CODE V® 101

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

OPTICAL RESEARCH ASSOCIATES
3280 East Foothill Boulevard
Pasadena, California 91107 USA
(626) 795-9101 Fax (626) 795-0184
e-mail: service@opticalres.com
World Wide Web: http://www.opticalres.com

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

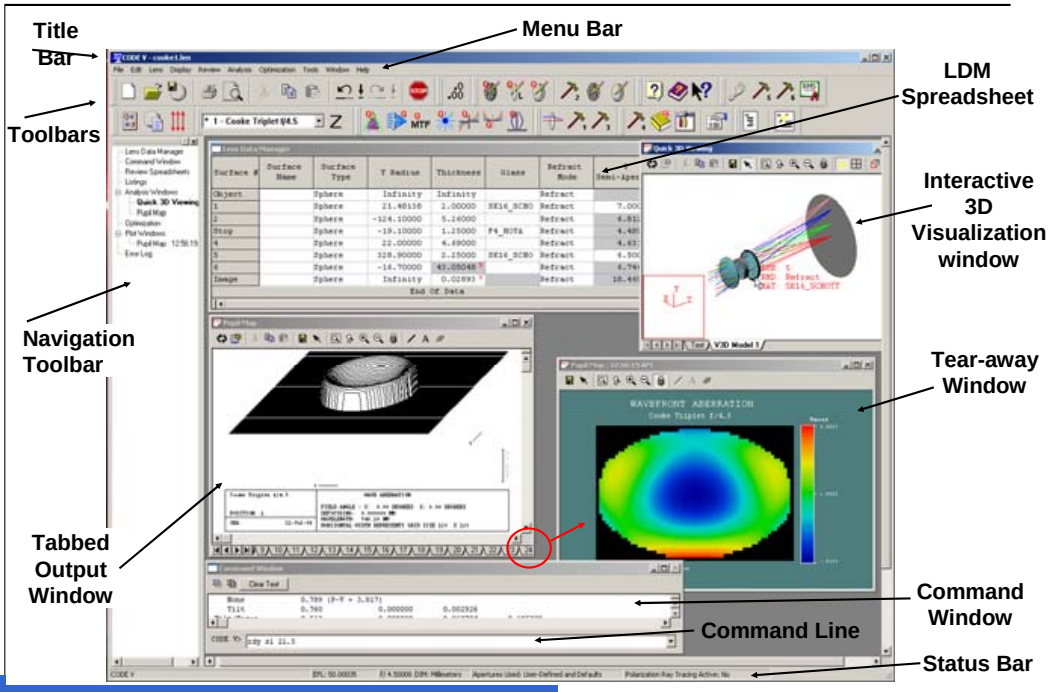
Purpose

- 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

Presentation Topics

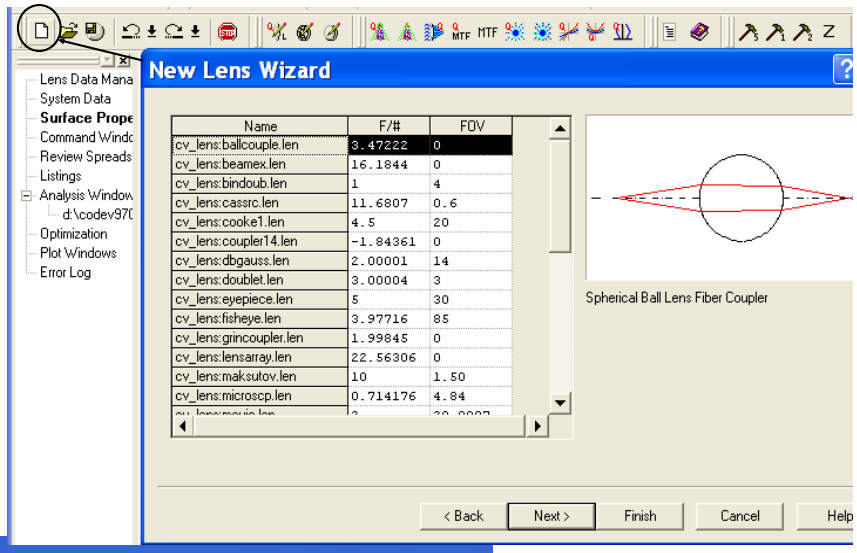
- Structure of CODE V
- Interface elements
- The Basics
  - How to enter a lens
  - How to analyze a lens
  - How to optimize a lens
- Resources for learning CODE V
- Frequently used analyses for homework
- *Useful supplied macros*
- *CODE V odds-&-ends*
- Conclusions

Interface Elements

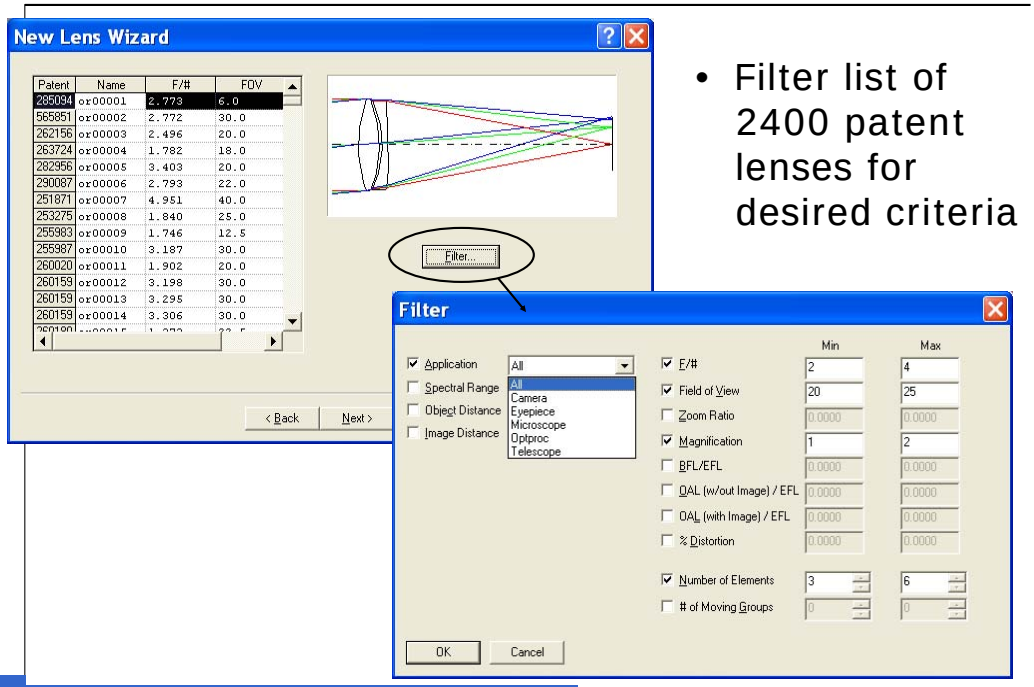


Opening a Lens

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



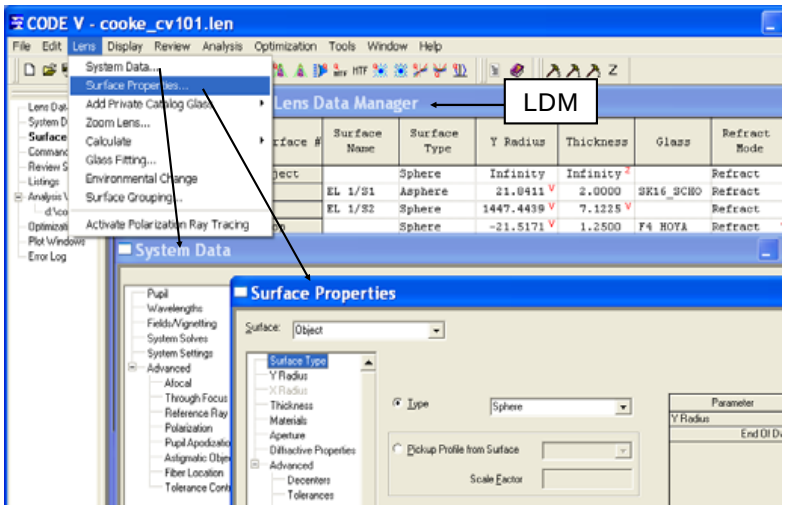
Opening a Lens



- Filter list of 2400 patent lenses for desired criteria

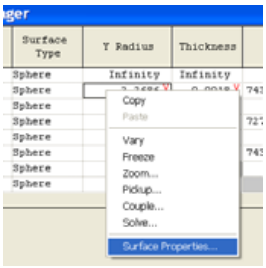
Data Entry

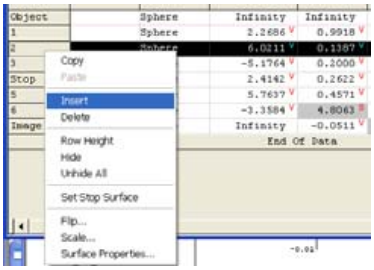
- 3 main windows for entering data
  - Lens Data Manager
  - System Data
  - Surface Properties



Data Entry

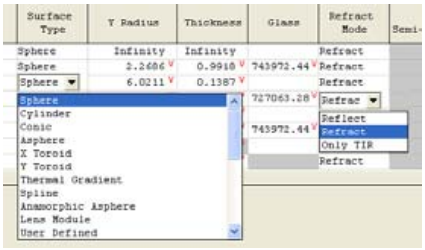
- Right-click for context sensitive menus





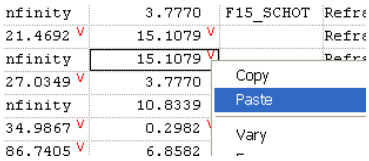
- Some operations (e.g. insert, delete) require you to highlight the row first

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



Data Entry

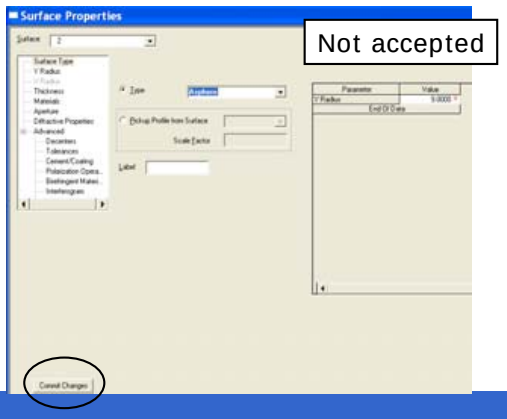
- Allows copy/paste of cell values or a range of cells



- Allows use of expressions in cells

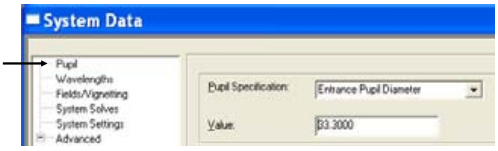
Data Entry

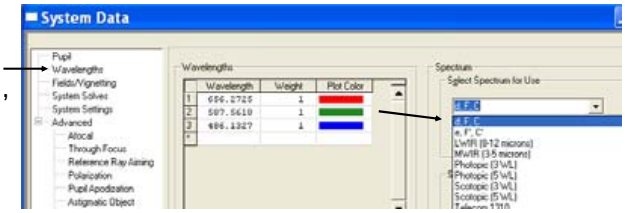
- Be sure that the program accepts data that is entered by one of these methods:
  - Clicking on a different cell
  - Clicking the “Commit Changes…” button
  - Hitting the TAB key
  - Hitting the ENTER key

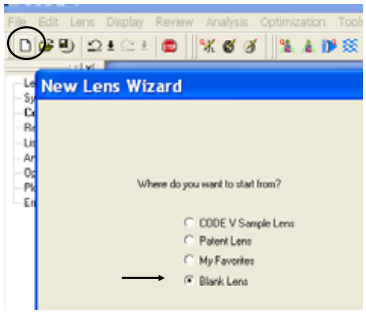


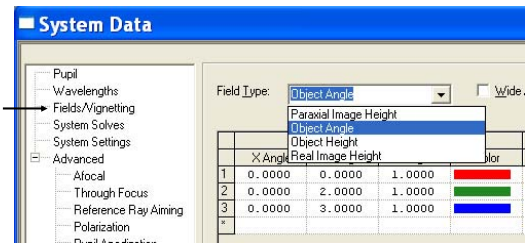
Data Entry – Ex. Doublet

- 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



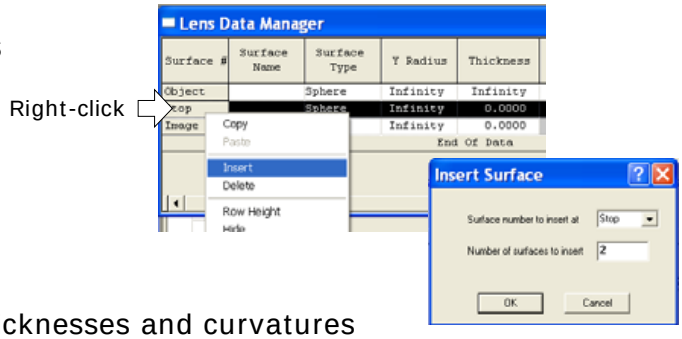




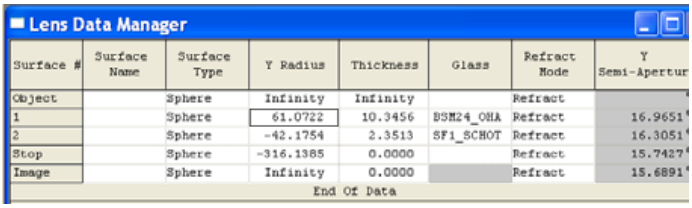


Data Entry – Ex. Doublet

- Insert 2 surfaces

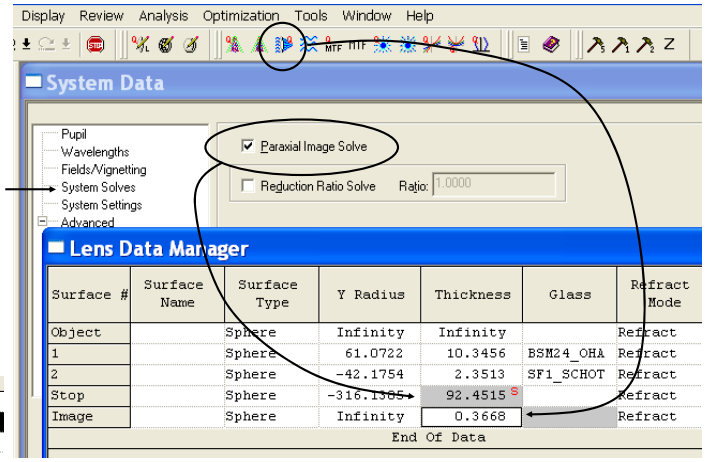


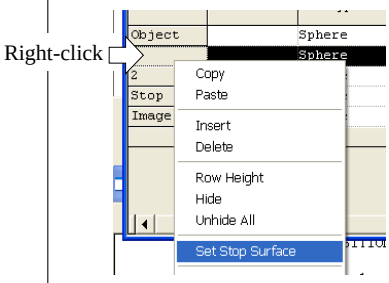
- Enter data for thicknesses and curvatures
  Type BSM24 and SF1 for glass material
  (automatically searches the catalogs)



Data Entry – Ex. Doublet

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





- Set surface 1 to be the stop

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
```


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

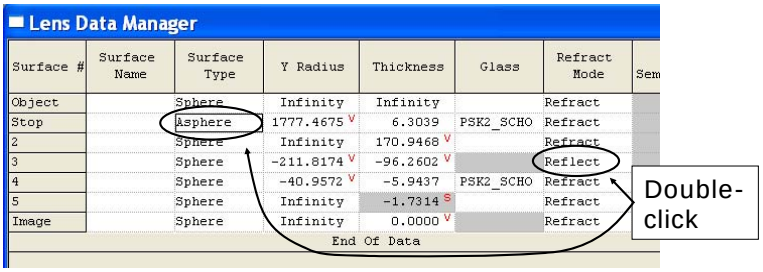
- Insert 4 surfaces, and make surface 1 the stop

Lens Data Manager

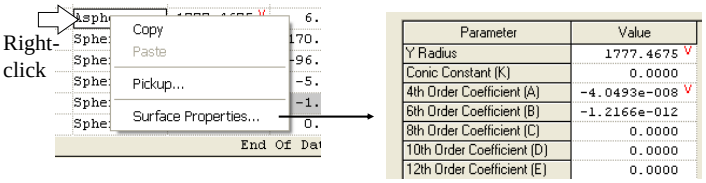
Surface #	Surface Name	Surf Ty
Object		Sphere
Stop		Asphe
2		Sphere
3		Sphere
4		Sphere
5		Sphere
Image		Sphere

Data Entry – Ex. Reflective

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



- Access Asphere coefficients in Surface Properties window



Data Entry – Ex. Reflective

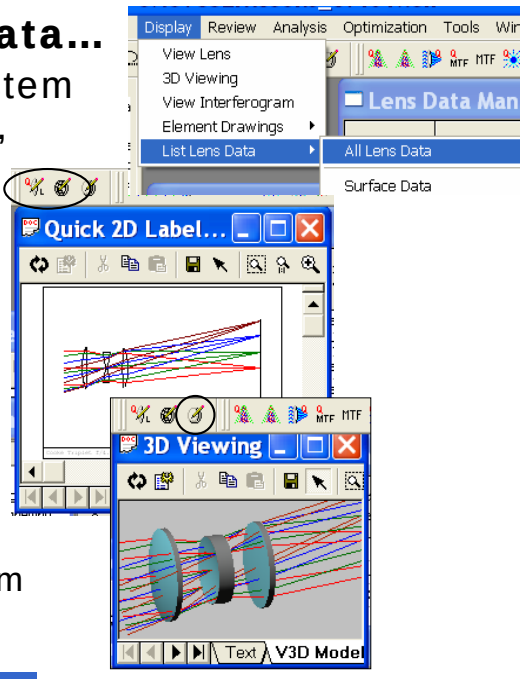
- Commands (copy and paste to the command line)

```
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" (www.oraservice.com)

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

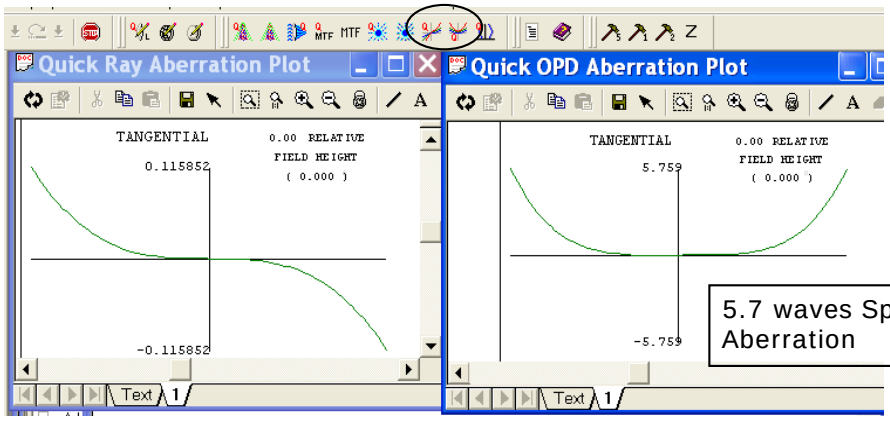


Homework Analyses

- **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

Homework Analyses

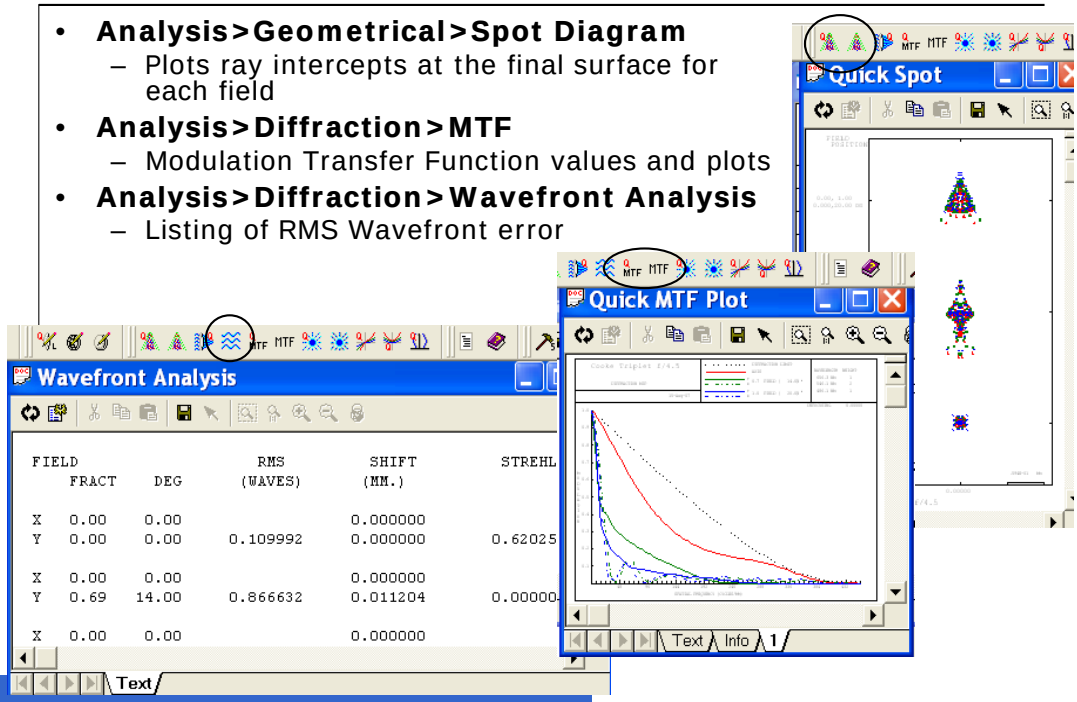
- **Analysis>Diagnostics>Ray Aberration Curves** or **OPD Aberration Curves**
  - Useful for determining which aberrations are present in the lens
  - Quick buttons actually run a macro which does autoscaling



5.7 waves Spherical Aberration

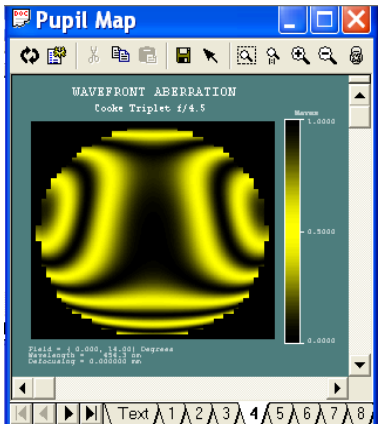
Homework Analyses

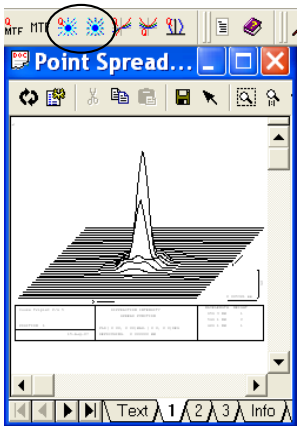
- **Analysis>Geometrical>Spot Diagram**
  - Plots ray intercepts at the final surface for each field
- **Analysis>Diffraction>MTF**
  - Modulation Transfer Function values and plots
- **Analysis>Diffraction>Wavefront Analysis**
  - Listing of RMS Wavefront error



Homework Analyses

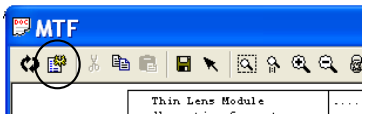
- **Analysis > Diagnostics > Pupil Map**
  - OPD or intensity plot of wavefront at the exit pupil
- **Analysis > Diffraction > Point Spread Function**
  - Intensity plot of the PSF





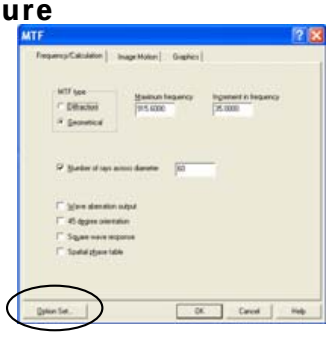
Homework Analyses

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



(quick options don't allow this)

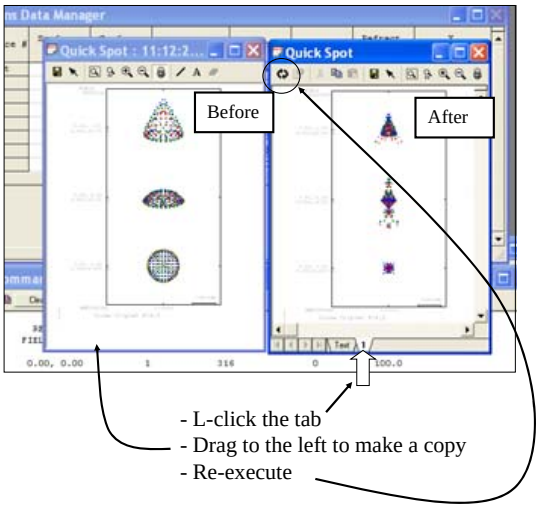
- **Option Set... button allows you to save your options to apply in the future**



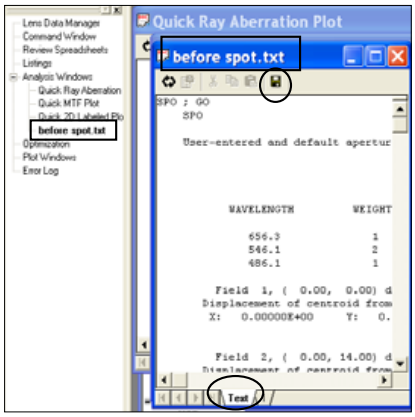
*** Leave windows open so you can re-execute with the same options**

Homework Analyses

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

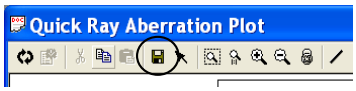


- Or save the text as a .txt file to see the name change in the navigation tree



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**

Demo – Setup Lens

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

Demo – Run Analysis

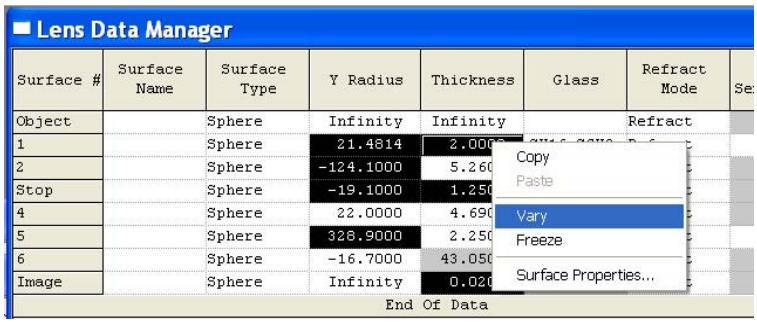
- Analysis > Diffraction > MTF, maximum freq. 68, increment freq. 17
- Analysis > Geometrical > Spot Diagram, select Aberration Scaling, Value 0.02
- Analysis > Diagnostics > Ray Aberration Curves, change Scale to 0.02

Optimizing a Lens

- One of CODE V's main strengths is the effectiveness of its optimization algorithms
  - In particular, CODE V's ability to control constraints exactly works better than any other commercial software
- CODE V optimization is easy to use, with very little input required by you in many cases
  - This is mainly achieved through CODE V's use of intelligent defaults
  - However, the **Automatic Design** feature is also flexible and you can control many details of the optimization if you wish to

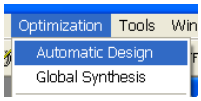
Optimizing a Lens

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



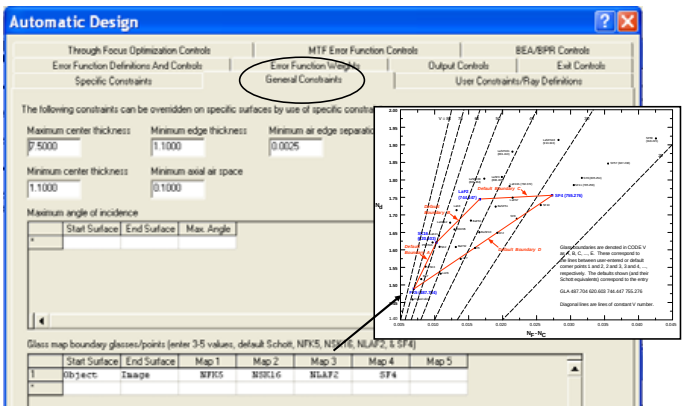
Optimizing a Lens

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



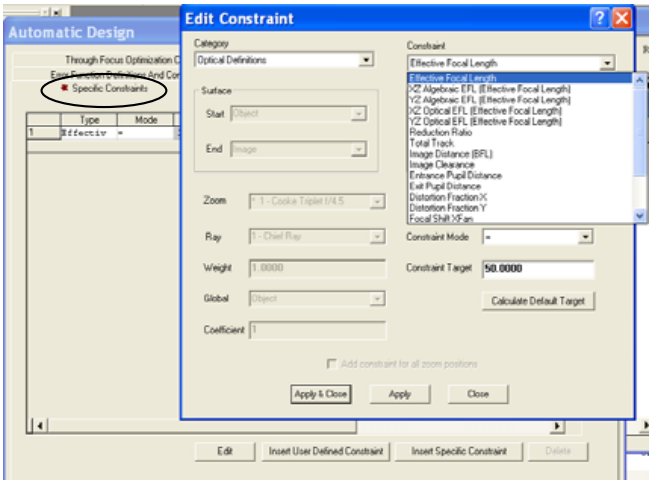
General constraints are limits placed on thicknesses for all surfaces.

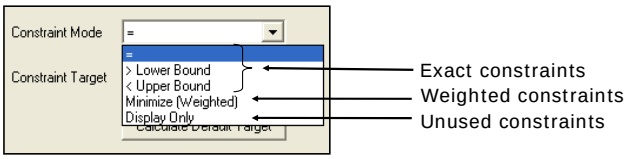
The glass map defines the boundary of glasses when varying the refractive index (**Tools > Macro Manager > Sample Macros > Materials Info > vp_plot.seq**)



Optimizing a Lens

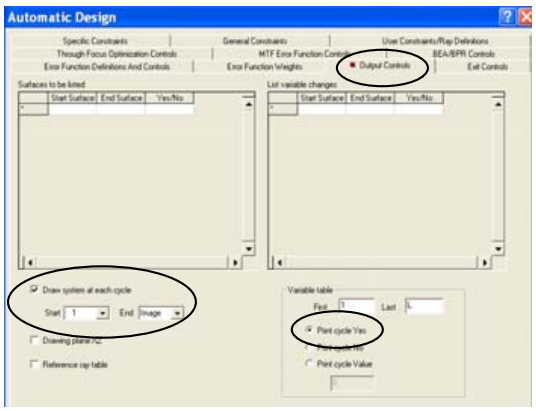
- Define any specific constraints (EFL, distortion, surface thicknesses, ray trace data, etc.). These may override general constraints.
- Note: exact constraints handled by linear algebra solutions (Lagrange multipliers) separate from error function, weighted constraints included in error function.

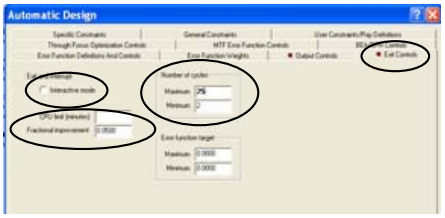




Optimizing a Lens

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





Demo - Optimization

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

Demo - Optimization

- Commands

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

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

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


Demo - Optimization

- Commands (cont'd)

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

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

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

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

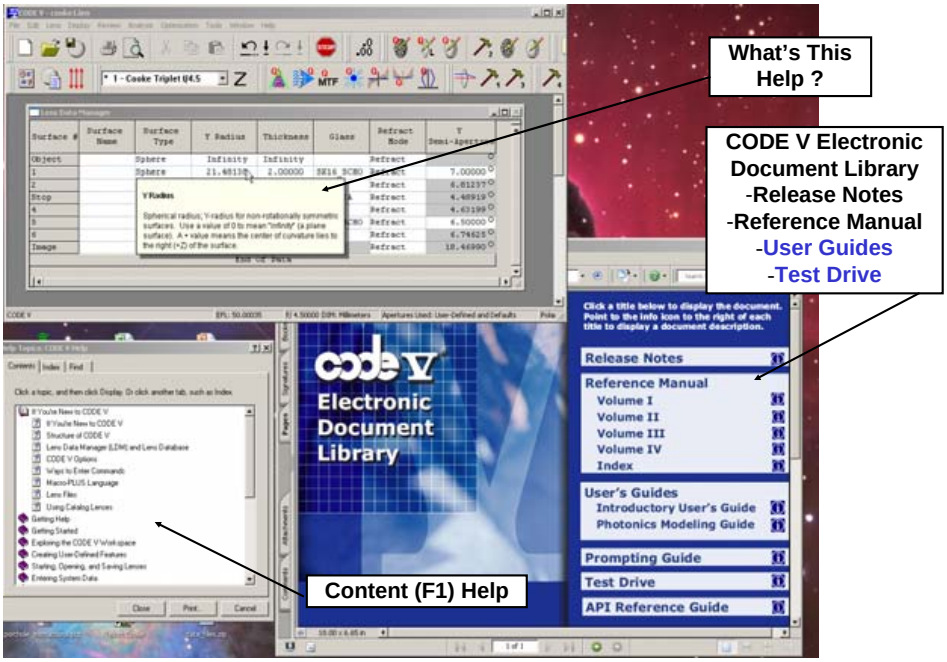
Resources for Learning CODE V

- 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

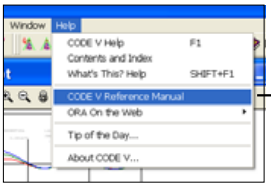
Optics 101
Digital Camera
User Interface
Tech Talk
Apertures/Vignetting
Performance Eval.
Optimization
Reflective Systems
Tilts/Decenters
Non-Spherical
Afocal
Zoom
Tolerance Analysis
Macros

CODE V Help Features

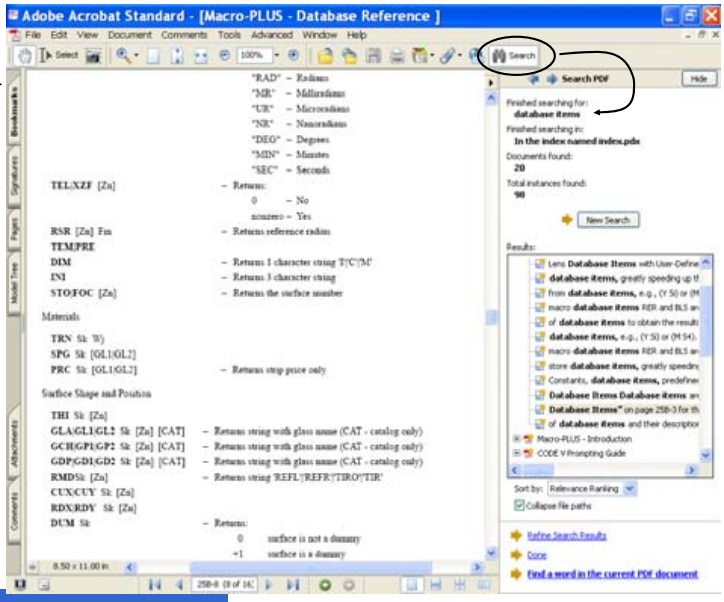


CODE V Help

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

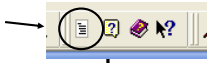


e.g. Search on "database items" provides links to syntax for various database info (curvatures, thicknesses, pupil size… any CODE V info)



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



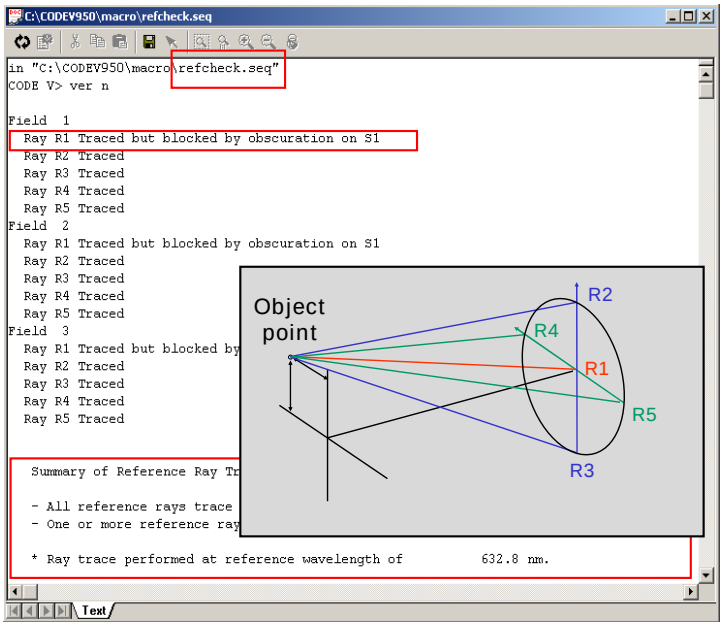
- You can add sample macros that you use frequently to a menu or to a toolbar

Useful CODE V Macros

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

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



Material Info: GLASSFIT

Lens Data Manager

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

N = 1.517
V = 64.2

Fictitious glass varied during optimization.

Command Window

Clear Text

```
Surface   1  Nd = 1.51700  Vd = 64.2000

 Fit Catalog      Glass         Delta Nd  Delta Vd  Avail  Price  DPF  Bubl  Stain
   1  SCHOTT      UBK7           0.00020  -0.0898     2     0.00   -4    0     0
   2  SCHOTT      NBK7           0.00020   0.0326     0    12.00   -6    0     0
   3  HOYA        BSC7           0.00020   0.0017    11     0.00  -12   Nul    1
   4  OHARA       SAPL1         -0.00028  -5.3633    25     0.00   35   Nul    -
   5  OHARA       SNSL36        -0.00042  11.7691    22    35.00   21   Nul    -

Input task choice:
```

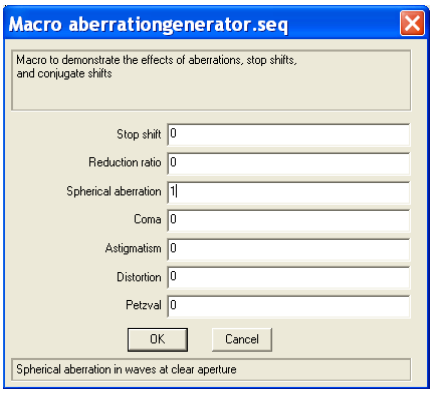
After optimization, substitutes real glasses that are close matches.

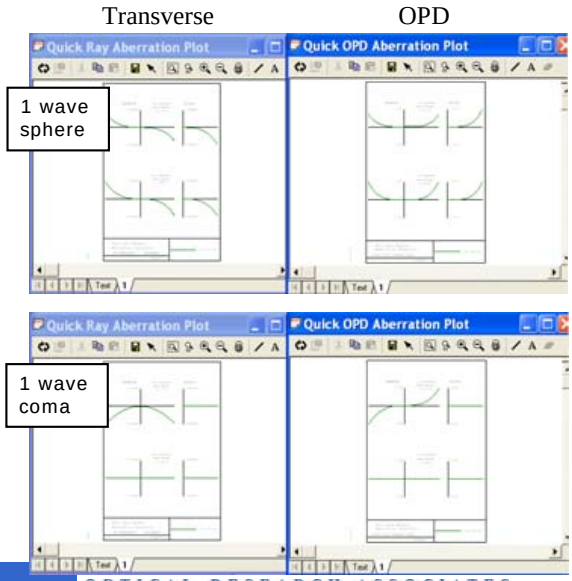
- Also under menu **Lens > Glass Fitting …**

Utilities: Aberration Generator

- ABERRATIONGENERATOR.SEQ sets up a lens module with user defined amounts of aberrations

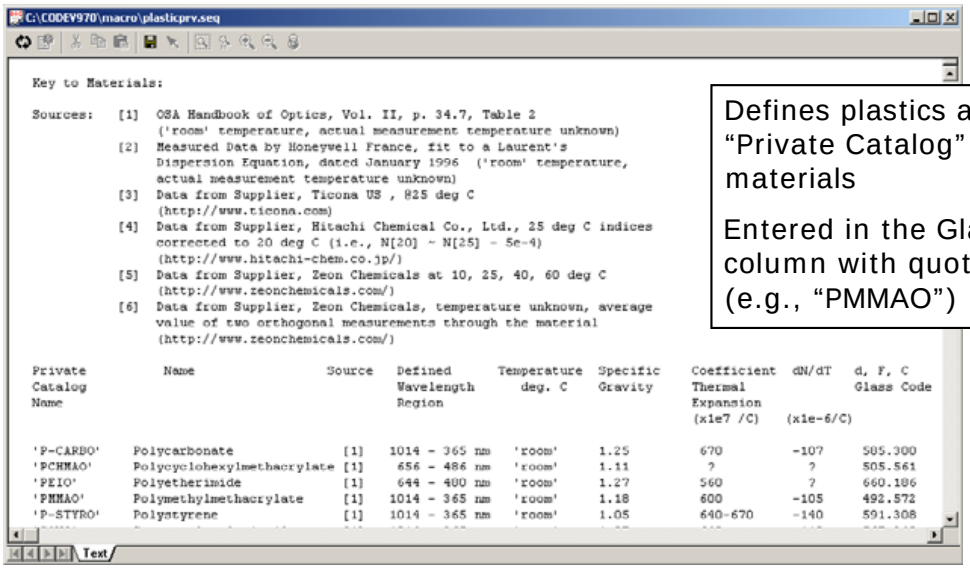
  – Characteristic curves for image plane transverse ray aberrations and exit pupil OPD aberrations can be viewed.





Material Info: PLASTICPRV

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

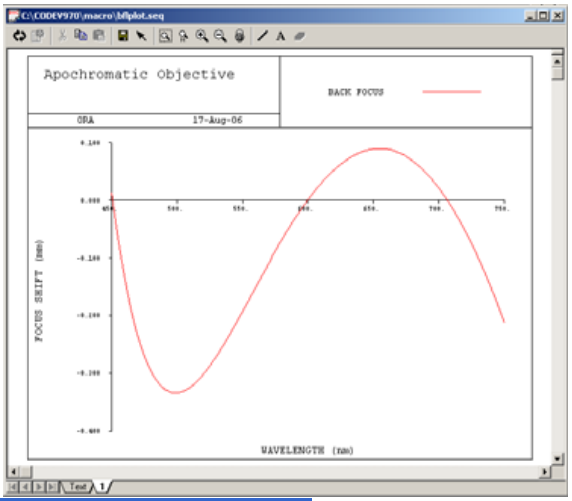


Defines plastics as "Private Catalog" materials

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

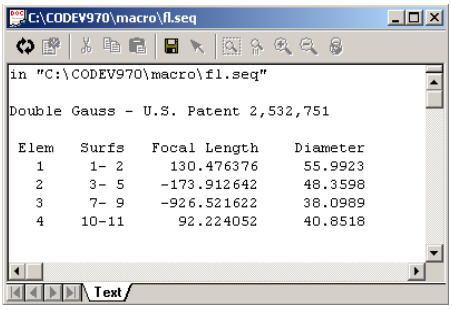
1st ORDER ANALYSIS: BFLPLOT

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

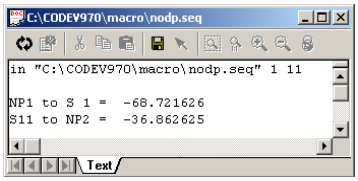


1st ORDER ANALYSIS: FL & NODP

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

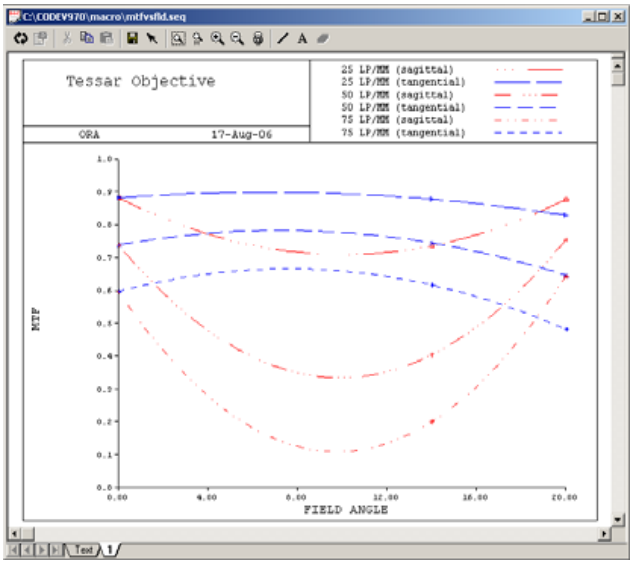


- NODP.SEQ computes and lists the Nodal Point positions for the designated surface range



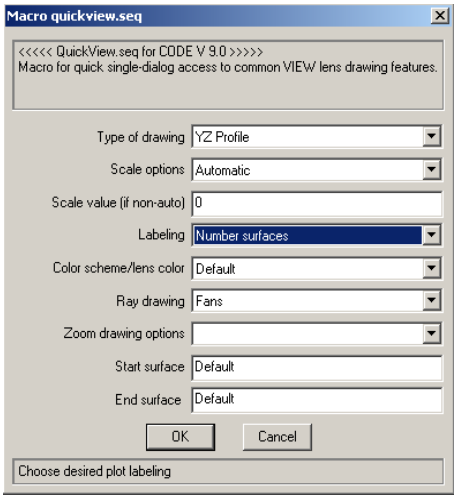
DIFFRACTION ANALYSIS: MTFVSFLD

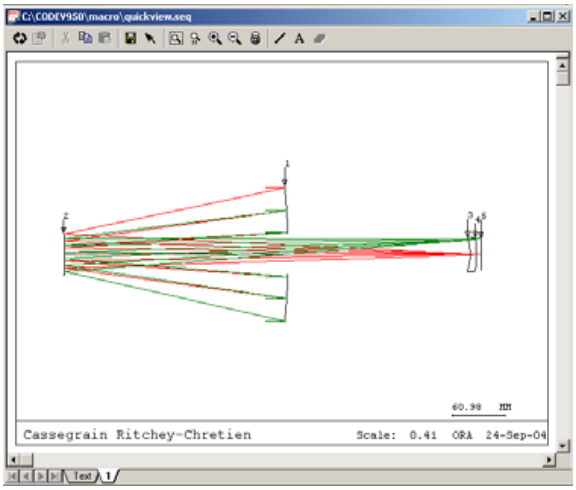
- MTFVSFLD.SEQ creates a plot of the MTF as a function of field



UTILITIES: QUICKVIEW

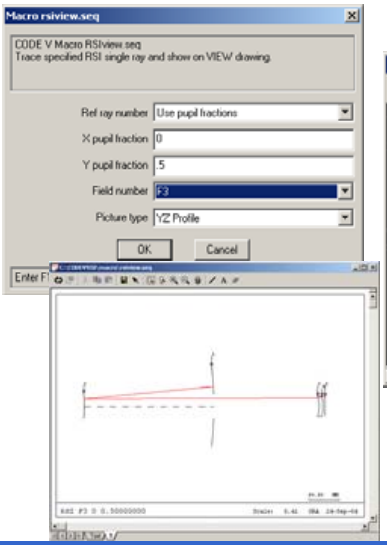
- QUICKVIEW.SEQ provides a simple one tab dialog with access to the most frequently utilized **Display > View Lens ...** choices

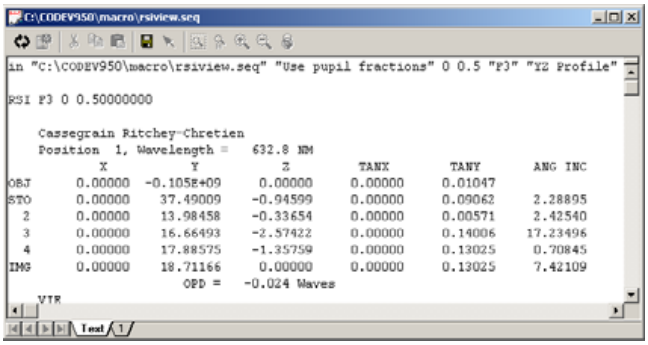




UTILITIES: RSIVIEW

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





FABRICATION SUPPORT: LENSTABLE

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

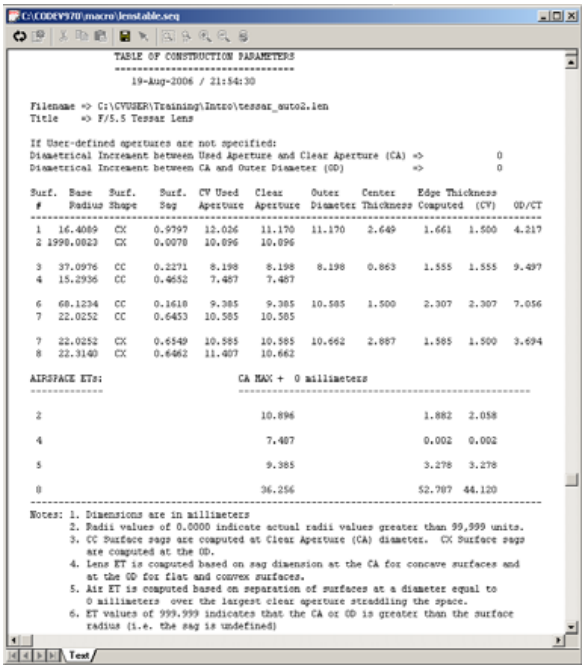


TABLE OF CONSTRUCTION PARAMETERS

19-Aug-2006 / 21:54:30

Filename => C:\CVUSER\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 Radius	Surf. Shape	Surf. Sag	CV Used Aperture	Clear Aperture	Outer Diameter	Center Thickness	Edge Thickness Computed (CV)	OD/CT
1	16.4089	CX	0.9797	12.026	11.170	11.170	2.649	1.661	1.500	4.217
2	1990.0823	CX	0.0070	10.096	10.096					
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					
7	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					

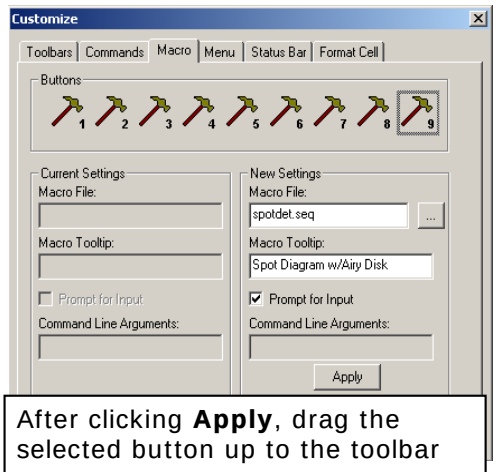
AIRSPACE ETs: CA MAX + 0 millimeters

2	10.896	1.882	2.058
4	7.487	0.002	0.002
5	9.385	3.278	3.278
8	36.256	52.707	44.120

Notes: 1. Dimensions are in millimeters
2. Radii values of 0.0000 indicate actual radii values greater than 99,999 units.
3. CC 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)

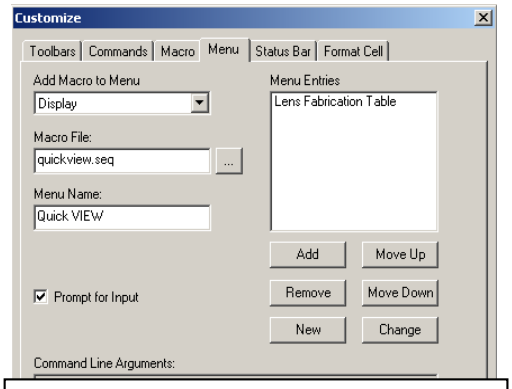
Interface Customization

- 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

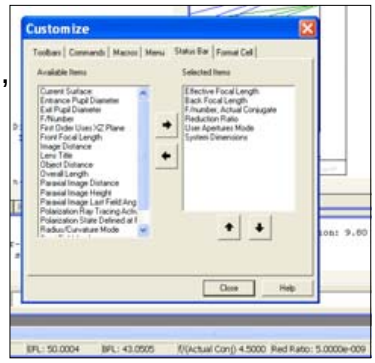
Hovering the mouse over the button will show the macro tooltip

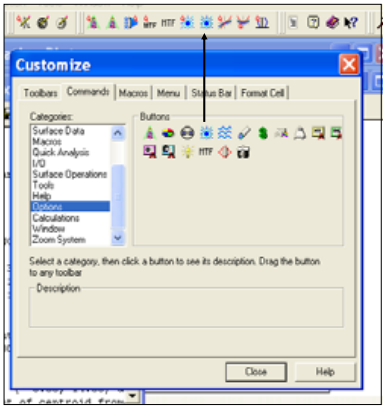


Click **Add** to add the macro to the menu. For both tool buttons and menus, if the macro has an input dialog, be sure to check **Prompt for Input**

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.

CODE V ODDS-&-ENDS

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

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

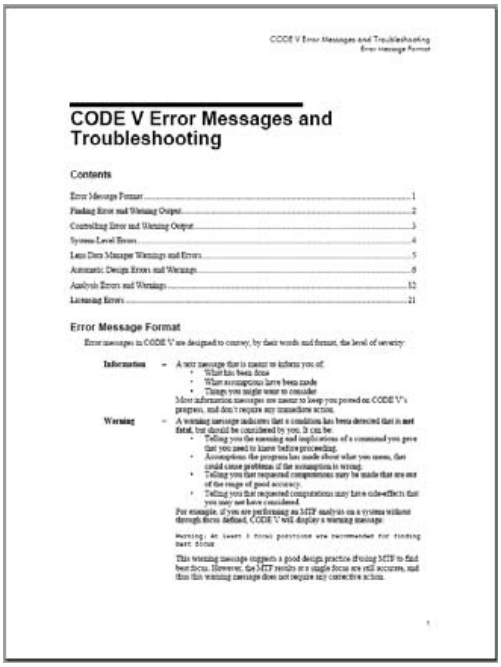
Odds & Ends: Warnings/Errors

- 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

Odds & Ends: Warnings/Errors (2)

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


CODE V Error Messages and Troubleshooting

Contents

Error Message Format

Demo:

RES CV_LENS:DBGAUSS
TOW PSF;GO

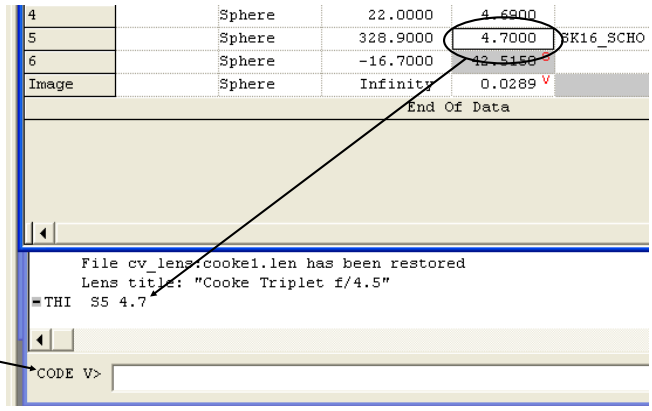
Search help for “There are energy levels as great”

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.

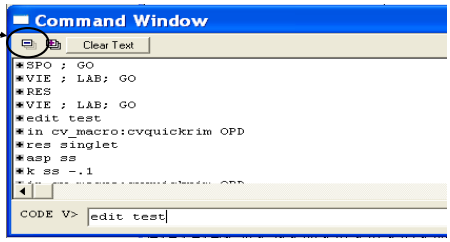
Typing this expression at the CODE V> prompt would do the same action.

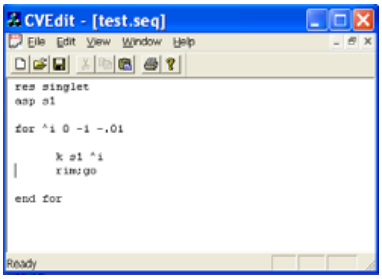


- Use commands and macros to save time

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

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 p1..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
```

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
```


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
```

Odds & Ends: Commands vs. GUI

- **Ex. – Use database items to calculate desired data**
  - **CODE V >** in calc_sf 1

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
```


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

    wl ^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
```

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
```


Odds & Ends: Commands vs. GUI

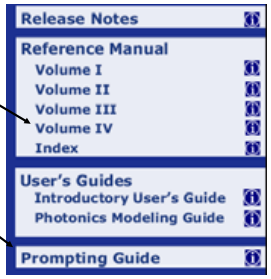
- Common commands

		Database item
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)	

Odds & Ends: Commands vs. GUI

	Database item
List buffer contents	Buf lis b1
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)



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

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)

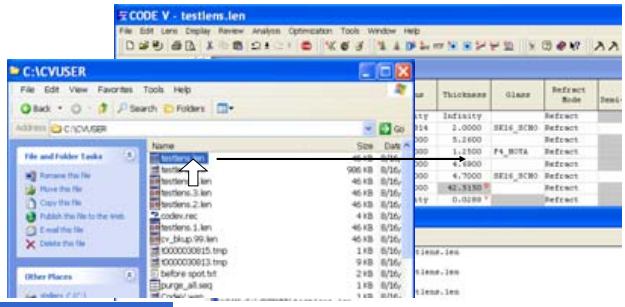
Purge command can clean up versioned files

purge.seq

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

- CODE V supports click and drag to open files

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

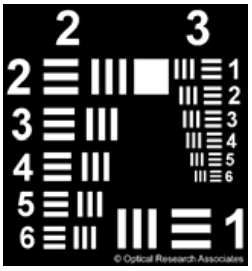


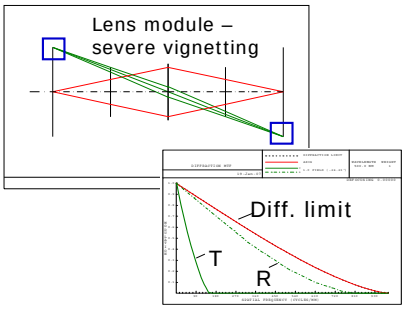
Odds & Ends: Strengths

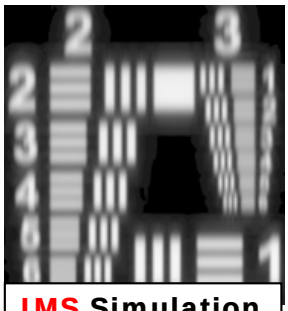
- Other CODE V features to be aware of:
  - Global Synthesis®, a power global optimization algorithm
  - TOR, an accurate and extremely fast tolerance analysis method for MTF and RMS wavefront error
    - Much faster than Monte Carlo methods
  - The Field Map (FMA) option to plot various metrics across 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)

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*







IMS Simulation

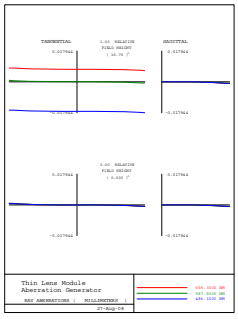
Odds & Ends: IMS Ex. (latcolor)

- Commands

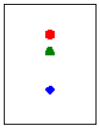
```
! Use aberration macro to setup lens module with 0.1 wvs spherical
in "c:\CODEV101\macro\aberrationgenerator.seq" 0 0 0.1 0 0 0 0

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)

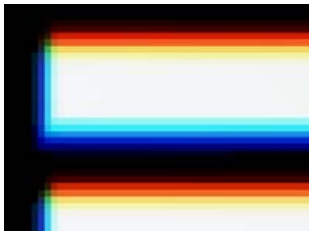
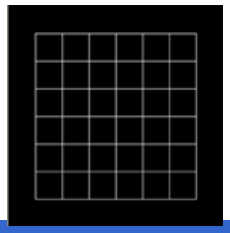
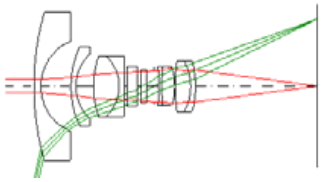


Image Simulation (IMS)

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





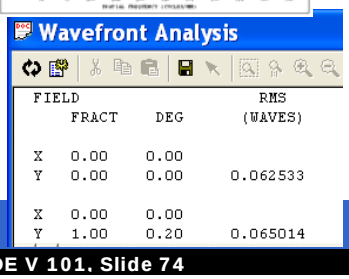
IMS Simulation

OPTICAL RESEARCH ASSOCIATES

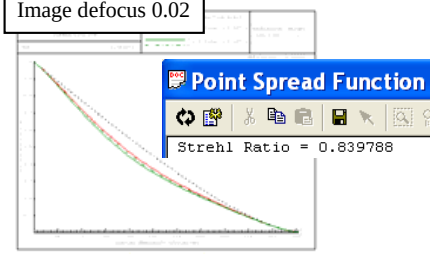
CODE V 101, Slide 73

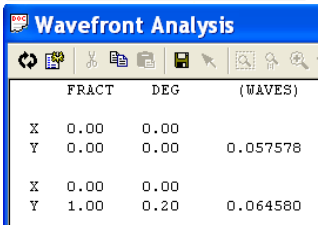
Odds & Ends: IMS Ex. (ripple)

- 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



No sinusoid
Image defocus 0.02



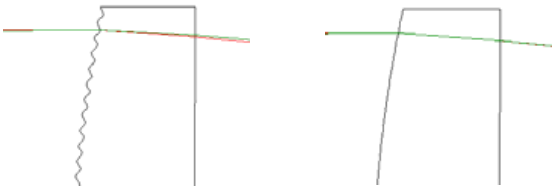


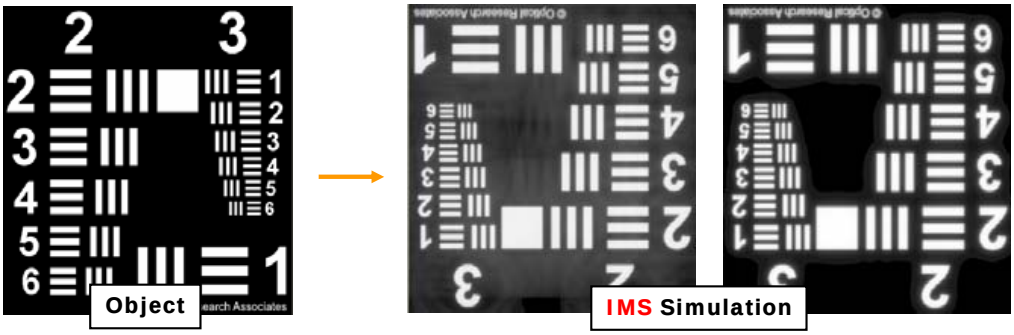
OPTICAL RESEARCH ASSOCIATES

CODE V 101, Slide 74

Odds & Ends: IMS Ex. (ripple)

- IMS results





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

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
```

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