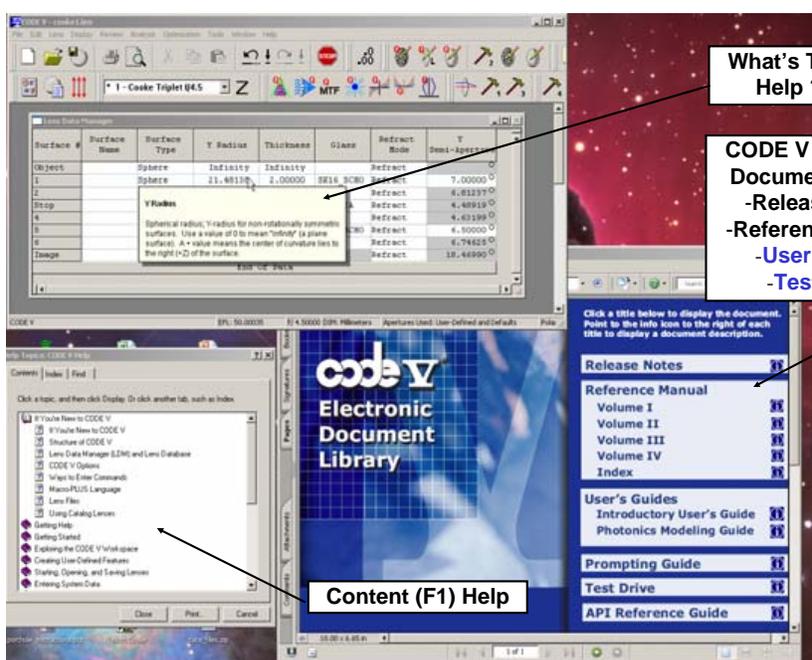
Intro Topics in CODE V Training

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

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CODE V Help Features

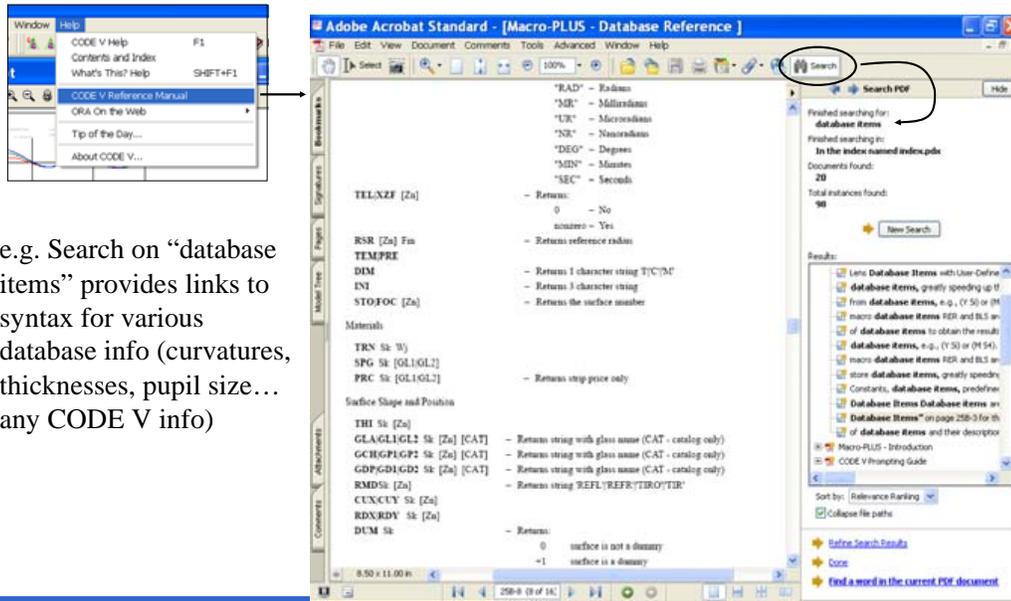


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CODE V Help

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



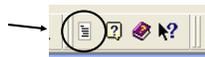
e.g. Search on “database items” provides links to syntax for various database info (curvatures, thicknesses, pupil size... any CODE V info)

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Useful CODE V Macros

- CODE V has a very powerful and easy-to-learn macro language
- In addition, many sample macros are supplied with CODE V
 - Many of these will perform analyses that you will want to use
- These macros are accessible from the **Tools > Macro Manager ... Sample Macros** menu choice, or



- You can add sample macros that you use frequently to a menu or to a toolbar



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Useful CODE V Macros

- A subset of particularly useful macros:
 - REFCHECK
 - GLASSFIT
 - ABERRATIONGENERATOR
 - PLASTICPRV
 - BFLPLOT
 - FL & NODP
 - MTFVSFLD
 - QUICKVIEW
 - RSIVIEW
 - LENSTABLE

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UTILITIES: REFCHECK

- CODE V uses 5 special “reference” rays for determining apertures, and verifying the system setup before running an analysis
- **REFCHECK.SEQ** verifies that these rays trace, and helps to diagnose problems

```
in "C:\CODEV950\macro\refcheck.seq"
CODE V> ver n

Field 1
Ray R1 Traced but blocked by obscuration on S1
Ray R2 Traced
Ray R3 Traced
Ray R4 Traced
Ray R5 Traced
Field 2
Ray R1 Traced but blocked by obscuration on S1
Ray R2 Traced
Ray R3 Traced
Ray R4 Traced
Ray R5 Traced
Field 3
Ray R1 Traced but blocked by obscuration on S1
Ray R2 Traced
Ray R3 Traced
Ray R4 Traced
Ray R5 Traced

Summary of Reference Ray Tracing
- All reference rays trace
- One or more reference rays blocked

* Ray trace performed at reference wavelength of 632.8 nm.
```

OPTICAL RESEARCH ASSOCIATES

CODE V 101, Slide 42

Material Info: GLASSFIT

Surface #	Surface Type	Y Radius	Thickness	Glass	Refract Mode	Y Semi-Aperture
Object	Sphere	Infinity	Infinity		Refract	0
Stop	Sphere	50.00000 V	5.00000	517000.642000 V	Refract	10.00000
2	Sphere	1165.15476 S	96.57196 S		Refract	9.71929
Image	Sphere	Infinity	0.00000 V		Refract	0.11582
End Of Data						

Fit Catalog	Glass	Delta Nd	Delta Vd	Avail	Price	DPF	Bubl	Stain
1	SCHOTT	0.00020	-0.0898	2	0.00	-4	0	0
2	SCHOTT	0.00020	0.0326	0	12.00	-6	0	0
3	HOYA	0.00020	0.0017	11	0.00	-12	Nul	1
4	OHARA	-0.00028	-5.3633	25	0.00	35	Nul	-
5	OHARA	-0.00042	11.7691	22	35.00	21	Nul	-

N = 1.517
Fictitious glass varied during optimization.

After optimization, substitutes real glasses that are close matches.

- Also under menu **Lens > Glass Fitting ...**

OPTICAL RESEARCH ASSOCIATES

CODE V 101, Slide 43

Utilities: Aberration Generator

- **ABERRATIONGENERATOR.SEQ** sets up a lens module with user defined amounts of aberrations
- Characteristic curves for image plane transverse ray aberrations and exit pupil OPD aberrations can be viewed.

Macro aberrationgenerator.seq

Macro to demonstrate the effects of aberrations, stop shifts, and conjugate shifts

Stop shift:

Reduction ratio:

Spherical aberration:

Coma:

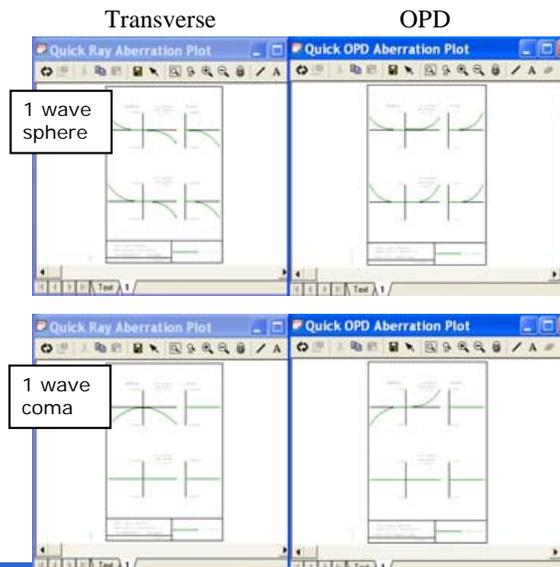
Astigmatism:

Distortion:

Petzval:

OK Cancel

Spherical aberration in waves at clear aperture



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CODE V 101, Slide 44

Material Info: PLASTICPRV

- To access a database of polymer optical materials, run the **PLASTICPRV.SEQ** macro

Key to Materials:

Sources:

- [1] OSA Handbook of Optics, Vol. II, p. 34.7, Table 2 ('room' temperature, actual measurement temperature unknown)
- [2] Measured Data by Honeywell France, fit to a Laurent's Dispersion Equation, dated January 1996 ('room' temperature, actual measurement temperature unknown)
- [3] Data from Supplier, Ticona US, 825 deg C (http://www.ticona.com)
- [4] Data from Supplier, Hitachi Chemical Co., Ltd., 25 deg C indices corrected to 20 deg C (i.e., $N[20] - N[25] - 5e-4$) (http://www.hitachi-chem.co.jp/)
- [5] Data from Supplier, Zeon Chemicals at 10, 25, 40, 60 deg C (http://www.zeonchemicals.com/)
- [6] Data from Supplier, Zeon Chemicals, temperature unknown, average value of two orthogonal measurements through the material (http://www.zeonchemicals.com/)

Private Catalog Name	Name	Source	Defined Wavelength Region	Temperature deg. C	Specific Gravity	Coefficient Thermal Expansion (x1e7 /C)	dN/dT (x1e-6/C)	d, F, C Glass Code
'P-CARBO'	Polycarbonate	[1]	1014 - 365 nm	'room'	1.25	670	-107	505.300
'PCHMAO'	Poly(1-cyclohexylmethacrylate)	[1]	656 - 486 nm	'room'	1.11	?	?	505.561
'PEIO'	Polyetherimide	[1]	644 - 400 nm	'room'	1.27	560	?	660.186
'PHEMA'	Polymethylmethacrylate	[1]	1014 - 365 nm	'room'	1.18	600	-105	492.572
'P-STYRO'	Polystyrene	[1]	1014 - 365 nm	'room'	1.05	640-670	-140	591.308

Defines plastics as "Private Catalog" materials

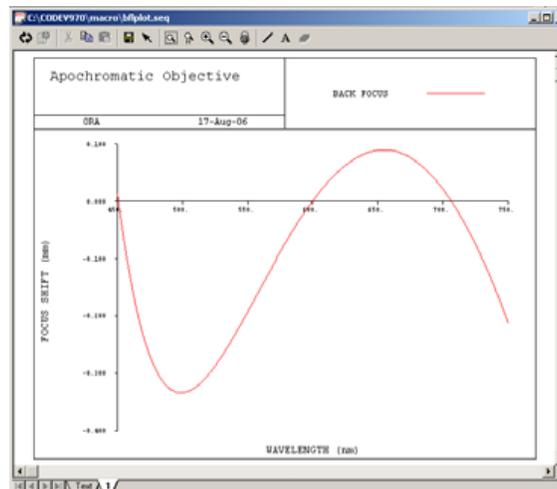
Entered in the Glass column with quotes (e.g., "PMMAO")

OPTICAL RESEARCH ASSOCIATES

CODE V 101, Slide 45

1st ORDER ANALYSIS: BFLPLOT

- BFLPLOT.SEQ** plots the longitudinal focus shift as a function of wavelength
- Very useful for color aberration studies

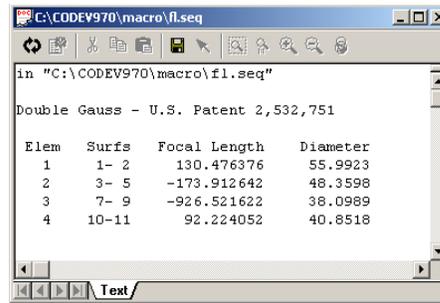


OPTICAL RESEARCH ASSOCIATES

CODE V 101, Slide 46

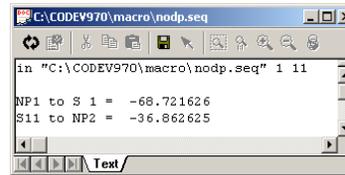
1st ORDER ANALYSIS: FL & NODP

- **FL.SEQ** computes and lists the EFL for the components in a lens



Elem	Surfs	Focal Length	Diameter
1	1- 2	130.476376	55.9923
2	3- 5	-173.912642	48.3598
3	7- 9	-926.521622	38.0989
4	10-11	92.224052	40.8518

- **NODP.SEQ** computes and lists the Nodal Point positions for the designated surface range



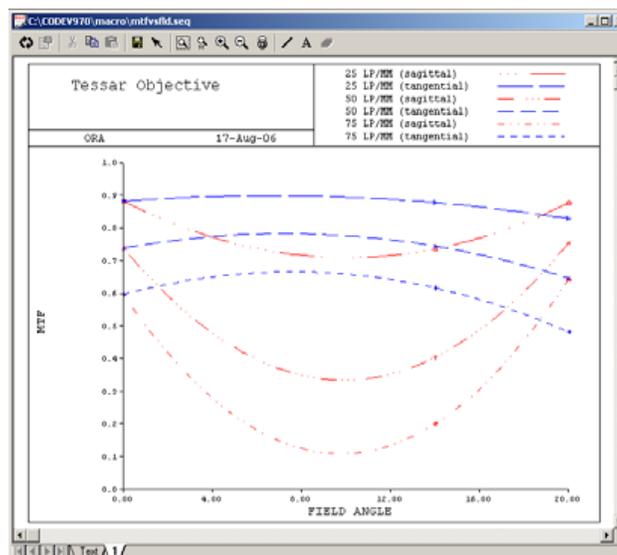
NP1 to S 1 =	-68.721626
S11 to NP2 =	-36.862625

OPTICAL RESEARCH ASSOCIATES

CODE V 101, Slide 47

DIFFRACTION ANALYSIS: MTFVSFLD

- **MTFVSFLD.SEQ** creates a plot of the MTF as a function of field

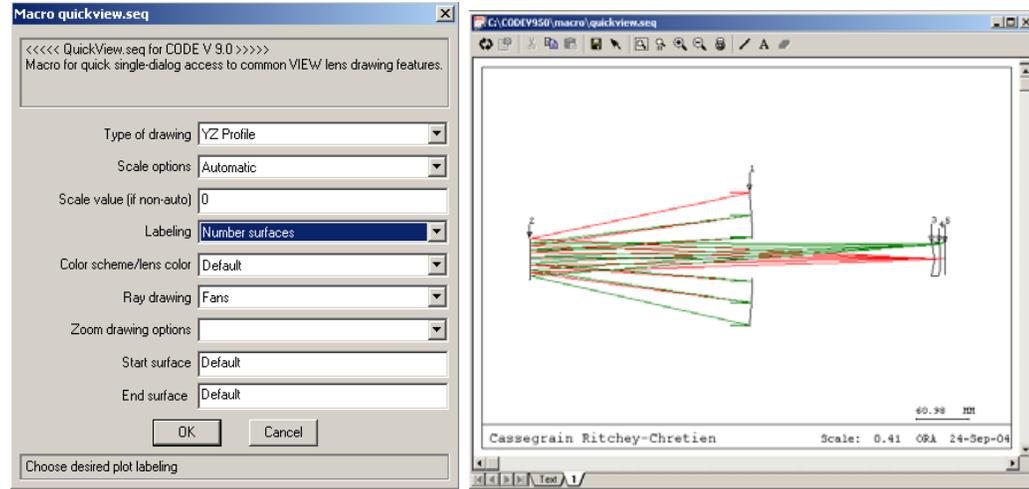


OPTICAL RESEARCH ASSOCIATES

CODE V 101, Slide 48

UTILITIES: QUICKVIEW

- **QUICKVIEW.SEQ** provides a simple one tab dialog with access to the most frequently utilized **Display > View Lens ...** choices

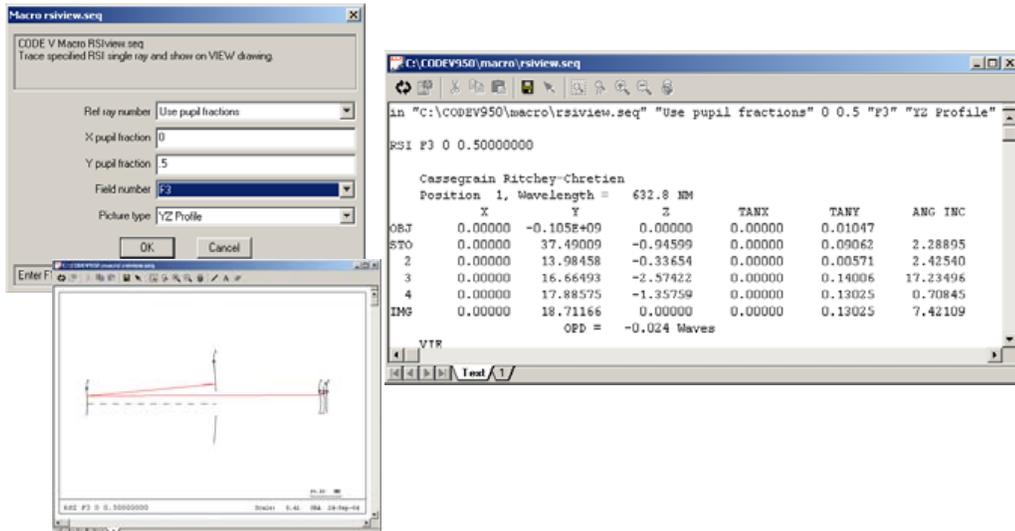


OPTICAL RESEARCH ASSOCIATES

CODE V 101, Slide 49

UTILITIES: RSIVIEW

- **RSIVIEW.SEQ** traces a single ray and displays that ray on a *view lens* plot



OPTICAL RESEARCH ASSOCIATES

CODE V 101, Slide 50

FABRICATION SUPPORT: LENSTABLE

- **LENSTABLE.SEO** creates a compact list of the constructional parameters of the lens including sag and edge thickness information

TABLE OF CONSTRUCTION PARAMETERS
 19-Aug-2006 / 21:54:30
 Filename => C:\CYUSER\Training\Intro\tessar_auto2.len
 Title => F/5.5 Tessar Lens

If User-defined apertures are NOT specified:
 Diametrical Increment between Used Aperture and Clear Aperture (CA) => 0
 Diametrical Increment between CA and Outer Diameter (OD) => 0

Surf. #	Base	Surf. Shape	Surf. Sag	CV Used	Clear Aperture	Outer Diameter	Center Thickness	Edge Thickness (ET)	OD/CT	
1	16.4089	CX	0.9797	12.026	11.170	11.170	2.649	1.661	1.500	4.217
2	1999.0823	CX	0.0078	10.896	10.896					
3	37.0976	CC	0.2271	8.198	8.198	8.198	0.863	1.555	1.555	9.497
4	15.2936	CC	0.4652	7.487	7.487					
6	68.1234	CC	0.1618	9.385	9.385	10.585	1.500	2.307	2.307	7.056
7	22.0252	CC	0.6453	10.585	10.585					
8	22.0252	CX	0.6549	10.585	10.585	10.662	2.887	1.585	1.500	3.694
8	22.3140	CX	0.6462	11.407	10.662					

AIRSPACE ETC: CA MAX + 0 millimeters

Surf. #	CA MAX	ET	
2	10.896	1.882	2.058
4	7.487	0.002	0.002
5	9.385	3.278	3.278
8	96.256	52.787	44.120

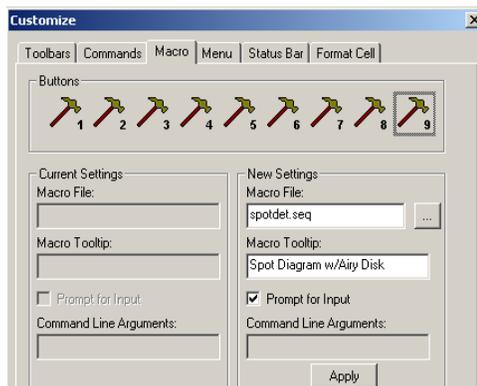
Notes: 1. Dimensions are in millimeters
 2. Radius values of 0.0000 indicate actual radii values greater than 99,999 units.
 3. CT Surface sags are computed at Clear Aperture (CA) diameter. CX Surface sags are computed at the OD.
 4. Lens ET is computed based on sag dimension at the CA for concave surfaces and at the OD for flat and convex surfaces.
 5. Air ET is computed based on separation of surfaces at a diameter equal to 0 millimeters over the largest clear aperture straddling the space.
 6. ET values of 999.999 indicates that the CA or OD is greater than the surface radius (i.e. the sag is undefined)

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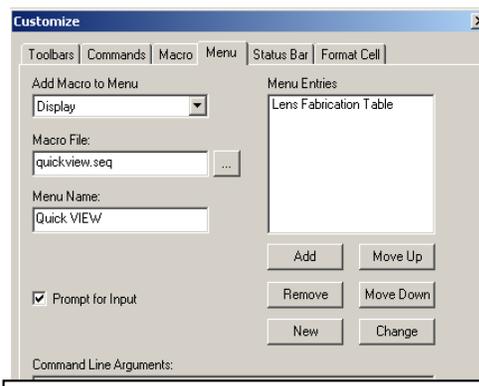
CODE V 101, Slide 51

Interface Customization

- Macros that you like can be added to a Menu and/or toolbar button (**Tools > Customize**):



After clicking **Apply**, drag the selected button up to the toolbar
 Hovering the mouse over the button will show the macro tooltip



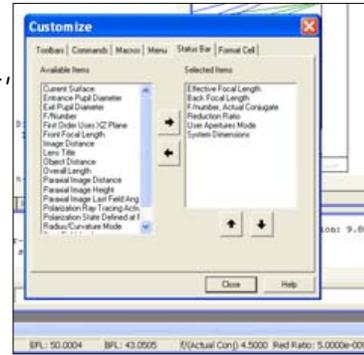
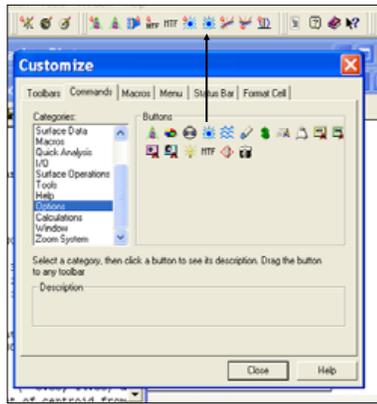
Click **Add** to add the macro to the menu. For both tool buttons and menus, if the macro has an input dialog, be sure to check **Prompt for Input**

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CODE V 101, Slide 52

Interface Customization

- Customize status bar with EFL, BFL, F/#, reduction ratio



- Common menu commands can be accessed via these icons. Just click and drag to the toolbar just like MS Word.

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CODE V 101, Slide 53

CODE V ODDS-&-ENDS

- Apertures and Vignetting
- CODE V errors and warnings
- Commands vs. GUI
- CODE V file types
- Other CODE V strengths

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CODE V 101, Slide 54

Odds & Ends: Apertures and Vignetting

- For accurate results in any optical design software, it is very important to understand how apertures are used
 - CODE V (and some other programs) also use the concept of Vignetting factors, whose use should be understood
- Review the *Apertures and Vignetting* section from the **Introduction to CODE V** training
 - www.oraservice.com > Training Course Notes > Introduction

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CODE V 101, Slide 55

Odds & Ends: Warnings/Errors

- During the execution of CODE V, you may encounter errors, and you will encounter warnings.
- Errors and warnings appear in:
 - Command window
 - Error log window
 - **Info** tab of tabbed output windows
- *Errors* stop execution, and action must be taken to solve the problem
- *Warnings* are informational, and you should evaluate if they are important for your system



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CODE V 101, Slide 56

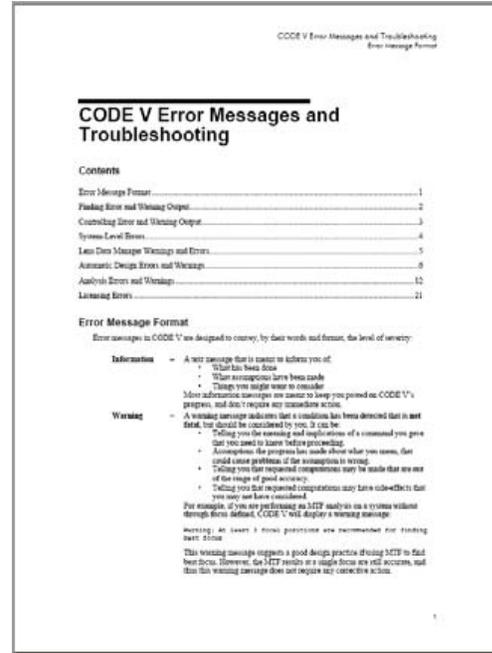
Odds & Ends: Warnings/Errors (2)

- Use an appendix to the Reference Manual to help troubleshoot problems in CODE V

Demo:

RES CV_LENS:DBGAUSS
TOW PSF;GO

Search help for "There are energy levels as great"



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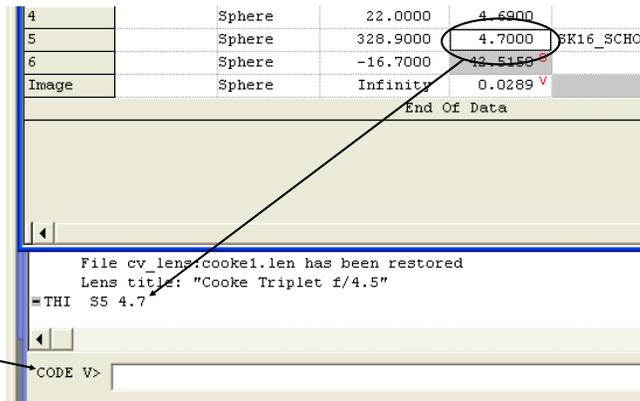
CODE V 101, Slide 57

Odds & Ends: Commands vs. GUI

- All GUI operations echo commands to command window.

Change thickness of surface 5 in the LDM, the equivalent command is printed in the command window.

Typing this expression at the CODE V> prompt would do the same action.



- Use commands and macros to save time

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CODE V 101, Slide 58

Odds & Ends: Commands vs. GUI

- To run a macro (also called a sequence file):
 - Do some action in the GUI
 - At the command window, collapse text to see the commands that were generated
 - Open CV editor,
 - CODE V > edit test
 - Add commands to the text file
 - Hit CTRL+S (saves as test.seq)
 - Run the macro,
 - CODE V > tow in test

Data displayed in a tabbed output window.
Navigate with the TAB key.

Keyboard shortcuts:	
CTRL+L	LDM
CTRL+SPACE	Command window
UP ARROW	Recall Last command

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CODE V 101, Slide 59

Odds & Ends: Commands vs. GUI

- Ex. – Run multiple Analyses at once**
 - Restore cassrc.len
 - Run **Display > View Lens**
 - Run **Analysis > Geometrical > Spot Diagram**
 - Run **Analysis > Diagnostics > Ray Aberration Curves**
 - Run **Analysis > Diffraction > MTF**
 - CODE V > edit plots
 - CODE V > tow in plots
 - Re-execute as desired to see system quality

plots.seq

```

wnd ope 4          ! Open 4 plot windows
wnd sca pl..4 .5  ! Set scale to 50%

vie;fan 0 5;go    ! 2D layout
rim;go           ! Ray aberration curves
fie;lsa;go       ! Field curves
mtf;go           ! MTF plot
    
```

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CODE V 101, Slide 60

Odds & Ends: Commands vs. GUI

- **Ex. – Iterate a lens parameter**

- Restore singlet.len
- Change stop surface to an asphere
- Under Surface Properties, change conic constant to -0.1
- Run **Analysis > Diagnostics > OPD Curves**
- CODE V > edit iterate
- CODE V > tow in iterate
- Re-execute and change increment as needed to minimize aberration

iterate.seq

```
^inc == -.1          ! Variable for increment
k s1 (k s1)+^inc     ! Set conic constant for surface 1 equal to the
                    ! current value + the increment
rim; wfr yes; go     ! Run ray aberration curves
```

OPTICAL RESEARCH ASSOCIATES

CODE V 101, Slide 61

Odds & Ends: Commands vs. GUI

- **Ex. – Loop through a lens parameter**

loop.seq

```
len new             ! New lens
epd 20              ! Pupil diameter
s1 0 3 nbk7         ! S1 curvature, thickness, glass
s2 0 0
Pim                 ! Paraxial image solve

ccy s2 0            ! Vary S2 curvature

for ^c .05 -.05 -.005001 ! Loop variable ^c from .05 to -.05 in
                    ! -.005001 steps

    rdy s1 1/^c      ! Set radius of surface 1 to inverse
                    ! curvature
    aut; efl=100; go ! Optimize
    vie; lab; tit num_to_str(^c); go ! 2D plot
    rim; wfr yes; ssi 9; go ! OPD aberration curves

end for
```

OPTICAL RESEARCH ASSOCIATES

CODE V 101, Slide 62

Odds & Ends: Commands vs. GUI

- **Ex. – Use database items to calculate desired data**

– **CODE V > in calc_sf 1**

$$\text{Shape factor } X = \frac{r_2 + r_1}{r_2 - r_1}$$

calc_sf.seq

```
^s == #1 ← ! Variable for surface #, uses input
parameter

! Store db items for ROC values
^r1 == (rdy s^s)
^r2 == (rdy s^s+1)

^sf == (^r1 + ^r2)/(^r2 - ^r1) ! Eqn. for shape factor

wri 'Shape factor' ^sf ! Print results
```

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CODE V 101, Slide 63

Odds & Ends: Commands vs. GUI

- **Ex. – Save data to buffer and plot results**

– Restore dbgauss.len

bufplotTRA.seq

```
out n ! turn off output for faster execution
ver n ! turn off echoing of commands

buf del b1 ! delete buffer 1 contents

^count == 0 ! variable to count # of points in loop

! loop variable ^w from 400 to 700, in steps of 10
for ^w 400 700 10

    ^count == ^count + 1

    w1 ^w ! define a single wavelength for the system

    buf del b0 ! delete the default buffer for recording
    buf y ! turn on recording of data into b0
    tra;go ! run transmission option
    buf n ! turn off recording of data into b0
```

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CODE V 101, Slide 64

Odds & Ends: Commands vs. GUI

- **Ex. – Save data to buffer and plot results (bufplot.seq cont'd)**

```

buf fnd b0 'Ave Transmittance'      ! find location of desired data
^tra == (buf.num b0 ic jc+1)        ! save data from b0, current row and
col+1
buf put b1 i^count ^w ^tra          ! put data into b1, at row ^count

end for

out y      ! turn on output
ver y      ! turn on echoing of commands

buf lis b1      ! list contents of b1

! user graphic
ugr
tit 'Transmission Plot'      ! plot title
xla 'Wavelength (nm)'        ! x-axis label
yla 'Avg. Transmittance'     ! y-axis label
dpo 'Tran. data'             ! define data set
spl pnt          ! spline fit curve and show data points
bim b1 1 1 1 2 ^count      ! import data from b1
end
go

```

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CODE V 101, Slide 65

Odds & Ends: Commands vs. GUI

- **Common commands**

		<u>Database item</u>
Restore a lens	RES CV_LENS:COOKE1	
Run a macro/sequence	IN TEST	
Save a lens	SAV TEMP	
Save a lens as a sequence file	WRL TEMP	
Change working directory	CD	(CD)
Show system specifications	SPC	
Set pupil		
entrance pupil diameter	EPD 20	(EPD)
image f/number	FNO 2.5	(FNO)
image numerical aperture	NA .2	(NA)
object numerical aperture	NAO .2	(NAO)
Set wavelengths	WL 656 587 486	(WL W1)
Set field points		
object angle	YAN 0 3 5	(YAN F1)
object height	YOB 0 5 7	(YOB F1)
real image height	YRI 0 2 3	(YRI F1)
Paraxial image solve	PIM	
Enter surface info	S1 -50 5 NBK7	
Set radius	RDY S1 -50	(RDY S1)
Set thickness	THI S1 5	(THI S1)
Define glass	GL1 S1 NBK7	(IND S1)
Evaluate an expression	EVA 2*(THI S1)	
Write multiple data	WRI "S1" (RDY S1) (THI S1)	

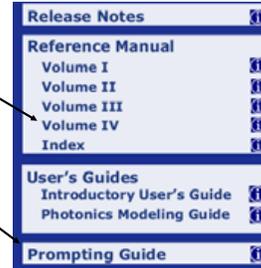
OPTICAL RESEARCH ASSOCIATES

CODE V 101, Slide 66

Odds & Ends: Commands vs. GUI

List buffer contents	Buf lis b1	<u>Database item</u>
Change separator between columns	Buf sep " "	
Delete buffer contents	Buf del b1	
Turn on/off buffer (b0) recording	Buf y n	
Query buffers	Buf?	
Export buffer to a text file	Buf exp b1 data.xls	
Import text file to a buffer	BUF IMP B1 DATA.DAT	
Put data into buffer	BUF PUT B1 I2 J3 3.14	
- use current row/col	BUF PUT B1 IC JC 3.14	
- relative to current row/col	BUF PUT B1 IC+1 JC+4 3.14	
Move pointer within a buffer	BUF MOV B1 I2 J5	
Find data in a buffer	BUF FND B0 "Ave Transmittance:"	
Return number from a buffer		(BUF.NUM B1 IC JC+1)
Return string from a buffer		(BUF.STR B1 IC JC)
Return all data from a row		(BUF.TXT B1 IC)

- For more commands, see p. 25-1 of the CODE V reference manual (pdf file)
- A list of all database items is found on p. 25B-1
 - Also, the prompting guide is a good quick reference for syntax (p. 157)



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CODE V 101, Slide 67

Odds & Ends: Files

- CODE V uses several files of the form *filename.ext*, where the *.ext* is descriptive of the type of file:
 - **.LEN** files are binary with all the LDM information
 - **.ENV** files are binary with all the GUI windows associated with a lens that is saved from the GUI
 - **.SEQ** files are ASCII files that contain CODE V commands and/or CODE V Macro-Plus
 - **.INT** files are ASCII files that typically contain interferogram information, but can be used for other purposes
 - **.MUL** files are ASCII files that contain multi-layer coating information
 - **.LIS** files are ASCII text output files
 - **.PLT** files are ASCII line plot files (HP plotting format)
 - **.RAS** files are ASCII raster plot files
 - **.V3D** files are ASCII V3D plot files

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CODE V 101, Slide 68

Odds & Ends: Files

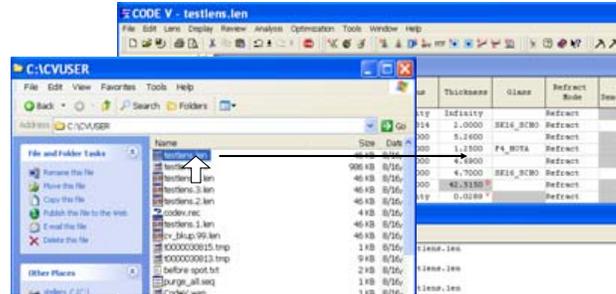
- CODE V supports file versioning, unless there is a space in the name
 - e.g. save a file 5 times → testlens.len (most recent)
 - testlens.4.len
 - testlens.3.len
 - testlens.2.len
 - testlens.1.len (oldest)

```

purge.seq
lib
pur *.seq
pur *.len
can
    
```

Purge command can clean up versioned files

Left-click on file in Explorer, drag to the right in open CODE V window.



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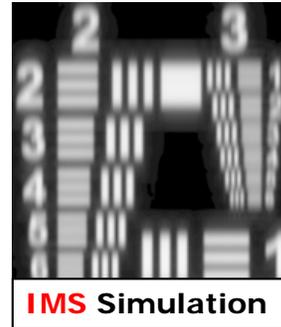
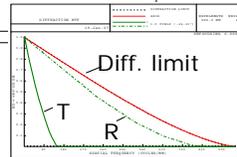
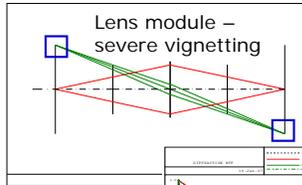
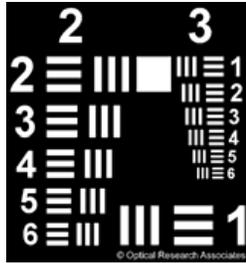
Odds & Ends: Strengths

- Other CODE V features to be aware of:
 - Global Synthesis®, a power global optimization algorithm
 - TOR, an accurate and extremely fast tolerance analysis method for MTF and RMS wavefront error
 - Much faster than Monte Carlo methods
 - The Field Map (FMA) option to plot various metrics across the 2D field (including Zernike wavefront coefficients)
 - Based on Dr. Kevin Thompson's and Dr. John Rogers' U of A doctoral work
 - Ideal for designing tilted & decentered systems
 - 2007 user group presentation, "Effective Use of the CODE V Field Map Option (FMA)" (www.oraservice.com)

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Odds & Ends: Strengths

- Other CODE V features to be aware of:
 - A COM API supporting CODE V interfaces with Excel, MATLAB, and other applications
 - *2D Image Simulation (IMS)*, the ability to simulate the appearance of an input .BMP object as imaged by the CODE V lens system



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CODE V 101, Slide 71

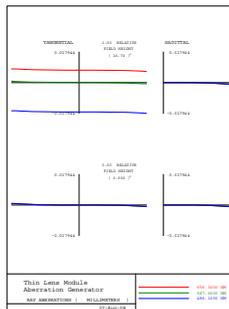
Odds & Ends: IMS Ex. (latcolor)

• Commands

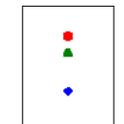
```
! Use aberration macro to setup lens module with 0.1 wvs spherical
in "c:\CODEV101\macro\aberrationgenerator.seq" 0 0 0.1 0 0 0 0
```

```
WL 656.3 587.6 486.1      ! add WL's
MCO S2 C7 3              ! 3 wvs W2 lateral color
MCO S2 C8 10             ! 10 wvs W3 lateral color
```

```
spo;go                  ! Spot diagram
ims;tgr 256; CME RGB; PDP YES; GO    ! Image simulation
```



Ray
Aberration
Curves
(RIM)



Spot
Diagram
(SPO)

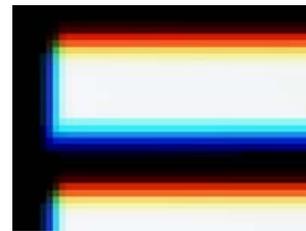


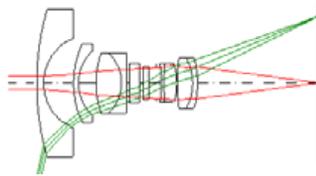
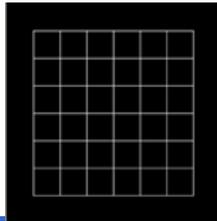
Image Simulation
(IMS)

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Odds & Ends: IMS Ex. (fisheye)

- Restore Fisheye
- Use field angles 0, 77 degrees
- **Analysis > Diffraction > Point Spread Function**
 - “Computation”, must use FFT Grid Size > 64
- **Analysis > Diffraction > 2D Image Simulation**
 - “Object Definition”, File grid400.bmp
 - “PSF Controls”, choose FFT Grid Size
 - “Color Controls”, set to RGB if color image
 - “Output Controls”, select Display PSF Map

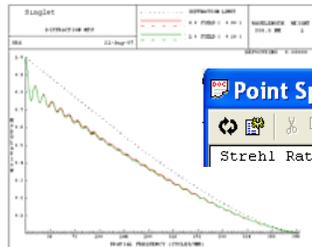


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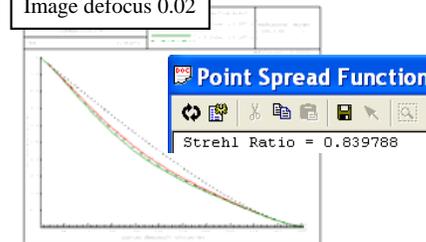
Odds & Ends: IMS Ex. (ripple)

- Restore singlet
- Change field angles to 0, 0.2 degrees
- Change S1 to user defined surface, name is cv_uds_sinusoid
- Conic constant -0.54
- Sinusoid wavelength 0.625
- Sinusoid amplitude 8.5e-5



Point Spread Function
Strehl Ratio = 0.837508

No sinusoid
Image defocus 0.02



Point Spread Function
Strehl Ratio = 0.839788

Wavefront Analysis

FIELD	FRACT	DEG	RMS (WAVES)
X	0.00	0.00	
Y	0.00	0.00	0.062533
X	0.00	0.00	
Y	1.00	0.20	0.065014

Wavefront Analysis

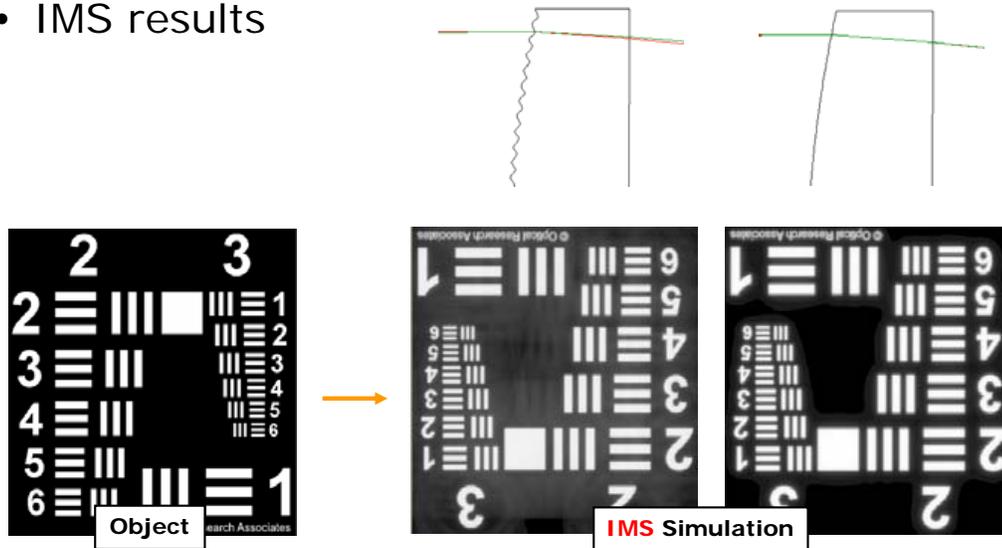
	FRACT	DEG	(WAVES)
X	0.00	0.00	
Y	0.00	0.00	0.057578
X	0.00	0.00	
Y	1.00	0.20	0.064580

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Odds & Ends: IMS Ex. (ripple)

- IMS results



- 2007 User Group presentation – “Slope Error Tolerances for Optical Surfaces”, Dr. J. Rogers, www.oraservice.com

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Odds & Ends: IMS Ex. (ripple)

- Commands

```
RES CV_LENS:SINGLET
YAN 0 .2
UDS S1
UMR UDS S1 CV_UDS_SINUSOID ; UMF UDS
S1
UCO S1 C1 -0.54
UCO S1 C7 0.625
UCO S1 C6 8.5E-005

MTF;GEO NO;NRD 128;PLO FRE Y;GO

PSF
TGR 512
NRD 128
COM YES
LIS YES
PLO YES
DIS YES
GO

WAV
BES NO; NOM YES;THR NO
NRD 128
GO
```

```
IMS
OBJ
C:\CODEV101\IMAGE\USAF1951_460KP.BMP
TGR 512
NRD 128
SYM ROT
PDP YES
GO
```

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Conclusions

- This covers a portion of the CODE V capabilities but should be enough for most of your classwork
- Be sure to submit your best CODE V project to our annual Student Design Contest (www.opticalres.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 those work that use CODE V or LightTools.
- Awards totaling **\$4,000** will be granted.
- Entry deadline is June 15. Winners will be announced in July.

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

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

COMPETITION RULES

FAQS

ENTRY FORM

Applications are invited for **The Michael Klöpper 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.

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