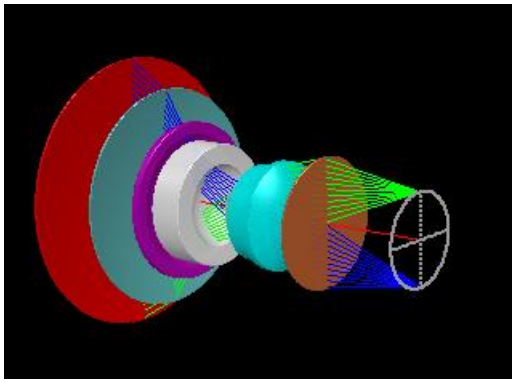
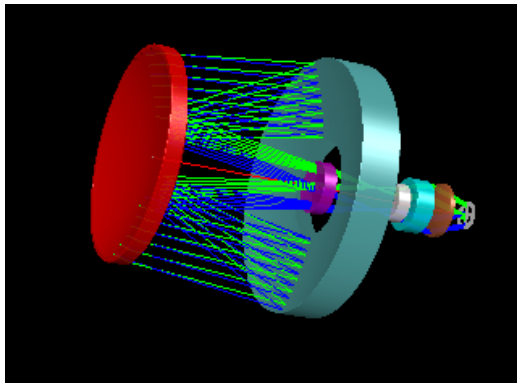
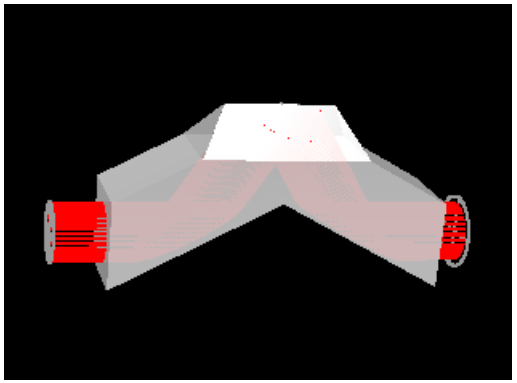
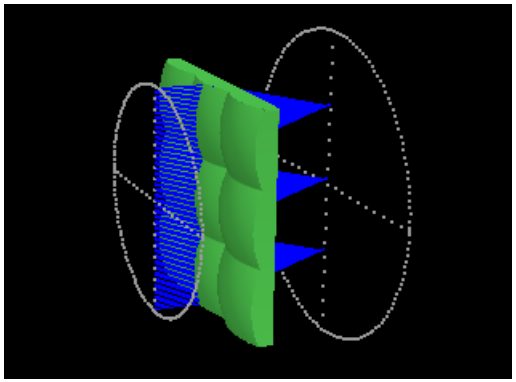
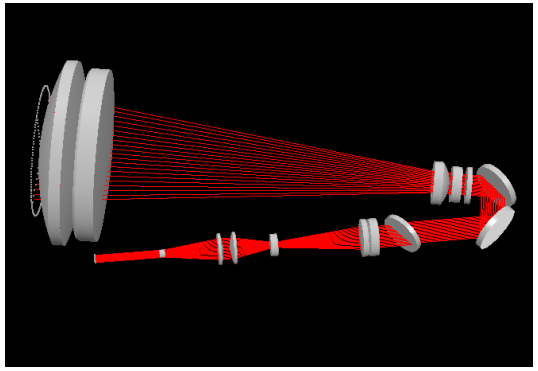
Comparison: SYNOPSYS™ *vs.* Code-V™

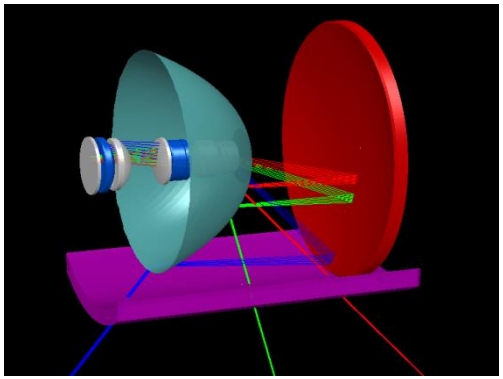








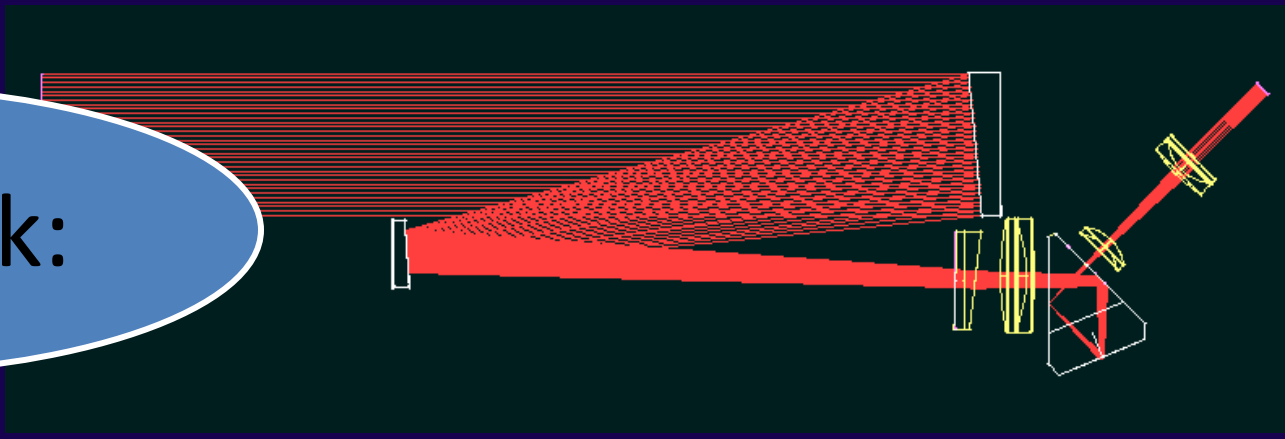




Disclaimer

- All of the information presented here is based on comments we have received from Code-V users and our reading of their documentation.
- It is our intention – and our belief – that everything contained here is correct.
- If you believe that any claims are not accurate, and have evidence to the contrary, please bring the matter to our attention. We want this comparison to be as complete and accurate as possible.

In This Talk:



- Brief comparison: SYNOPSYS vs. Code-V™
- Features
- Ease of use
- Documentation
- Feedback from users

What is SYNOPSYS?

- SYNthesis of OPtical SYStems
- Started in 1962
- First ran on vacuum-tube computer!
- First used on Apollo project at MIT
- First commercial use in 1976
- Under continuous development since then
- Updates are released about every two weeks.

Similar concepts

- Both have a command language.
- Both have a graphical user interface (GUI)
- Both have a great many features
  - Each has features not found in the other

Similar features

- Aspherics
- Diffractive elements
  - HOEs, DOEs, gratings
- Gradient index materials
- Statistical tolerancing
- Monte-Carlo simulation
- Diffractive propagation
- Gaussian beam trace
- MTF optimization
- Polarization raytracing
- Infrared materials catalog
- Narcissus evaluation and control
- Ghost image evaluation
- MTF, spot diagram, wavefront analysis
- Throughput calculation
  - Absorption
  - Coatings
- Nonsequential raytracing

SYNOPSYS™ can read many seq files written by Code-V

Major differences

- Faster optimization
  - Code-V optimization is based on DLS method
  - SYNOPSYS™ uses the PSD III method

Why wait for your results?

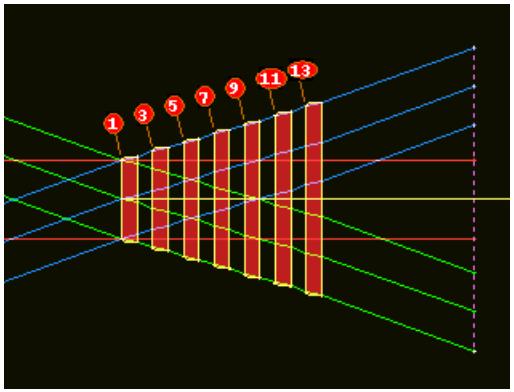
SYNOPSYS™ has the fastest lens optimization in the world.

Is PSD III better?

- You bet!

We gave SYNOPSYS™ and
Its competitors a simple problem:

7 elements
All plano
Thicknesses and airspaces 5 mm
All elements Nd 1.6 Vd 50
Back focus 50
Infinite object, 40-degree TFOV,
25.4 mm pupil diameter,
CdF lines, equal weights.

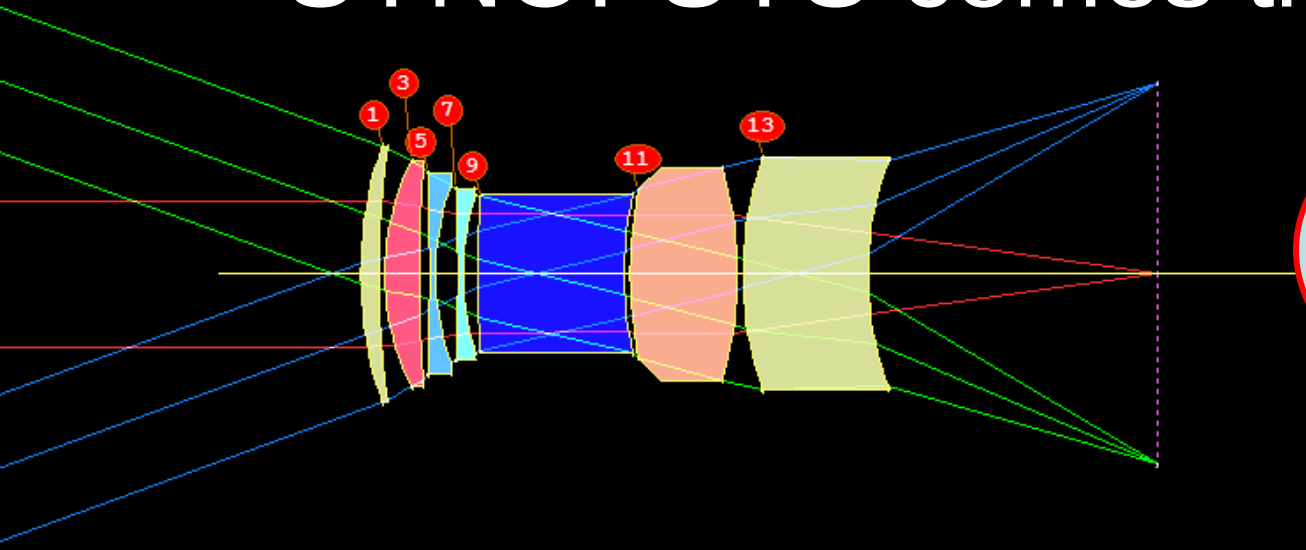


Optimization time
no more than
15/S, where
S is the CPU speed.

Those are the rules:

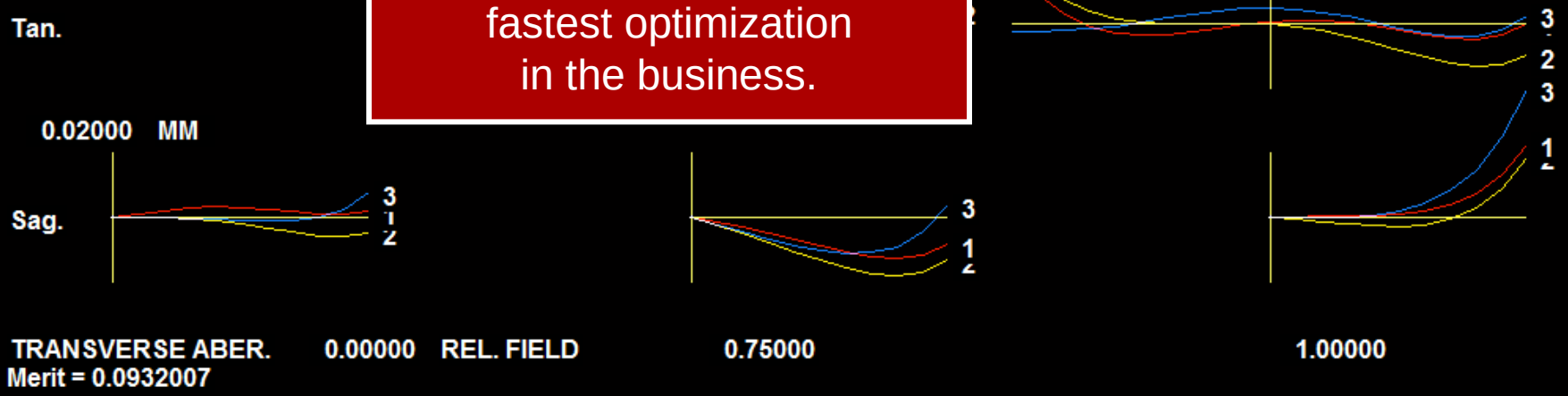
And the results…

SYNOPSYS comes through!



SYNOPSYS™: Average RMS spot: 6.9 uM

SYNOPSYS™ has the fastest optimization in the business.



Compare optimization methods:

Code-V

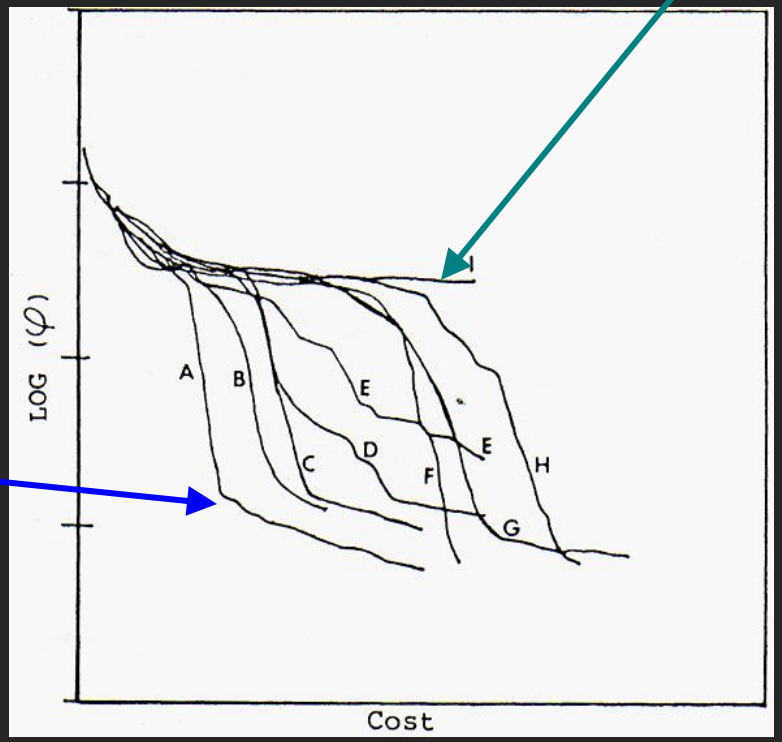
- Proprietary
  - DLS based

SYNOPSYS

- PSD III

DLS

PSD III

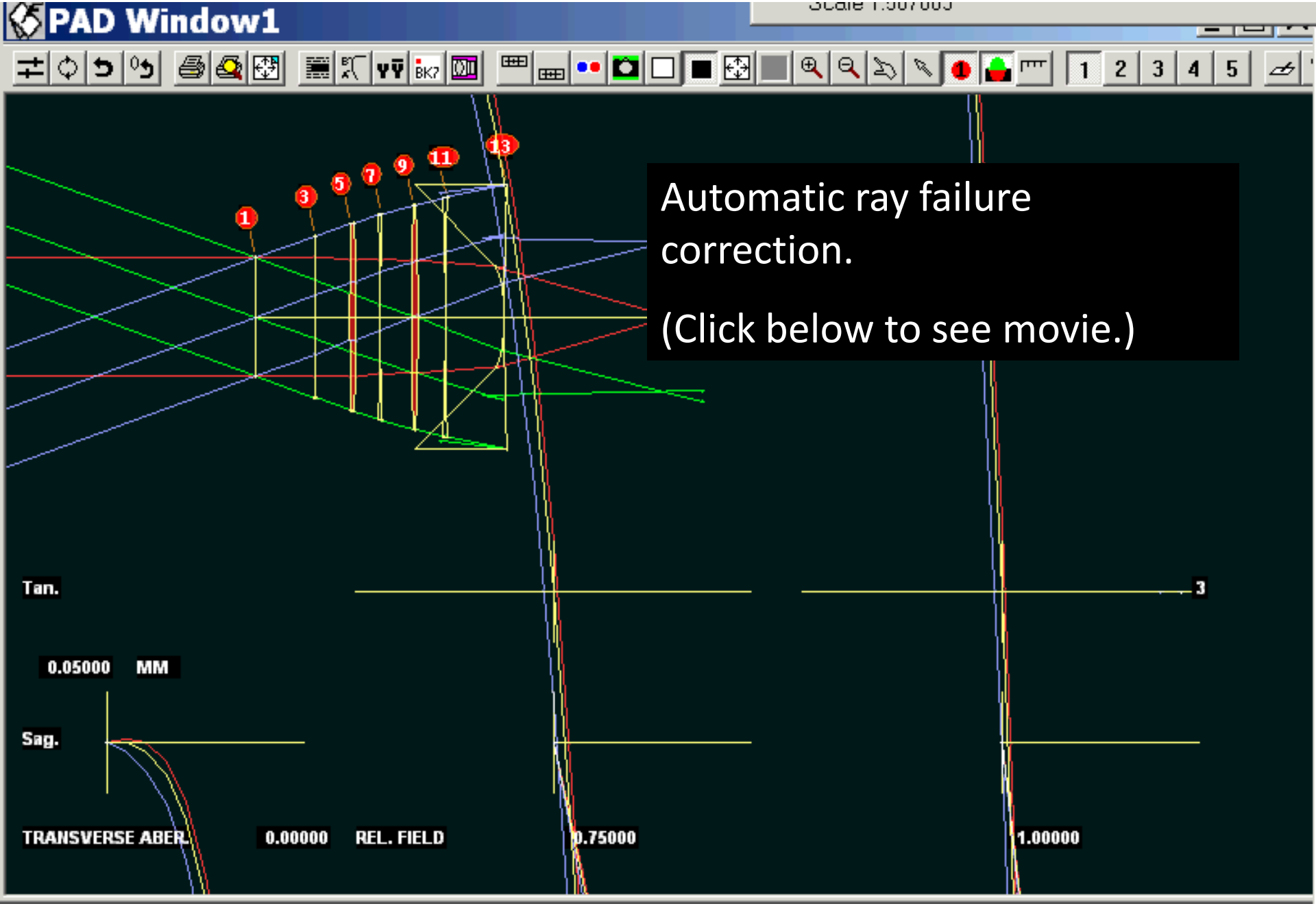


The Scorecard:

	SYNOPSYS	ZEMAX	CODE-V
CPU speed	2.0 GHz	2.4 GHz	2.0 GHz
Time limit	4.89 sec.	6.25 sec.	7.5 sec.
Ave. RMS	6.9uM	>150	364.7
Time to get this quality	1.88 sec.	3600 sec. (1 hour)	2400 sec. (40 minutes)
Cores used	1	2	2
Times slower	-	1915	320

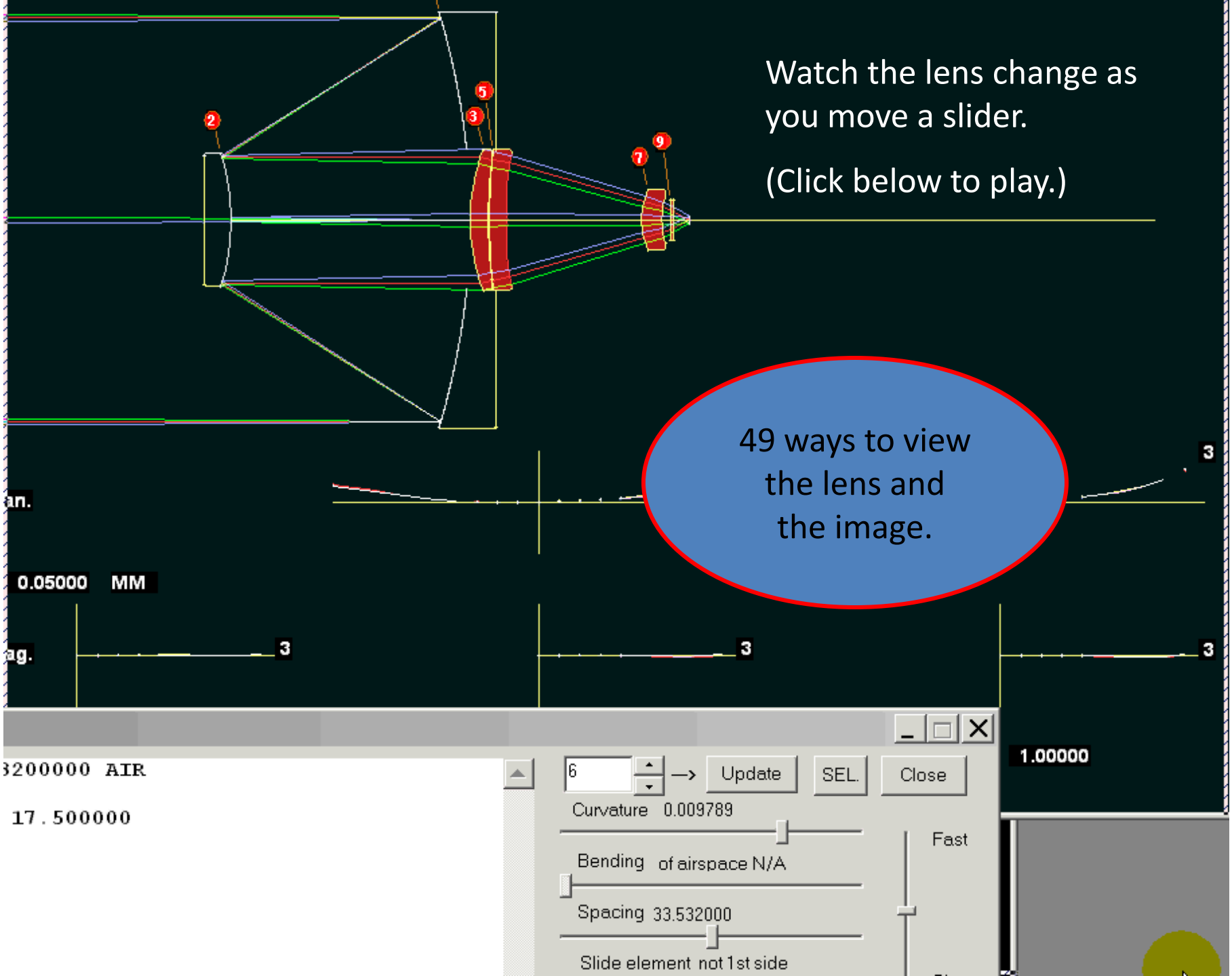
More differences

- SYNOPSYS™ has the fastest ray-failure correction in the business.
- Watch the movie on the next slide. See how SYNOPSYS™ can optimize a system even though rays will not trace through the starting lens.

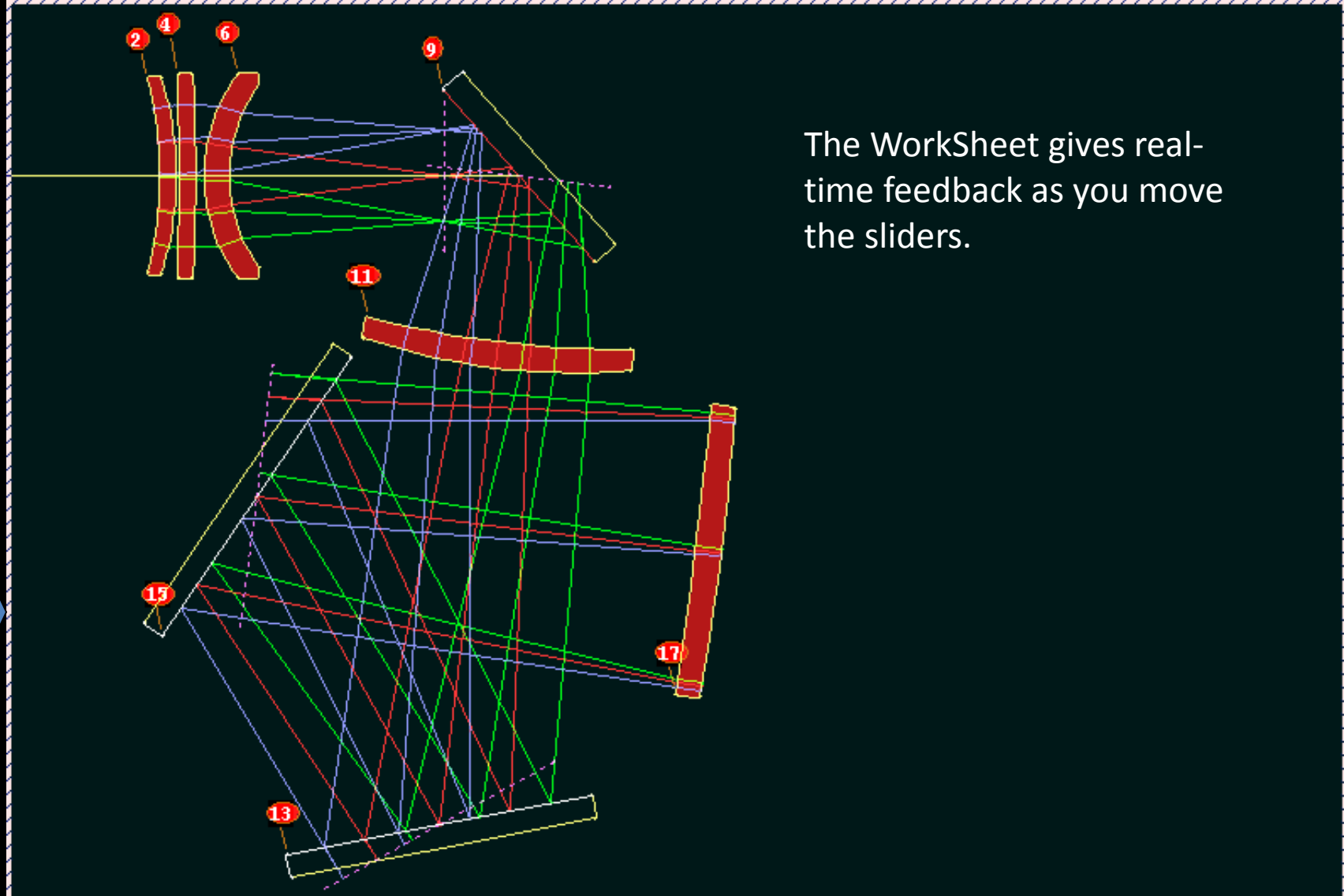

PAD Window1
1
2
3
4
5
1
3
5
7
9
11
13
Automatic ray failure correction.
(Click below to see movie.)
Tan.
3
0.05000 MM
Sag.
TRANSVERSE ABER
0.00000
REL. FIELD
0.75000
1.00000

User-assignable sliders

- SYNOPSYS™ can alter lens parameters with sliders in the WorkSheet™
  - Watch the image change as you change a radius, thickness, or the bending of an element
  - Code-V has no sliders
- Watch the movie on the next slide. See how you can change a parameter and see the results instantly.


Watch the lens change as you move a slider.
(Click below to play.)
49 ways to view the lens and the image.
0.05000 MM
1.00000
3200000 AIR
17.500000
6
Update
SEL.
Close
Curvature 0.009789
Bending of airspace N/A
Spacing 33.532000
Slide element not 1st side
Fast

Click



The WorkSheet gives real-time feedback as you move the sliders.

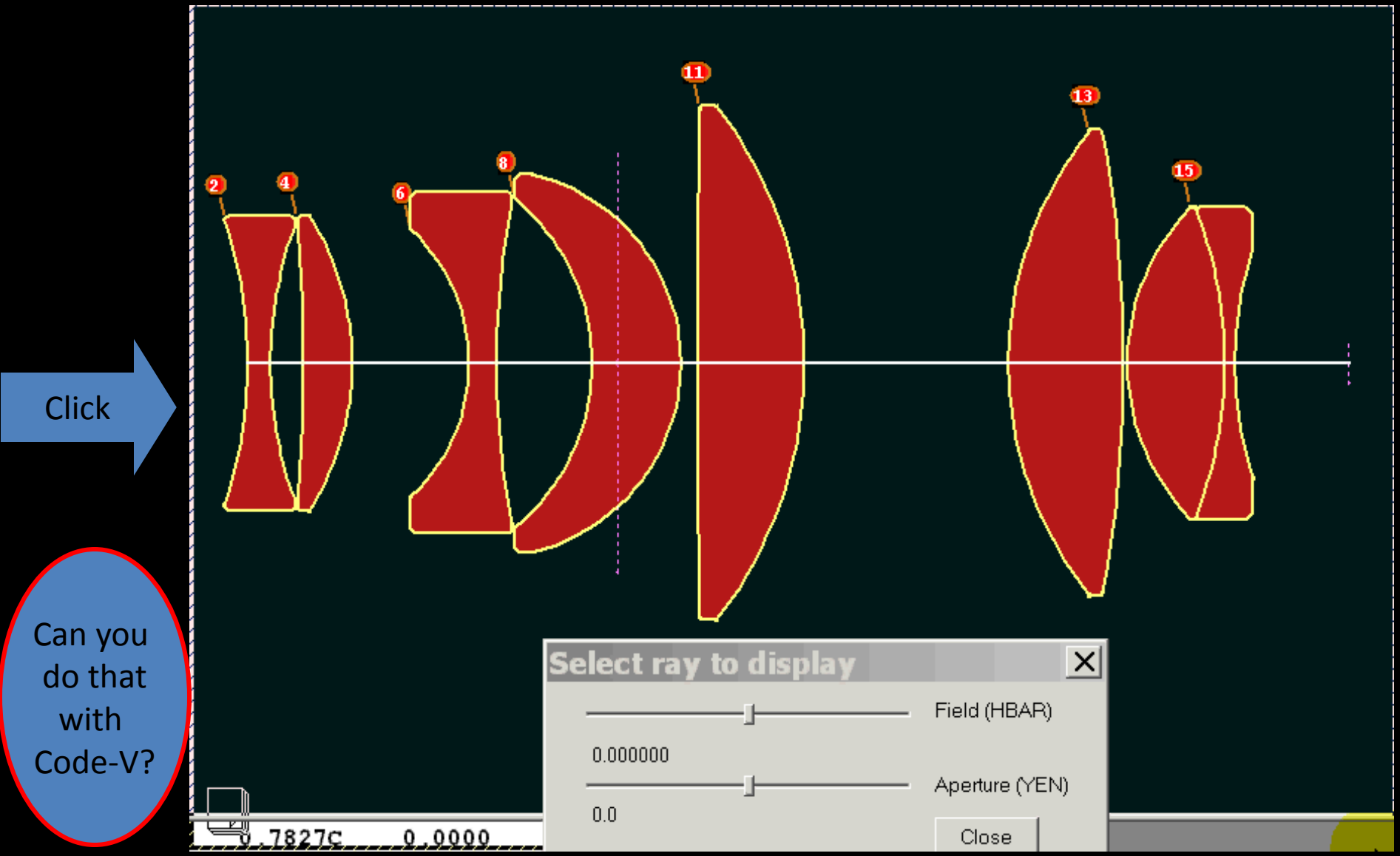
0 0.00000000 0.00000000
.00000000 AIR
00 0.00000000 100

9 —> Update SEL. Close
Tilt angle 41.500000
Bending of airspace N/A
Fast

Up-close view of your lens and a single ray

- Watch the movie on the next slide and watch the path of a ray to see what happens as the field or aperture position change.

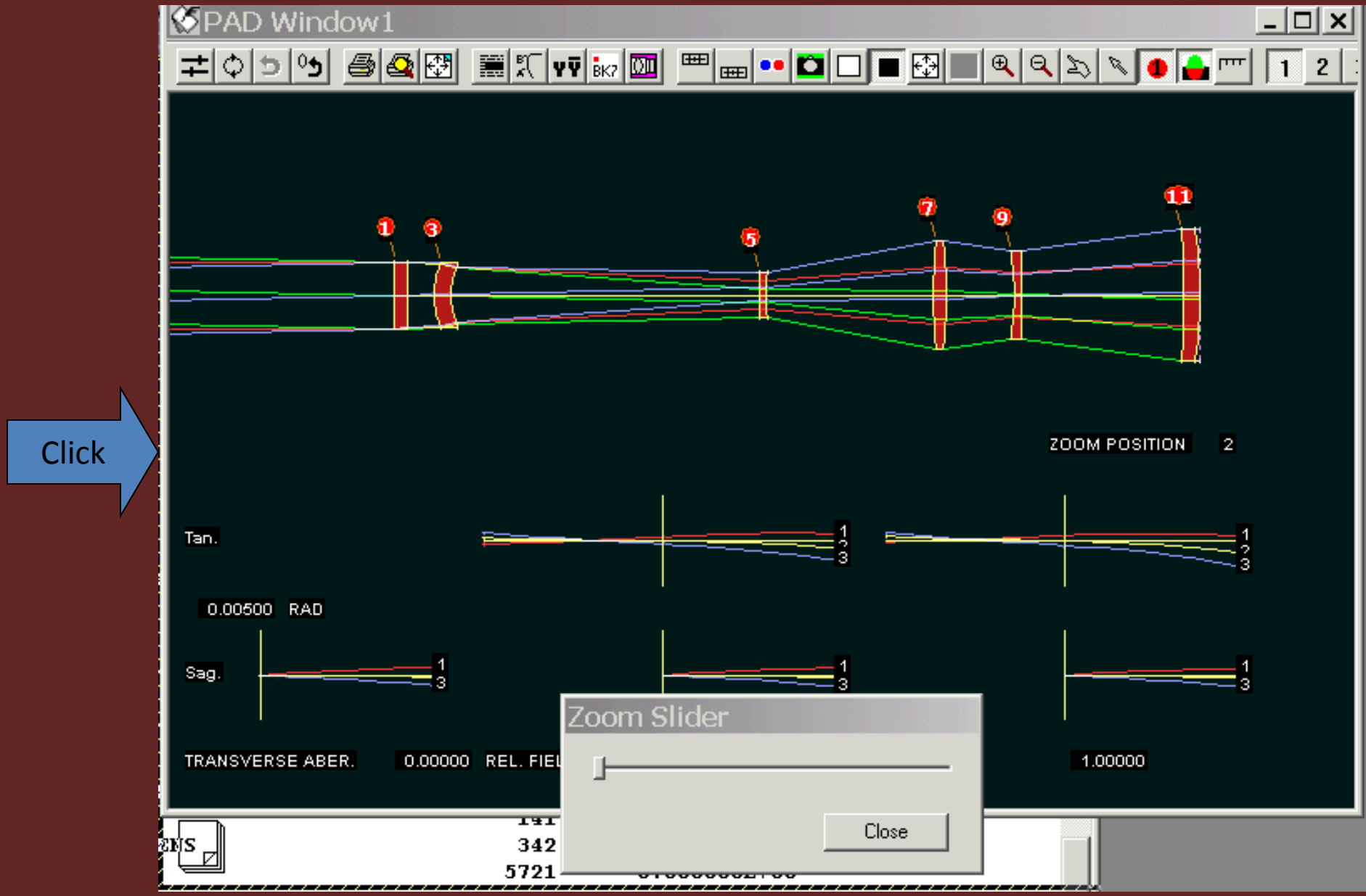
Single ray option in SketchPad



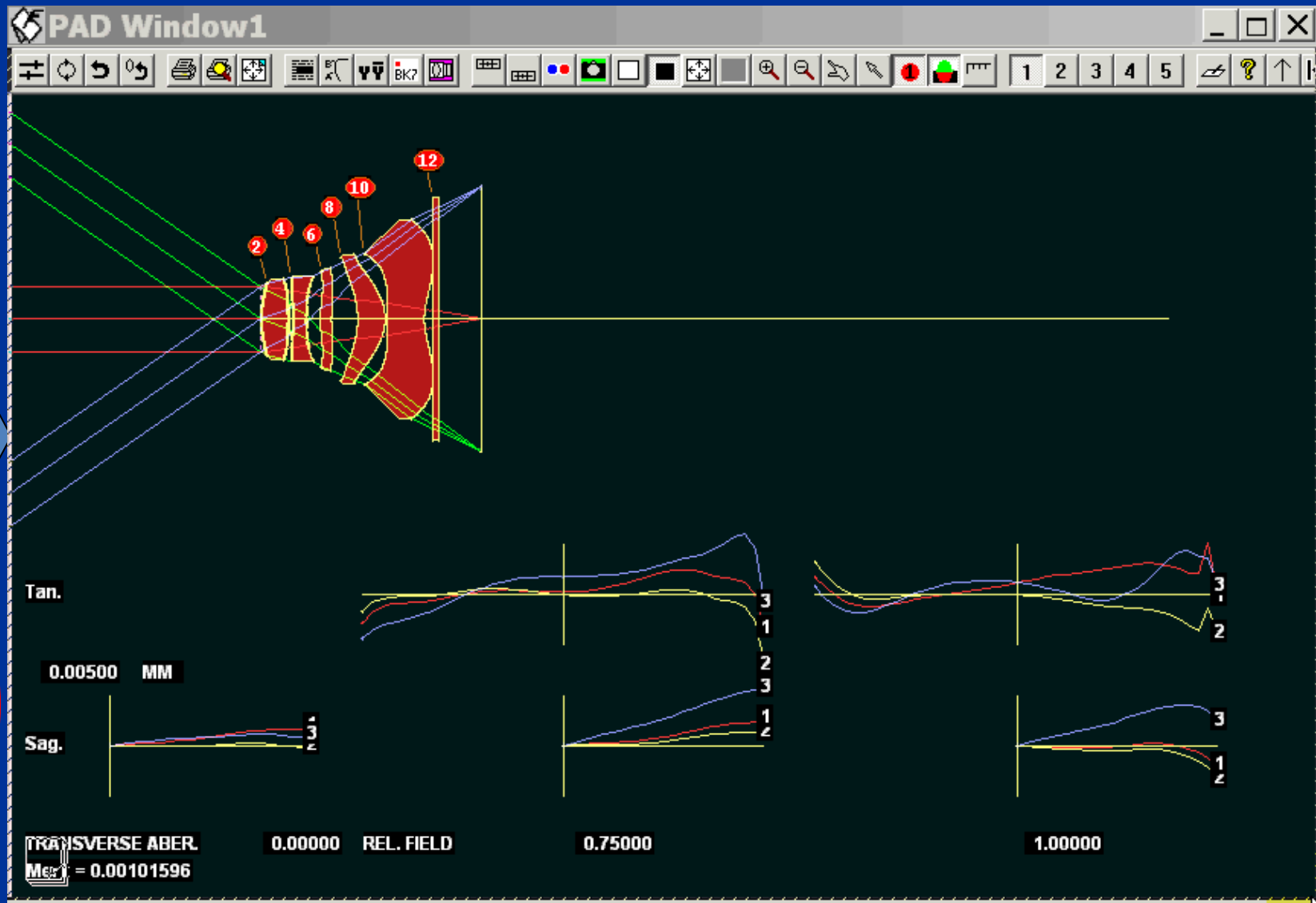
Zoom lens slider

- Watch the position of zooming groups change over the zoom
- See how the image quality changes
- Spot any points in the zoom that need further correction
- Watch the movie on the next slide as the elements of an optically-compensated zoom lens are zoomed.

ZOOM slider: One configuration. Automatic undo.



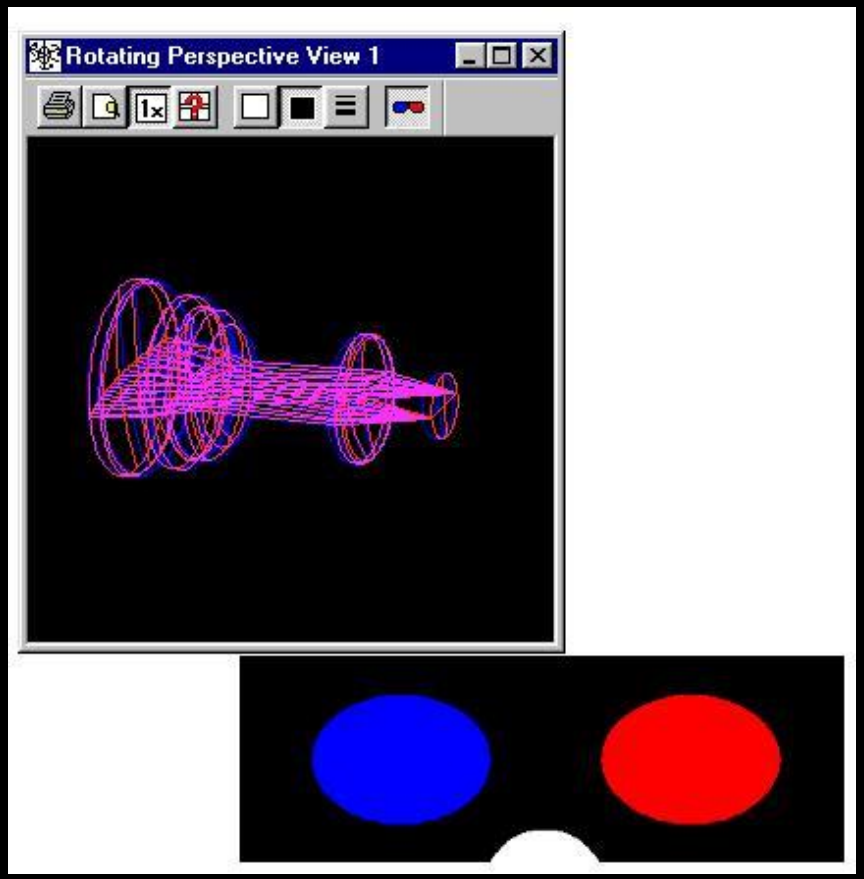
PAD scan button: see performance over the field



Click

Can you do that with Code-V?

3D Stereo display



Great for complex systems. See what is in front of what.

Can you do that with Code-V?

SYNOPSYS™ can tell you:

- Where is the best place to insert an element? (Based on saddle-point theory)
- Where is the best place to delete an element? (Inverse saddle-point)

Can you do that as easily with Code-V?

SYNOPSYS coordinates:

- Five varieties:
  - Relative
    - Undo is automatic
  - Local
    - In coordinates of previous surface
    - Specify Euler angles
  - Group
    - Compound, automatic undo
  - Global
    - In coordinates of surface 1
  - External.
    - See a ray path in the coordinates of the telescope pier. Any coordinate system.

Code-V cannot change Euler angles; must use dummy surfaces

Tolerancing options

Code-V

- 3rd-order
- Wavefront variance
- MTF

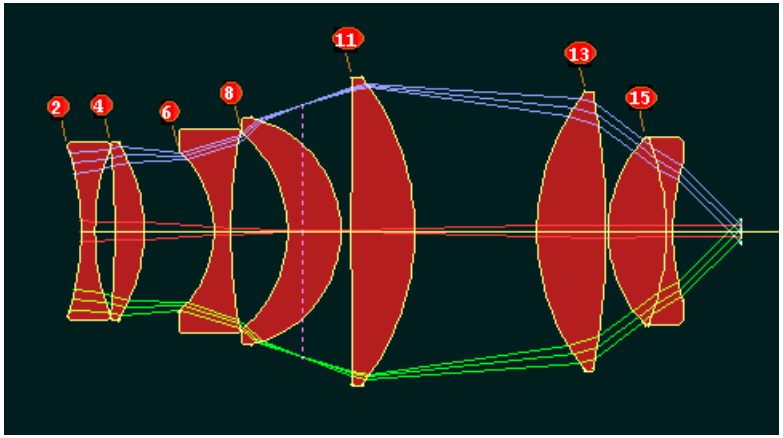
SYNOPSYS™

- RMS spot size
- Wavefront variance
- Strehl ratio
- MTF
- Fabrication adjustments simulation

Evaluate tolerance statistics when wedge errors are clocked

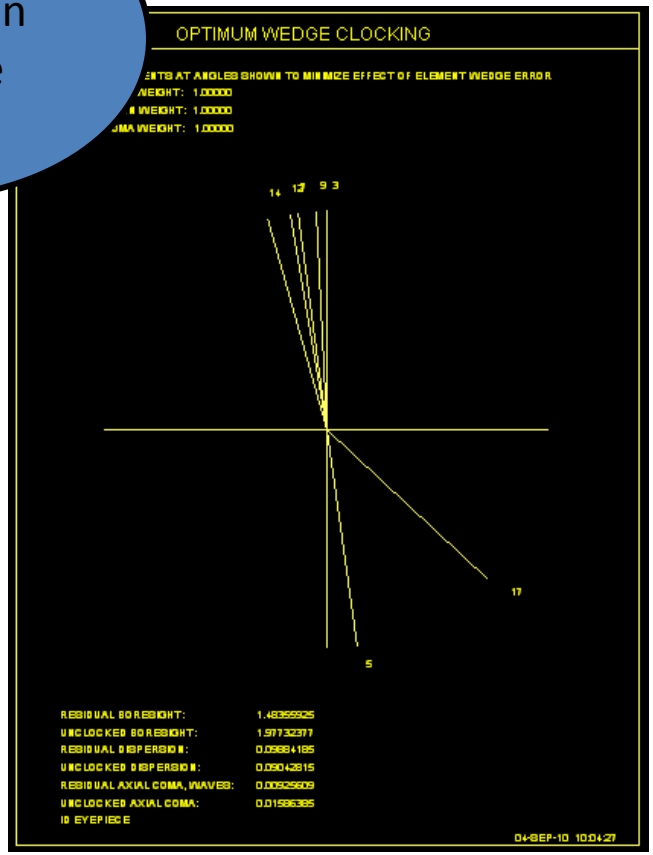
- Measure the wedge on each element
- Run the UCLOCK program
  - Finds the optimum clocking angles
  - Reduces ill effects of the wedge
- The Monte-Carlo program can simulate the improvement
  - Demonstrate the benefit.

Sample problem:



In this eyepiece, each element has a small wedge. How to compensate?

The UCLOCK feature can clock the wedges.



Now you have a lens with an alpha tilt on seven surfaces to model the wedge, and a gamma tilt on seven others to model the clocking. In SYNOPSYS, this is done by the program.

With Code-V, you have to do it by hand.

Ghost Image Evaluation and Control

Code-V

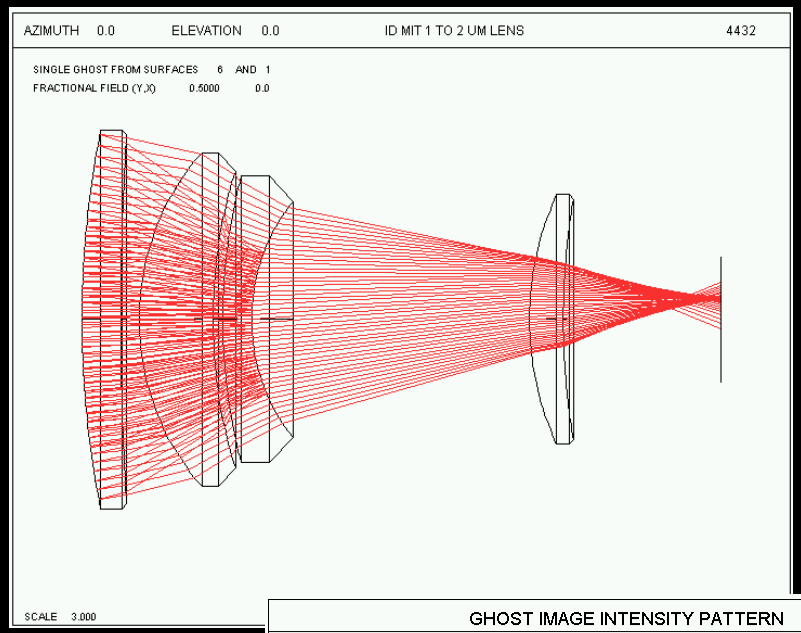
- Paraxial
- Real-ray

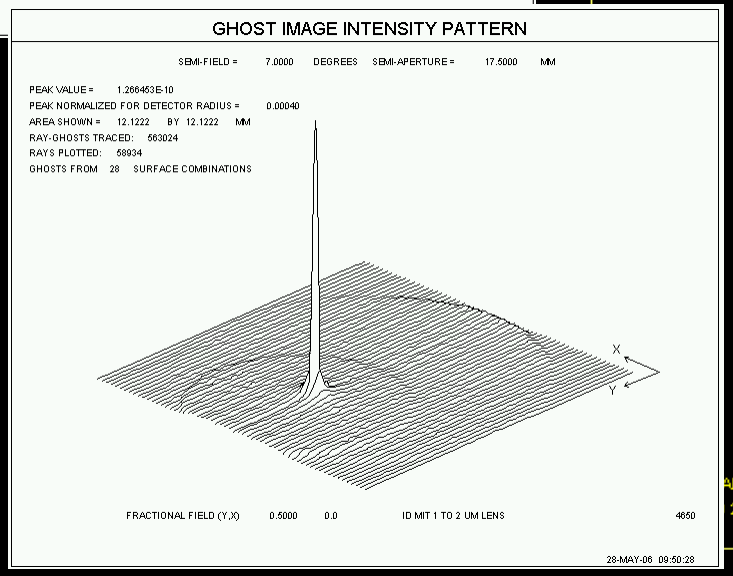
SYNOPSYS has the most powerful ghost-image analysis of any lens design program.

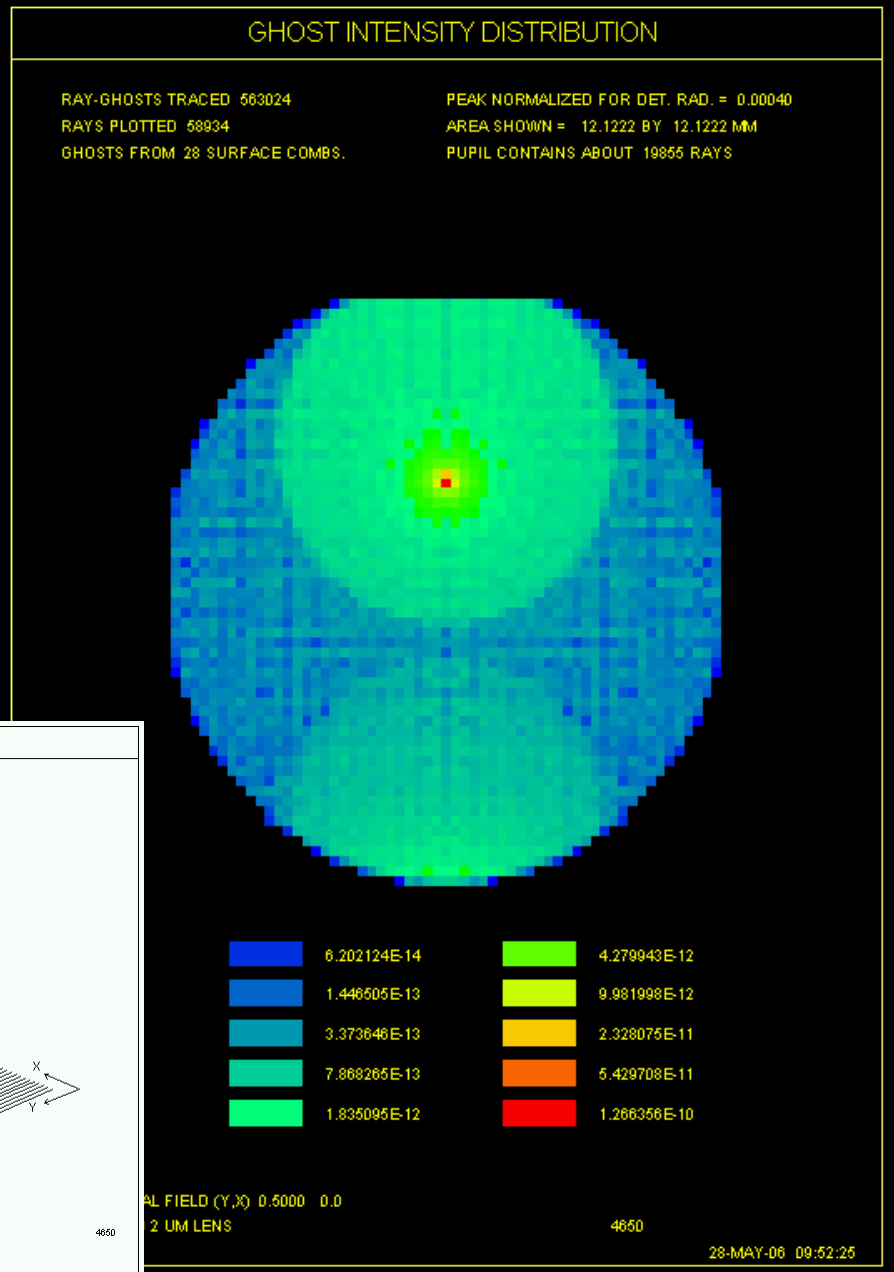
SYNOPSYS™

- Paraxial
- Real-ray
- Buried
  - Paraxial
  - Real
- Power density of ghost
- Control ghosts in optimization
  - 2-bounce paraxial
  - Buried

Example plotted ghost image analysis







The SYNOPSYS™ online manual is friendlier.

- Instant access.
- Type 3 characters of a command, and …
  - The syntax is shown at the bottom of the screen.
  - Press the F2 key, and the User's Manual *instantly* opens to that topic.
  - Type HELP topic, and the Manual opens to it.
  - Just *select* a command in the MACro editor, and the syntax is shown.

Plus, it's always up to date.

The Code-V online manual is less convenient.

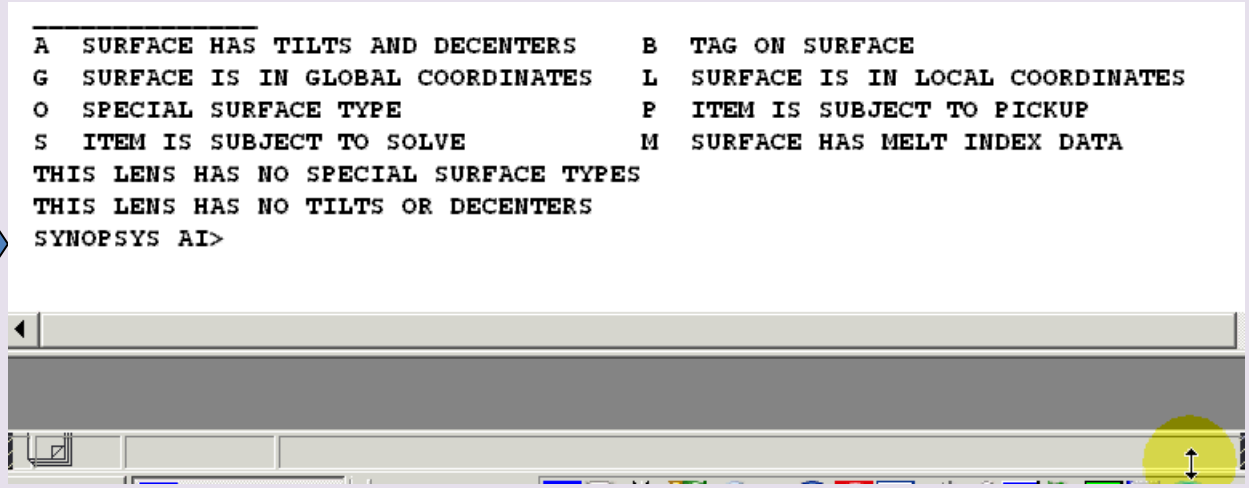
Watch the Instant Help in action

1. Type 3 characters of a command.

2. Look at the Tray

3. It remembers the command syntax for you.

Click



Press F2 and the manual opens.

ZOOM lenses

- Code-V must do zoom lenses with the multiconfiguration feature.
  - No native zoom.
  - No automatic undo
  - No zoom slider

Make a plot of almost anything over the zoom

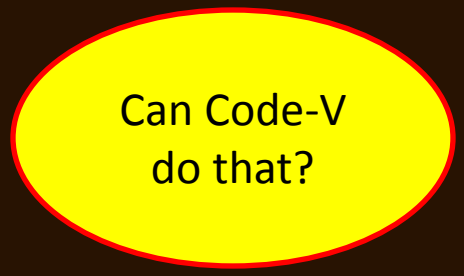
- SYNOPSYS has a native zoom feature: 20 zooms in a single configuration.
  - Automatic undo beyond group.
  - ZOOM slider: see the lens and image at 100 zoom points. Check image and clearances.
  - Adjust zooms with another slider.
  - Plot a cam curve.
  - Find zoom lens construction automatically.

Can Code-V do that?

Multiconfiguration logic is different

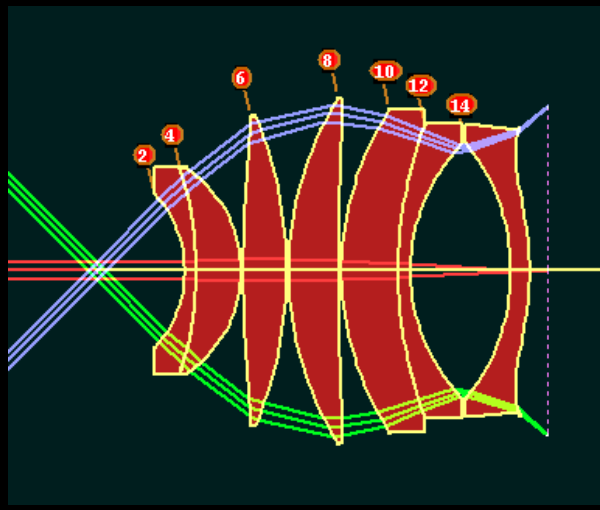
- Code-V has only a single configuration
  - Others are emulated by declaring differences

- SYNOPSYS™ has 6 true multiconfigurations
  - Separate lenses unless pickups are declared
- Load with different lenses
- Switch back and forth with a single mouse click.



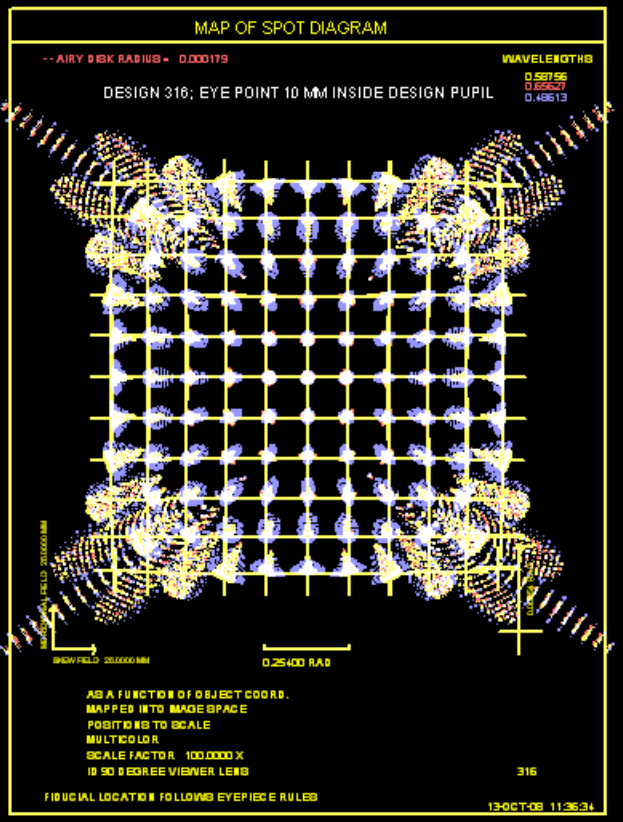
MAP feature:

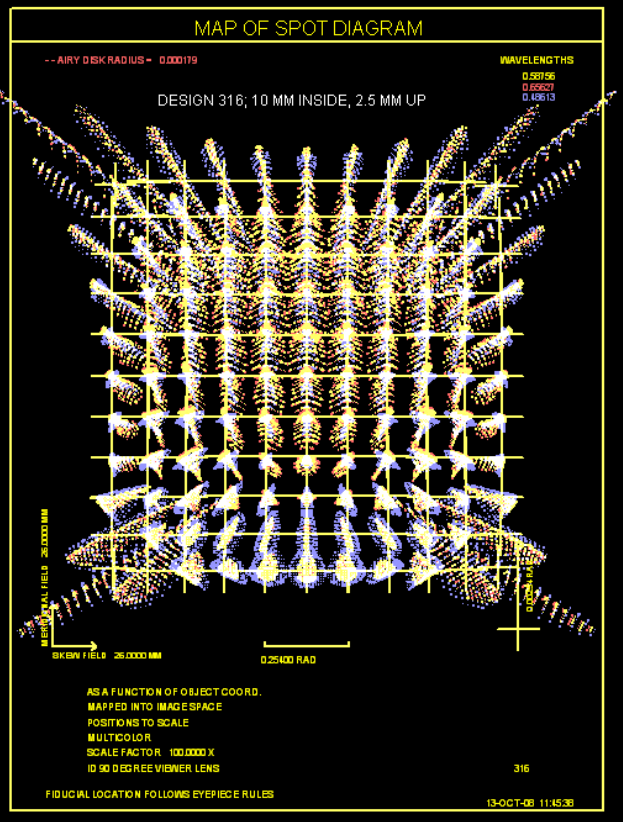
Spot diagram mapped over the field



When you look at the center you see this.

When you look near the bottom you see this.



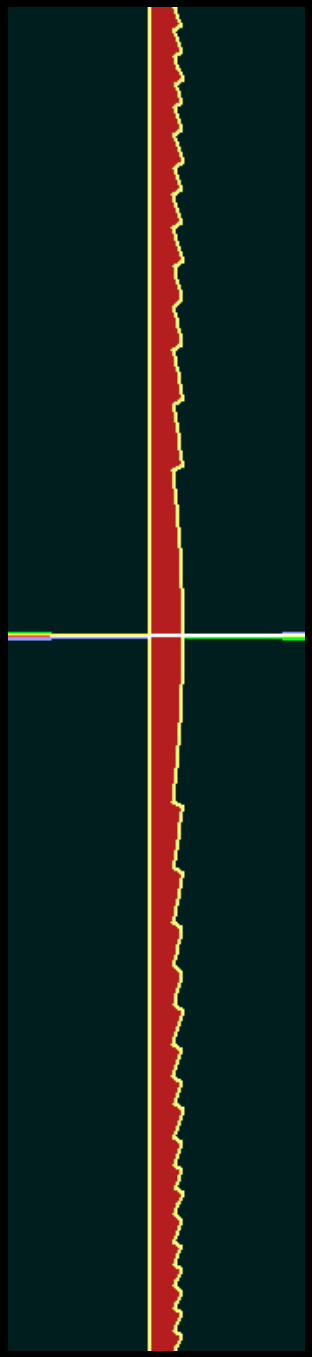


That's one of 19 things MAP can show.

Can Code-V do that?

More unique features:

- Explicit Fresnels
  - Sequential raytrace
- Longitudinal PSF
- Coating design program
- 3-D stereo display
- PSD optimization



Still more:

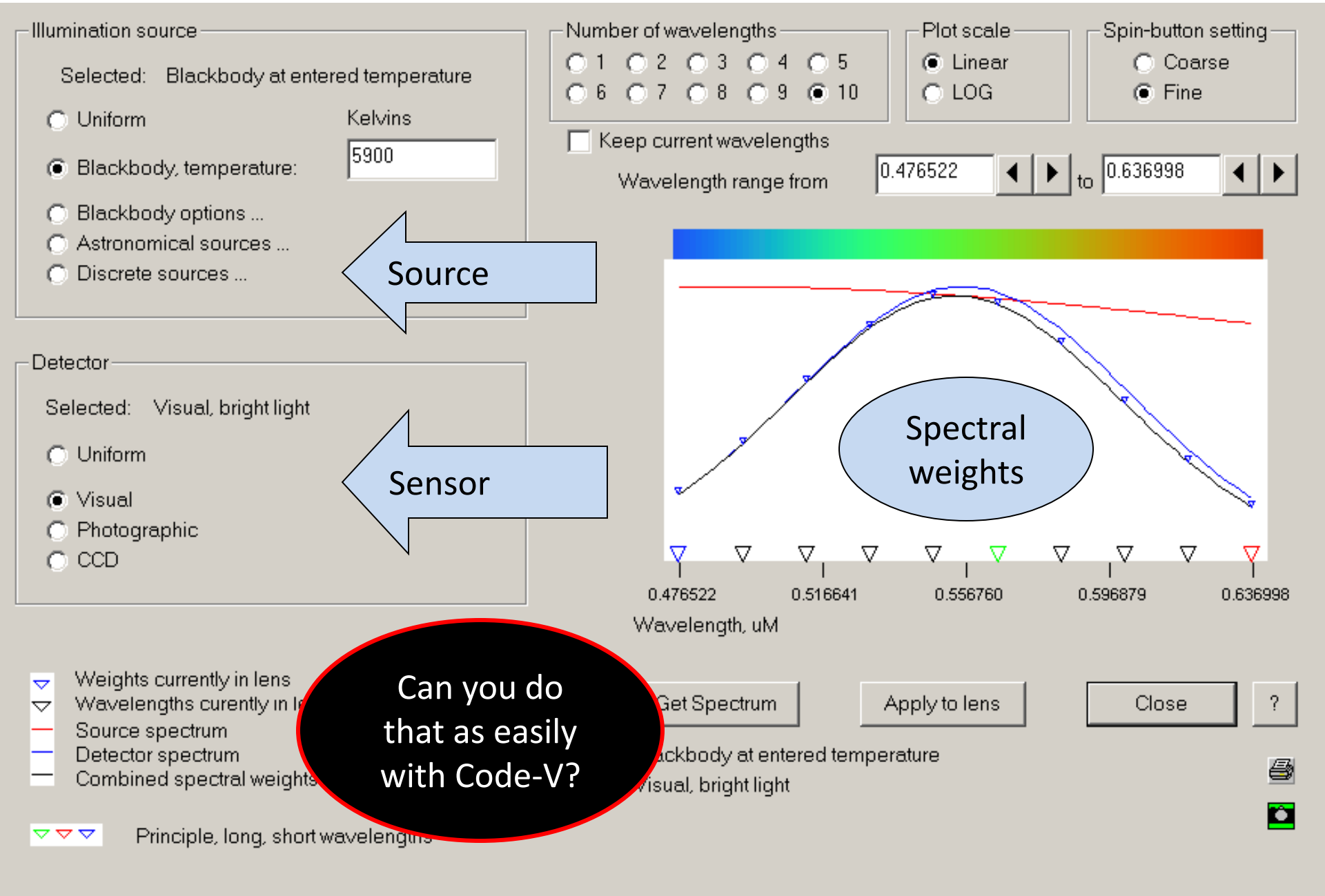
- Can vary the paraxial chief-ray height. Let the program tell you where the stop should go.
  - Simple with SYNOPSYS
  - Not so simple with other codes.

- *Eight kinds of t*olerance desensitization, from 3rd-order theory.

- Images displayed in realistic colors
  - Geometric
  - Diffraction-based
  - Coherent

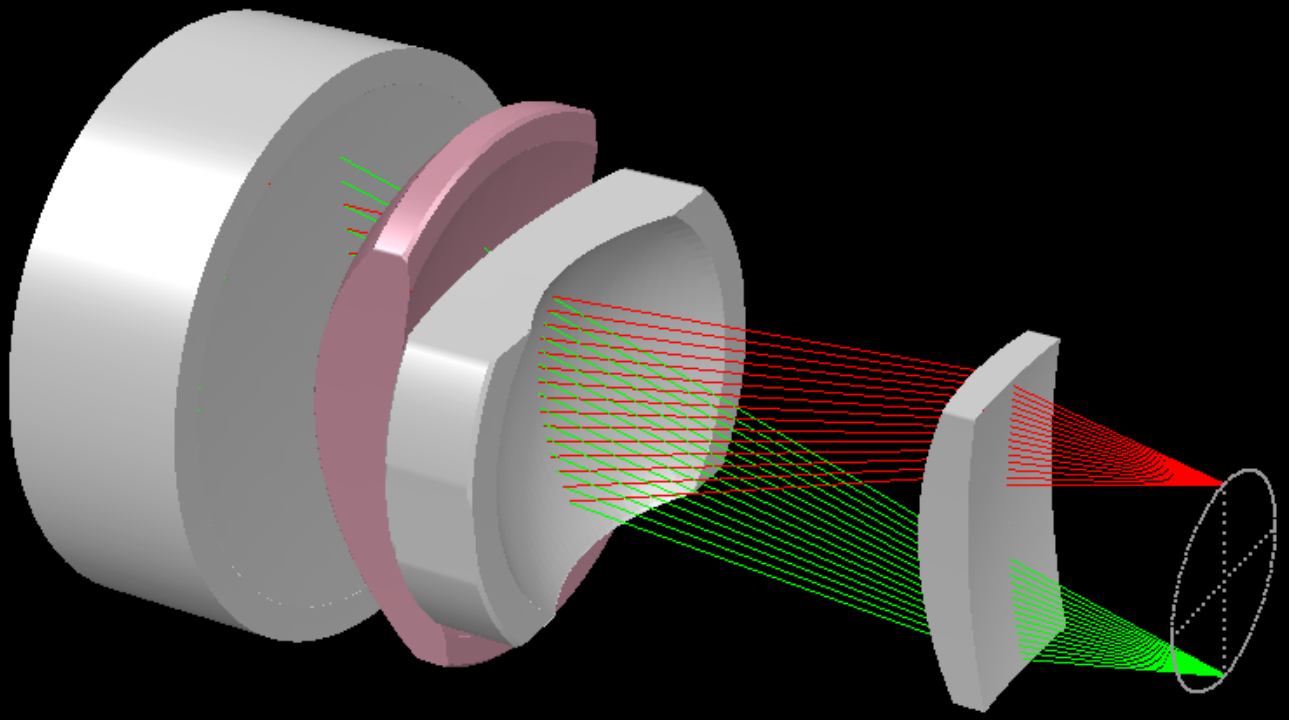
- Spectrum Wizard

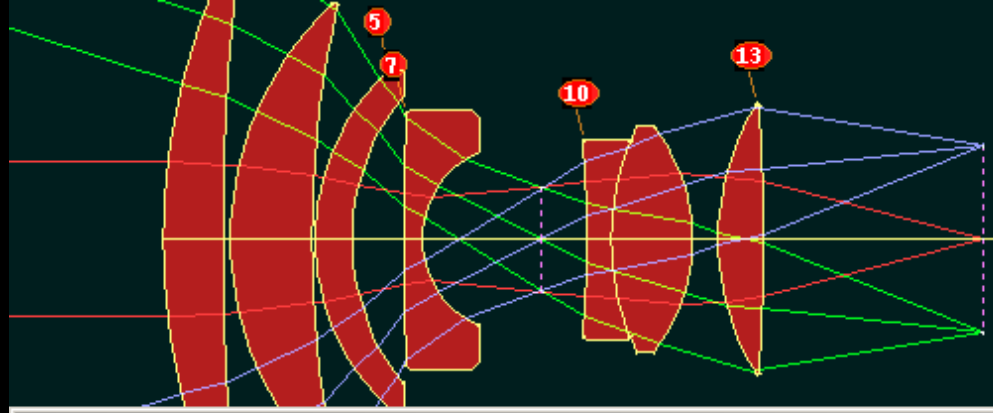
The Spectrum Wizard can find spectral weights for you.



Edge geometry

- Code-V has few options
- SYNOPSYS has many possibilities.





Use the Edge Wizard to define edge dimensions, flats, and bevels …

Edge Definition Wizard

?

From surface 7 — Semi-aperture 19.8905 — To surface 8 — Semi-aperture 13.1204

Prev. el. <- -> Next el.

If you change the spin increment, click in any other box to to register it.

Dia / Rad: 21.4145

Bevel BC 0.635004 — Bevel DC 1.27001

Face AB 0 — Face ED 5.75409

Angle 1 0 — Angle 2 0

-B -F

C 21.4145 — D 20.1445

B 20.7795 — E 14.3904

A 20.7795 — Thickness

Angle 1 0 — Angle 2 0

Spin increment: 0.127000

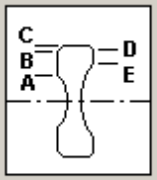
Add rectangular edge to EFILE circular apertures

Create parameters

Margin 1.27

Bevel 0.254001

Create all



Set 5 numbers

offset (X,Y)

Select edge rules

Off / Up / Down / Mixed / Explicit

Update

If you change anything, click Update to process the new data.

no CAOs

Click this button to free all CAOs on this element

Set CAOs

Set CAOs to equal point A and E

Click the spin buttons to increment the value instantly.

Buttons "-B" remove the bevel, and "-F" remove the flat section of the edge.

Angles 1 and 2 apply only to the otherwise flat portions A-B and D-E. The bevels are always at 45 degrees.

Pickup EFILE data from

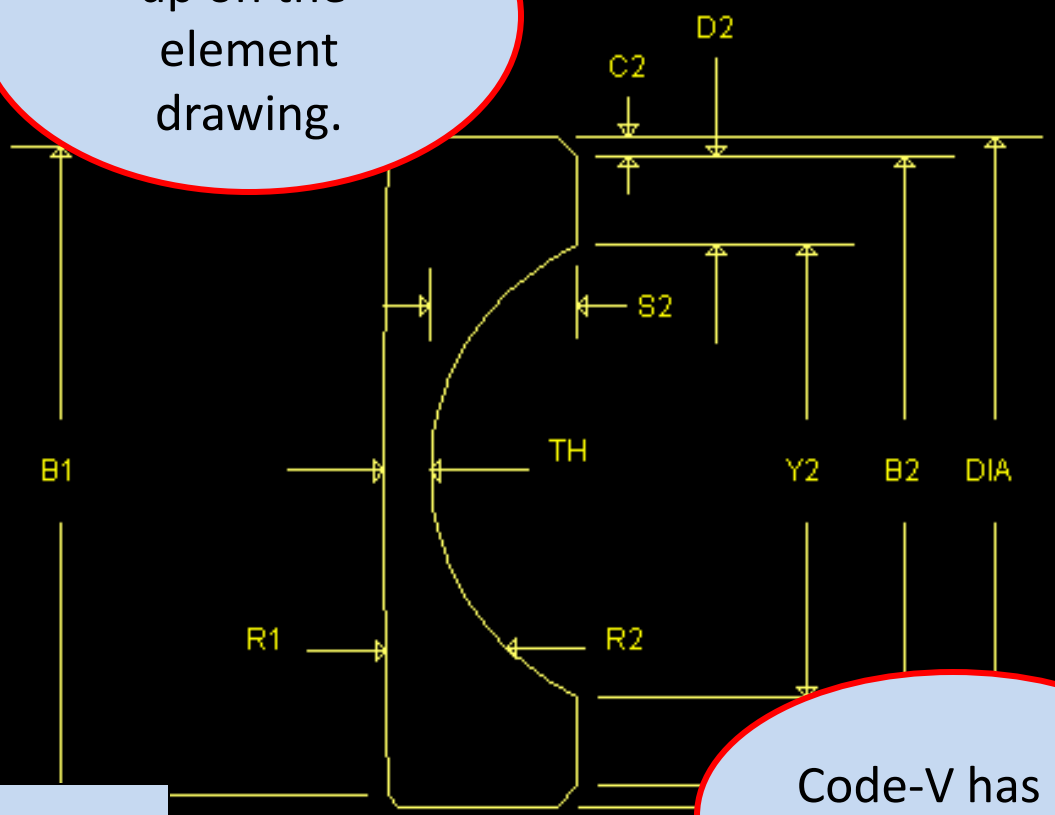
(Use negative number to flip)

Draw: This element — This range: 1 999

Erase all — Checkpoint — Close — Help

PARAMETERS	SIDE 1	SIDE 2
RADIUS OF CURVATURE	R1 805.8884	R2 15.7408
RADIUS TOLERANCE	TESTPLATE	TESTPLATE
FRINGE TOLERANCE	3.88	3.55
CYLINDER FRINGES	1.06	1.18
EDGE ROLL FRINGES	0.86	0.87
FINISH		
COATING		
CLEAR AP. DIAMETER	39.7809	26.2407
SAGITTA		S2 9.36193
DIA. TO FACE		Y2 28.7808
DIA. TO BEVEL	B1 41.5589	B2 40.2889
FACE WIDTH TO BEVEL		D2 5.7541
BEVEL WIDTH	C1 0.6350	C2 1.2700
FACE ANGLE		
THICKNESS	TH 3.0000	
TH. TOL.	0.0929	
WEDGE TOL.	6.18 MIN.	
FLAT TIR	0.0406	
DIAMETER	DIA 42.8289	
DIA. TOL.	0.0418	
MATERIAL	F5	
GRADE	B	
ANNEAL	FINE	
SLOPE	0.179 FR/MM	

… and they show up on the element drawing.



Code-V has no edge wizard

Tolerances too.

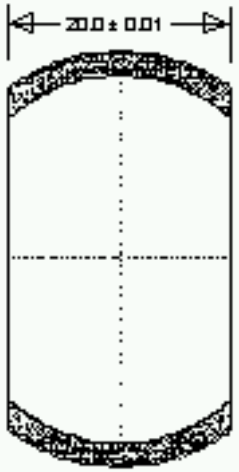
2.000 X	JMBER	
DATE 07-SEP-10	REV.	
DESIGNER	APPROVED	
CHECKER		
TEST WAVL		
DIMENSIONS MM		SYNOPSYS LOG 21571

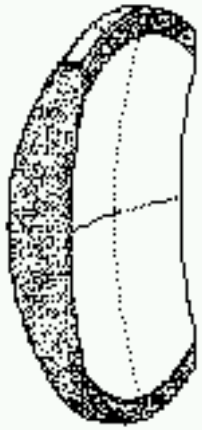
SAMPLE LEN

ELEMENT 4

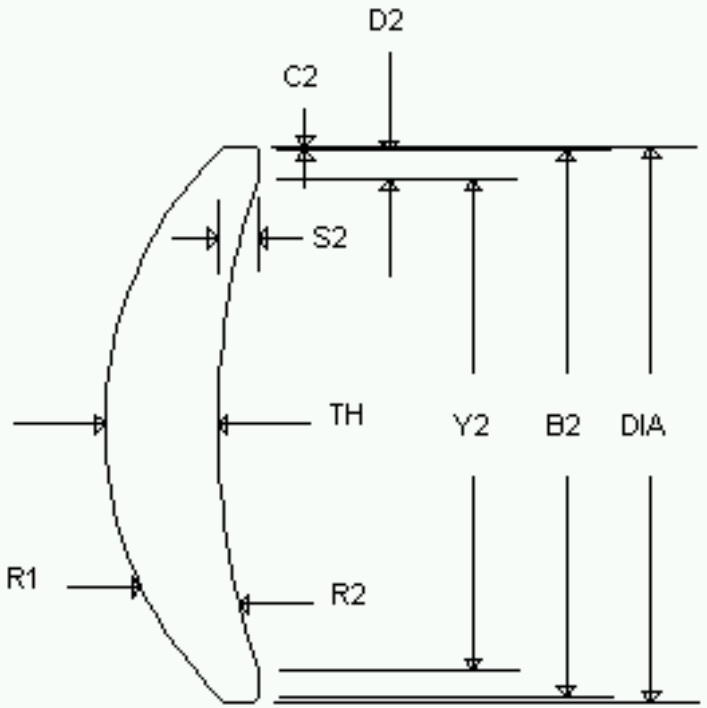
OSD, INC

PARAMETERS	SIDE 1	SIDE 2
RADIUS OF CURVATURE	R1 23.3200	R2 46.0900
RADIUS TOLERANCE		
FRINGE TOLERANCE		
IRREG. TOLERANCE		
FINISH		
COATING		
CLEAR AP. DIAMETER	40.0000	40.0000
SAGITTA		S2 2.73056
DIA. TO FACE		Y2 31.2568
DIA. TO BEVEL	B1 35.2900	B2 34.7820
FACE WIDTH TO BEVEL		D2 1.7626
BEVEL WIDTH	C1 0.0	C2 0.2540
FACE ANGLE		
THICKNESS	TH 7.6487	
TH. TOL.		
WEDGE TOL.		
FLAT TIR		
DIAMETER	DIA 35.2900	
DIA. TOL.		
MATERIAL	ZNS	
GRADE		
ANNEAL		
MELT		
SLOPE		





Superimpose solid view of element.

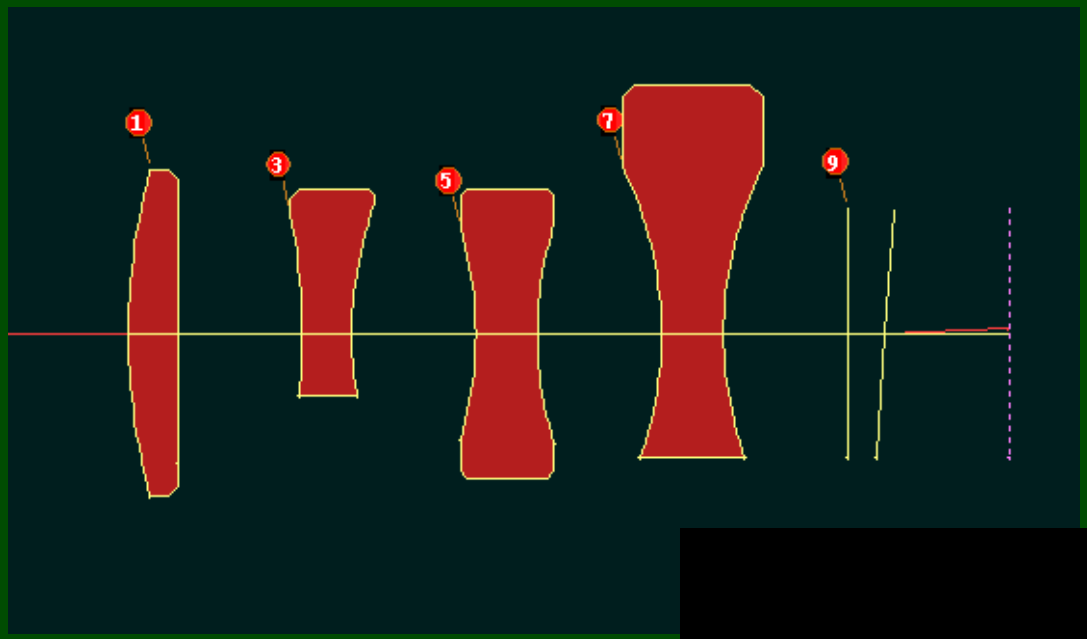


SCALE 2.000 X	NUMBER	
DATE 03-OCT-05	REV.	
DESIGNER	APPROVED	
CHECKER		
TEST WAVL		
DIMENSIONS MM		SYNOPSYS LOG 1861

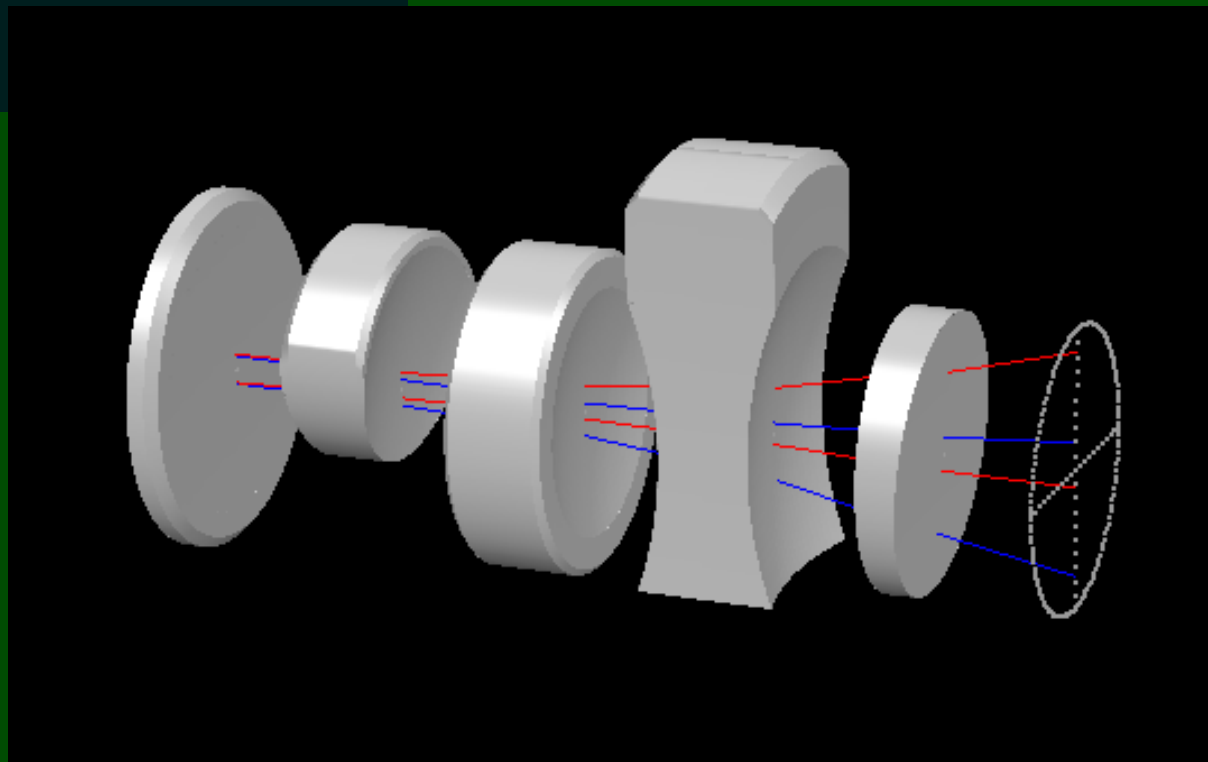
ELD EXAMPLE
COMPLEX APERTURE

OSD. INC.

Edges can be simple or complex.



Can you do
that
with Code-V?

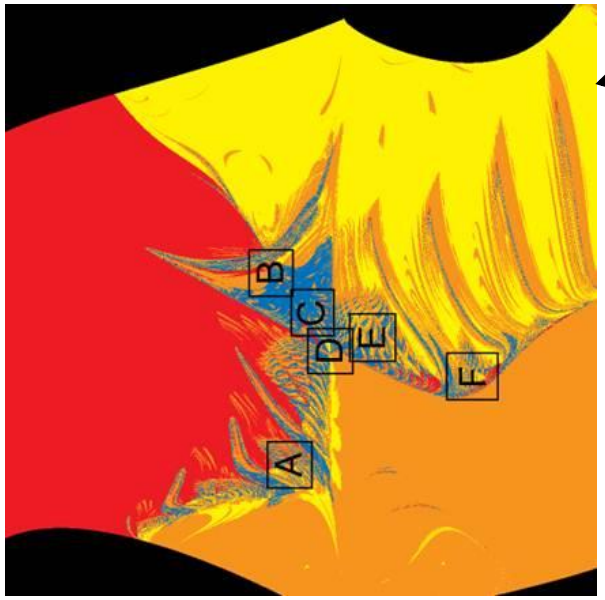


And there's more…

- Examples are known where the optimization in Code-V is chaotic*.
  - Starting points very close together can yield very different results
  - This has been documented by Dr. Florian Bociort of TU Delft.

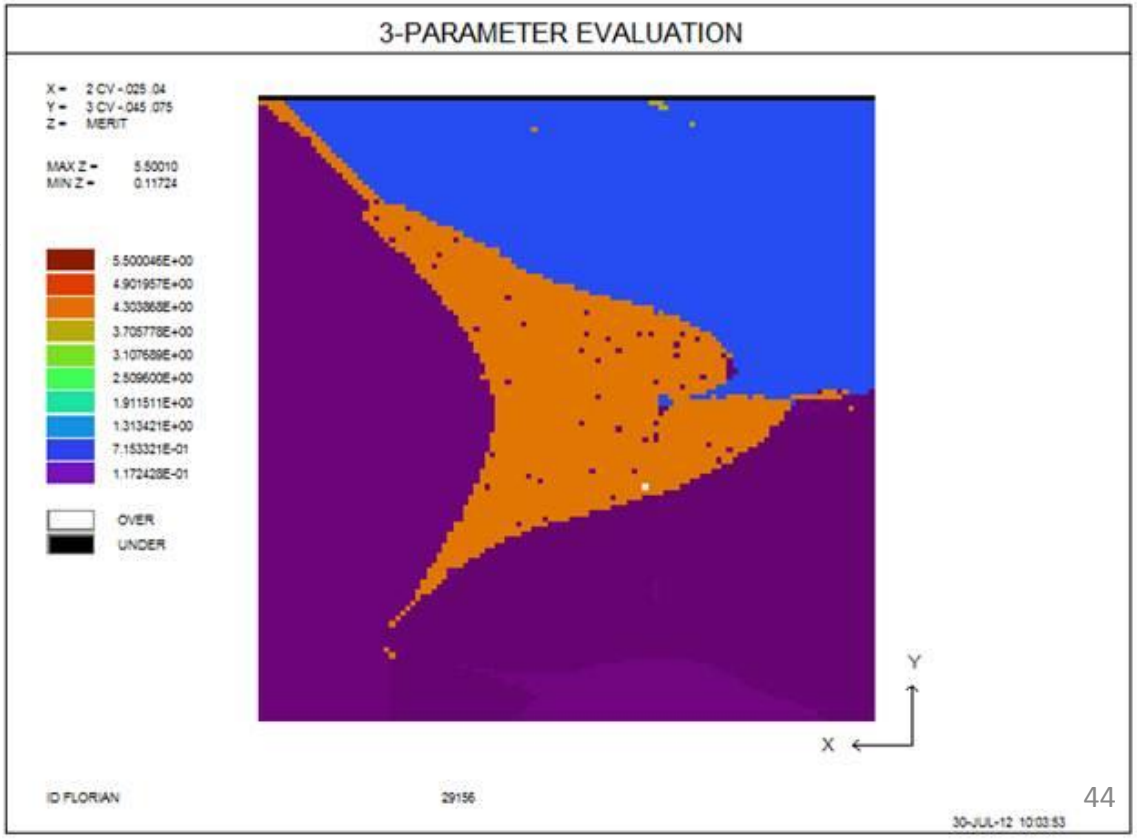
This is a defect.

*M. van Turnhout and F. Bociort, Instabilities and fractal basins of attraction in optical system optimization, Opt. Express 17, 314-328 (2009), (open access at http://dx.doi.org/10.1364/OE.17.000314)

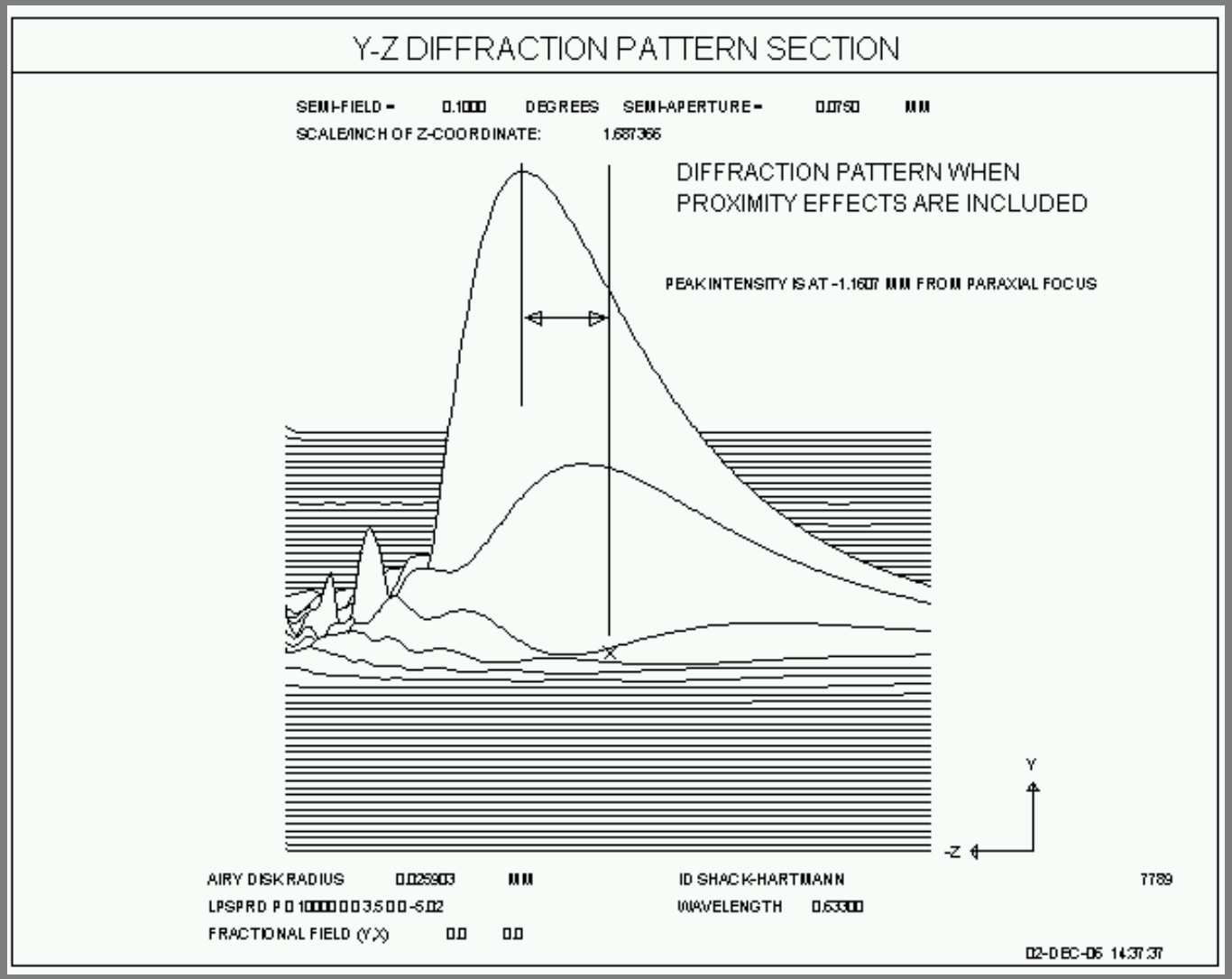


- This evaluation was done on Code-V
- Note the *chaotic* performance at the edges of the zones of attraction
- The black areas show where Code-V encountered ray failures and could not optimize.

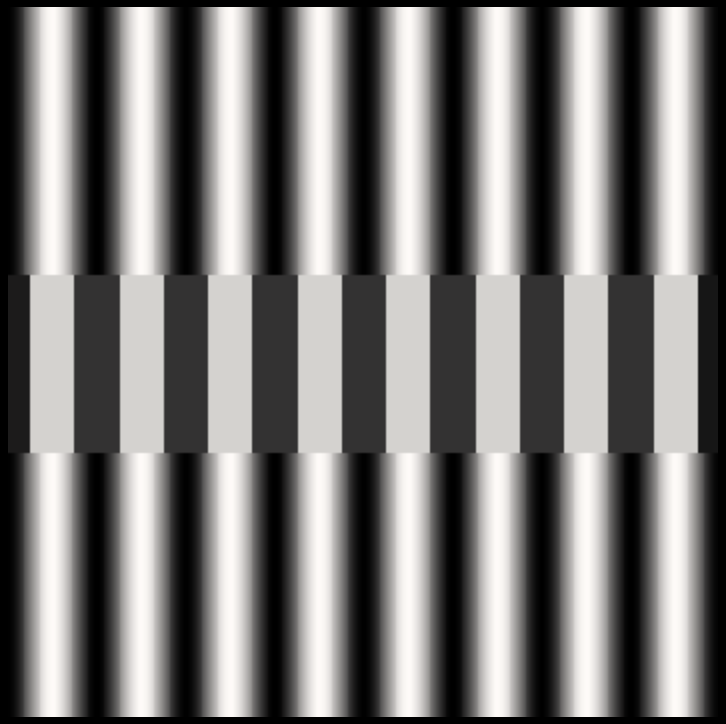
- This is the same problem, run on SYNOPSYS™
- Note the *absence* of chaos
- No black areas
  - SYNOPSYS™ can fix ray failures.

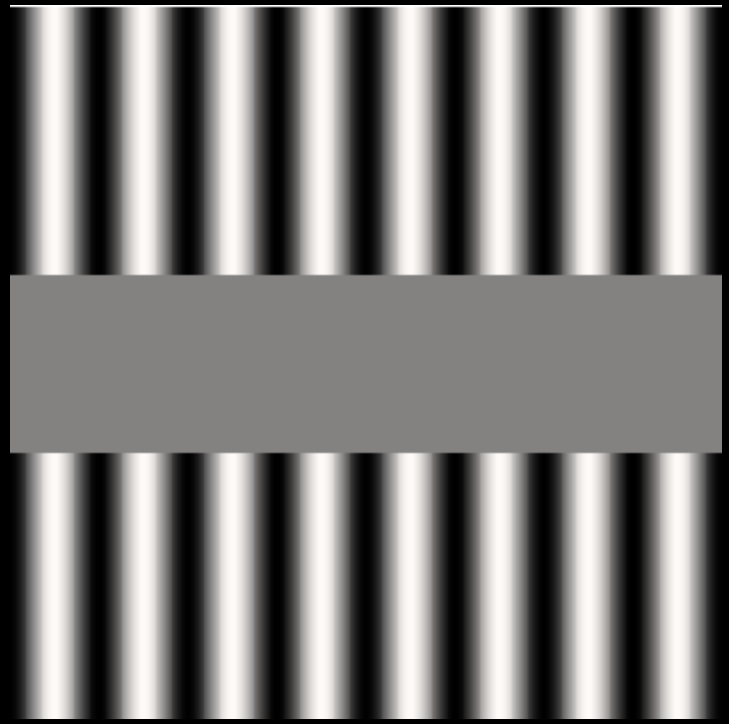


This is a *longitudinal* PSF



See what happens if your detector is not lined up with image peaks





One of the Image Tools features

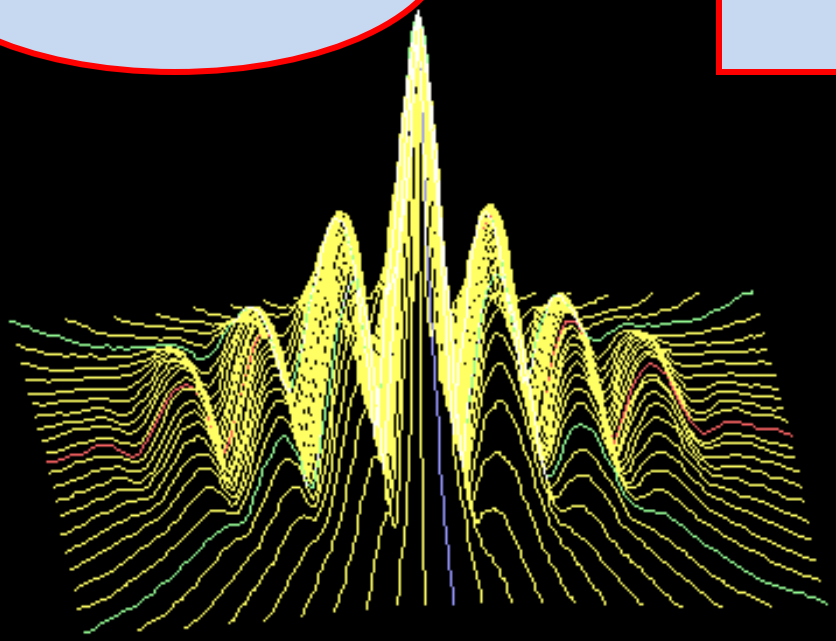
Can you do that with Code-V?

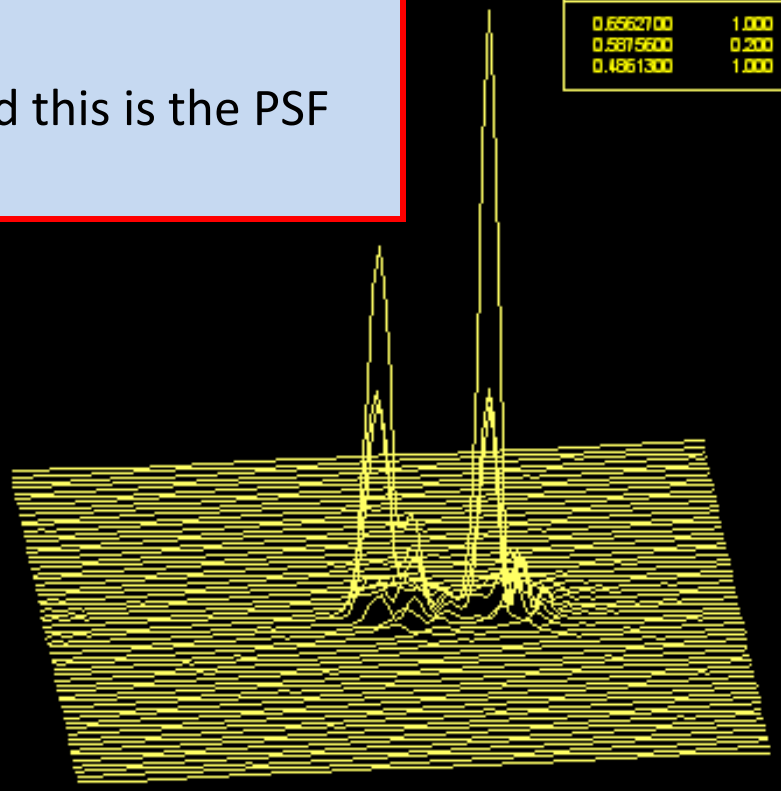
FOURIER-TRANSFORM MTF

POINT-SPREAD FUNCTION

This is the MTF!

And this is the PSF





CUTOFF FREQUENCY

AIRY DISK RA 0.0035838 MM

Spin both of these around on the screen with a slider.

Can you do that with Code-V?

5.0000 MM

2176

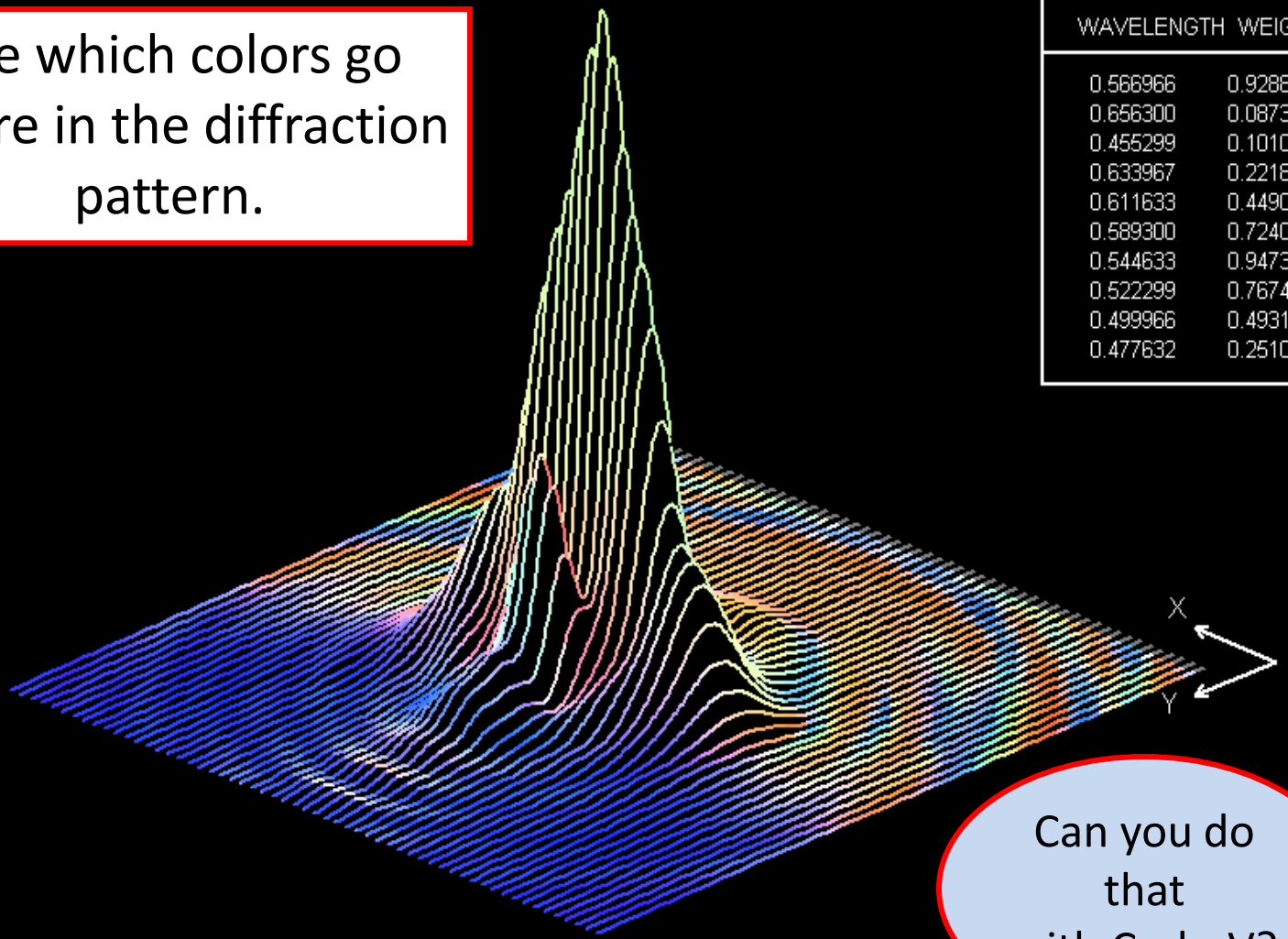
30-AUG-10 14:09:25

DIFFRACTION INTENSITY PATTERN

SEMI-FIELD = 0.2500 DEGREES SEMI-APERTURE = 8.0000 INCH

See which colors go where in the diffraction pattern.

WAVELENGTH	WEIGHT
0.566966	0.9288
0.656300	0.0873
0.455299	0.1010
0.633967	0.2218
0.611633	0.4490
0.589300	0.7240
0.544633	0.9473
0.522299	0.7674
0.499966	0.4931
0.477632	0.2510



Can you do that with Code-V?

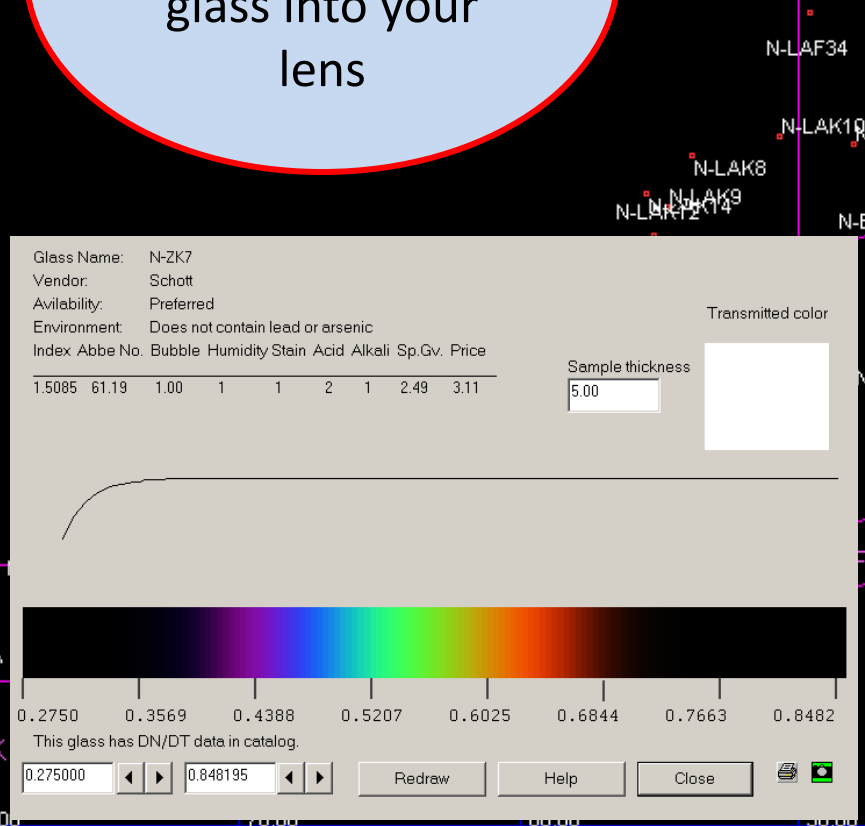
AIRY DISK RADIUS 0.000191 INCH ID RELAY FLAT 10344

PSPRD M 1 2000 0 0 3.5 L C

FRACTIONAL FIELD 1.0000 0.0

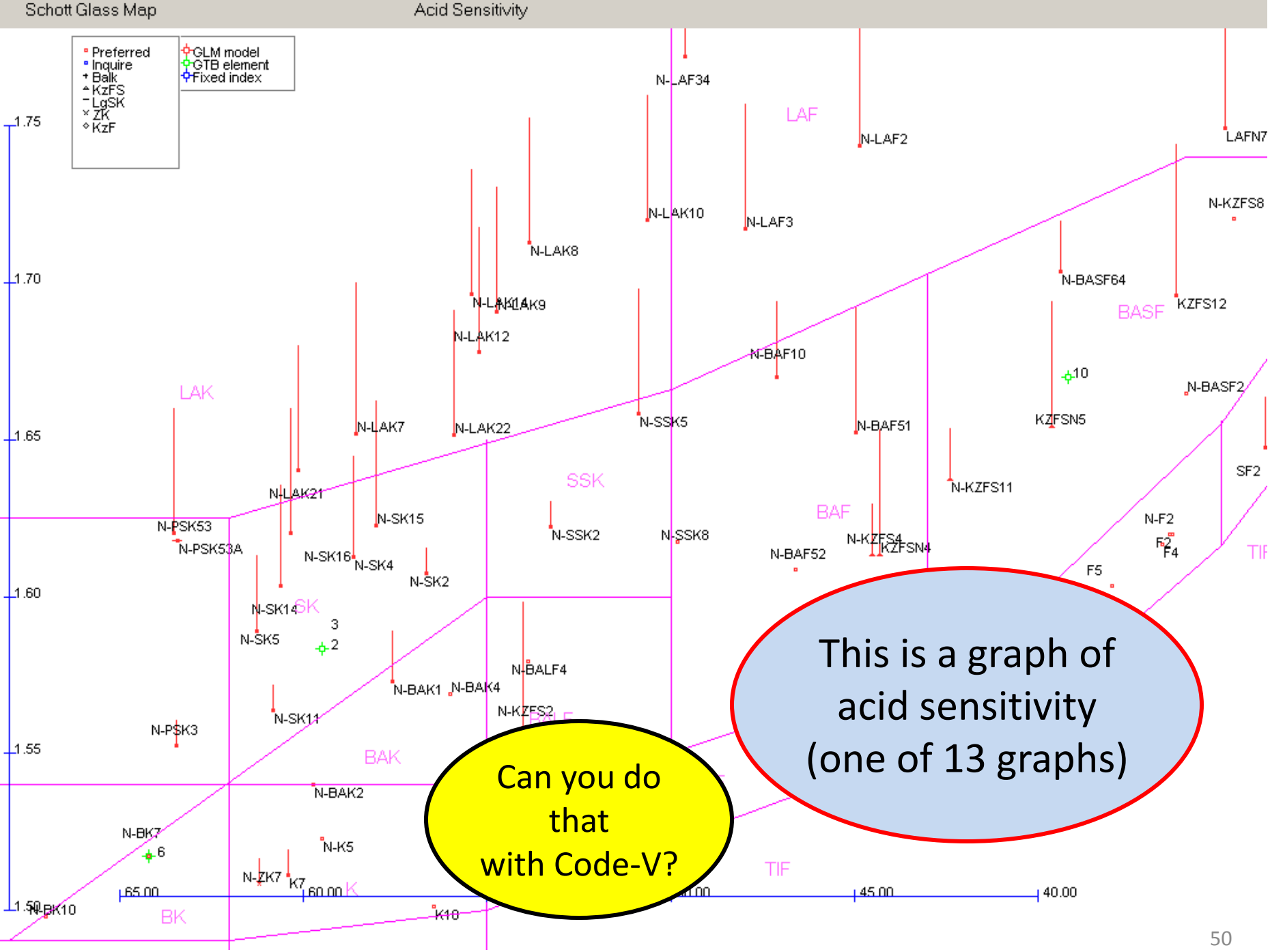
Glass tables: onscreen display

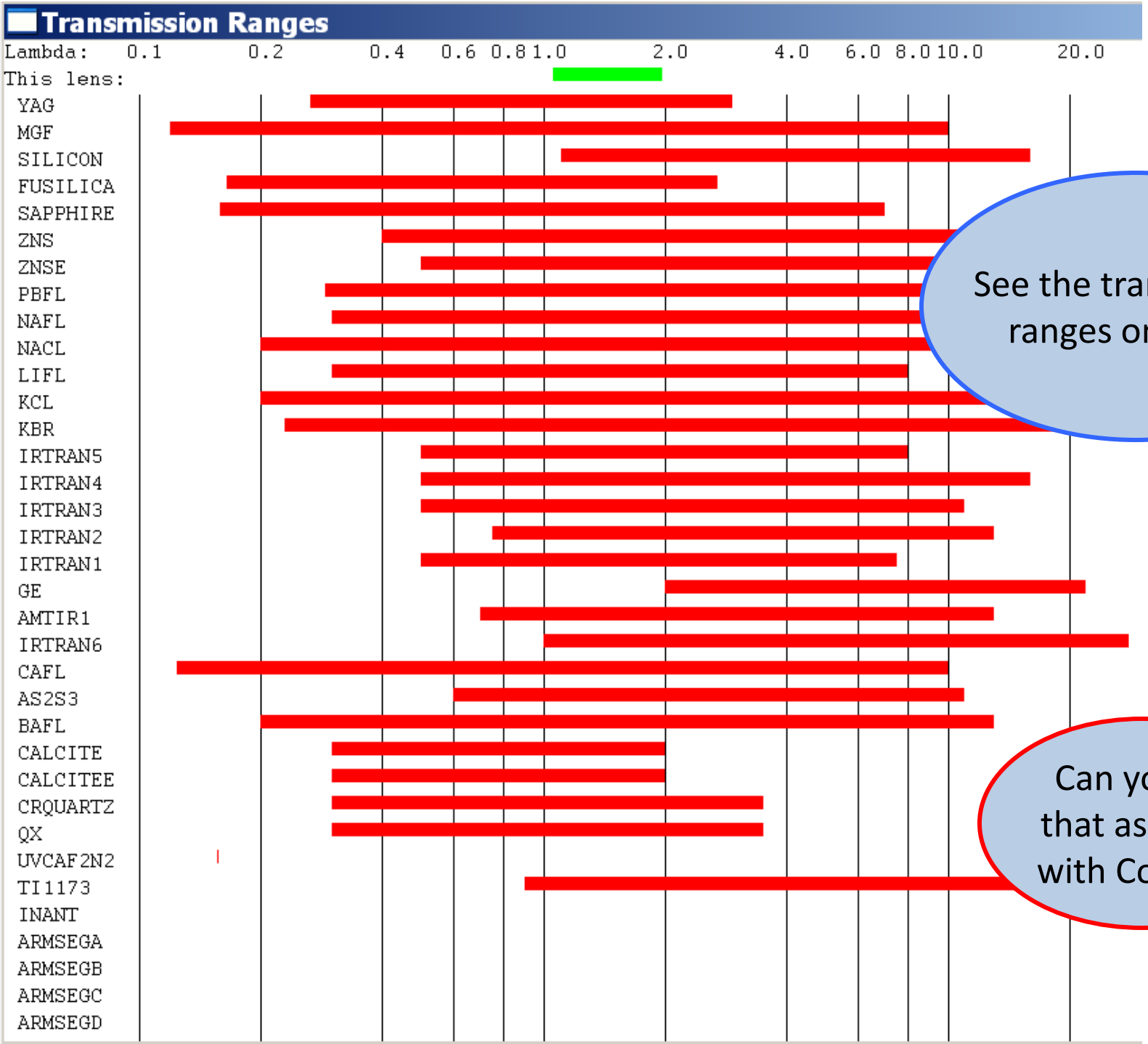
Two clicks will insert a desired glass into your lens



Two clicks to view glass properties.

Can you do that with Code-V?


Schott Glass Map
Acid Sensitivity
Preferred
Inquire
Balk
KzFS
LgSK
ZK
KzF
GLM model
GTB element
Fixed index
1.75
1.70
1.65
1.60
1.55
1.50
65.00
60.00
45.00
40.00
LAK
LAF
BASF
SSK
BAF
BAK
TIF
BK
N-LAF34
N-LAF2
LAFN7
N-LAK10
N-LAF3
N-KZFS8
N-LAK8
N-BASF64
N-LAK14
N-LAK9
KZFS12
N-LAK12
N-BAF10
10
N-BASF2
N-LAK7
N-LAK22
N-SSK5
N-BAF51
KZFSN5
SF2
N-KZFS11
N-LAK21
N-SSK2
N-SSK8
N-F2
N-PSK53
N-SK15
N-KZFS4
KZFSN4
N-PSK53A
N-SK16
N-SK4
N-BAF52
F4
F5
N-SK2
N-SK14
SK
3
N-SK5
2
N-BALF4
N-BAK1
N-BAK4
N-KZFS2
N-SK11
N-PSK3
N-BAK2
N-BK7
6
N-K5
N-ZK7
K7
K
N-BK10
K18
This is a graph of acid sensitivity (one of 13 graphs)
Can you do that with Code-V?



See the transmission ranges onscreen

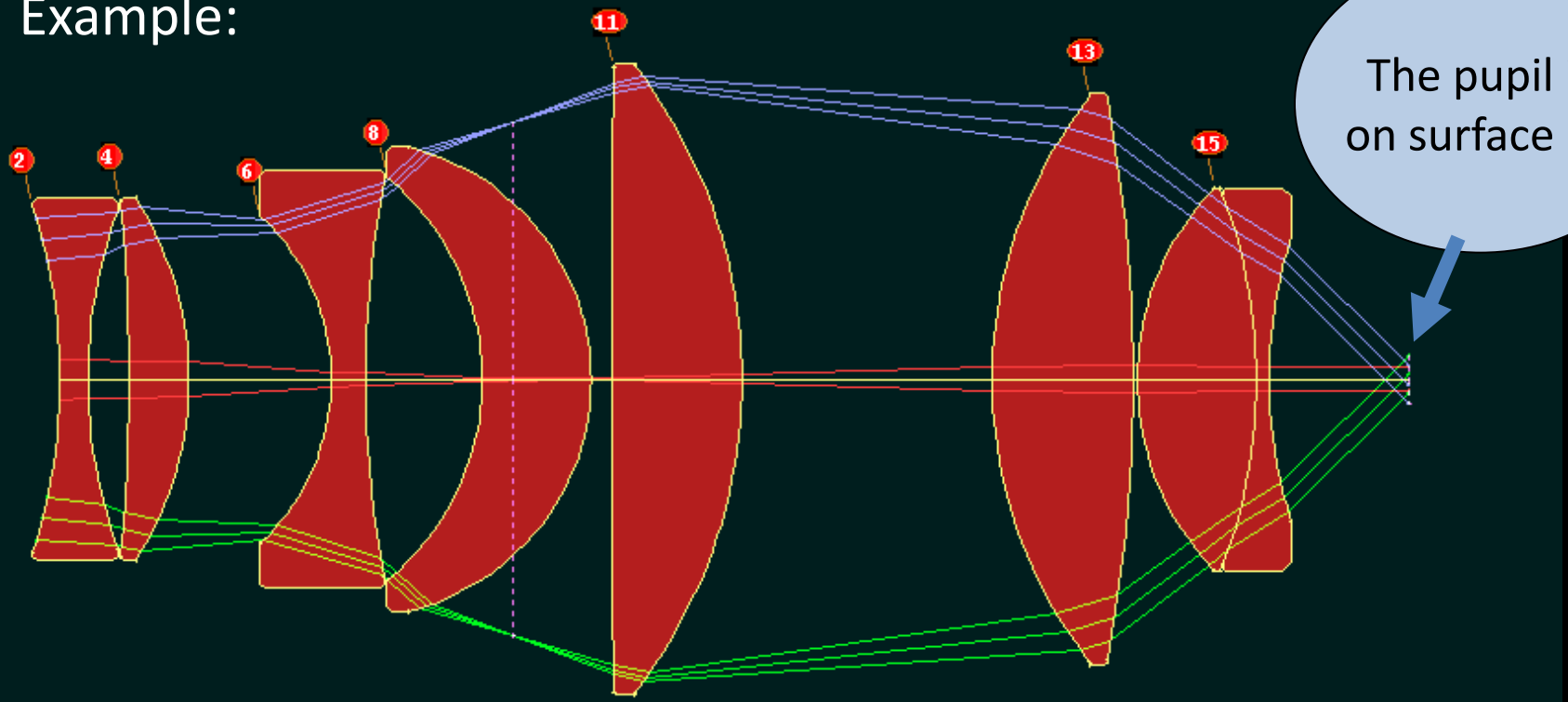
Can you do that as easily with Code-V?

Artificial Intelligence

- What if you want a feature that is not in the program?
- Code-V: write a letter.
- SYNOPSYS: tell the program what you want, in plain English.
  - Example: find the spherical aberration of the exit pupil of an eyepiece.
  - There is no command for that.

No matter!

Example:

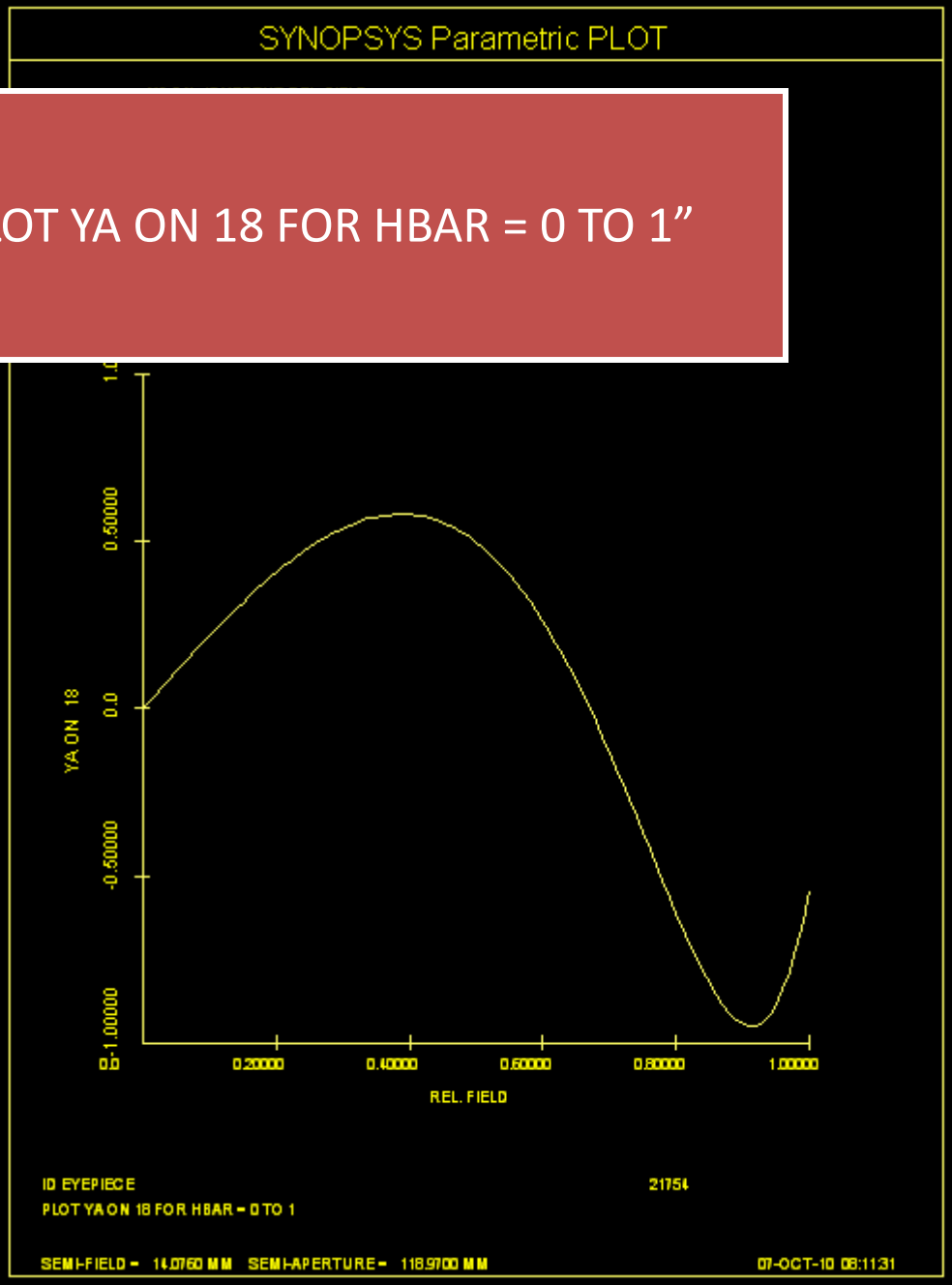


We want the Y-coordinate of the chief ray on surface 18 as the field varies from 0 to 1

Just ask for it!

"PLOT YA ON 18 FOR HBAR = 0 TO 1"

And here is the plot.



Can you do that as easily with Code-V?

Artificial Intelligence

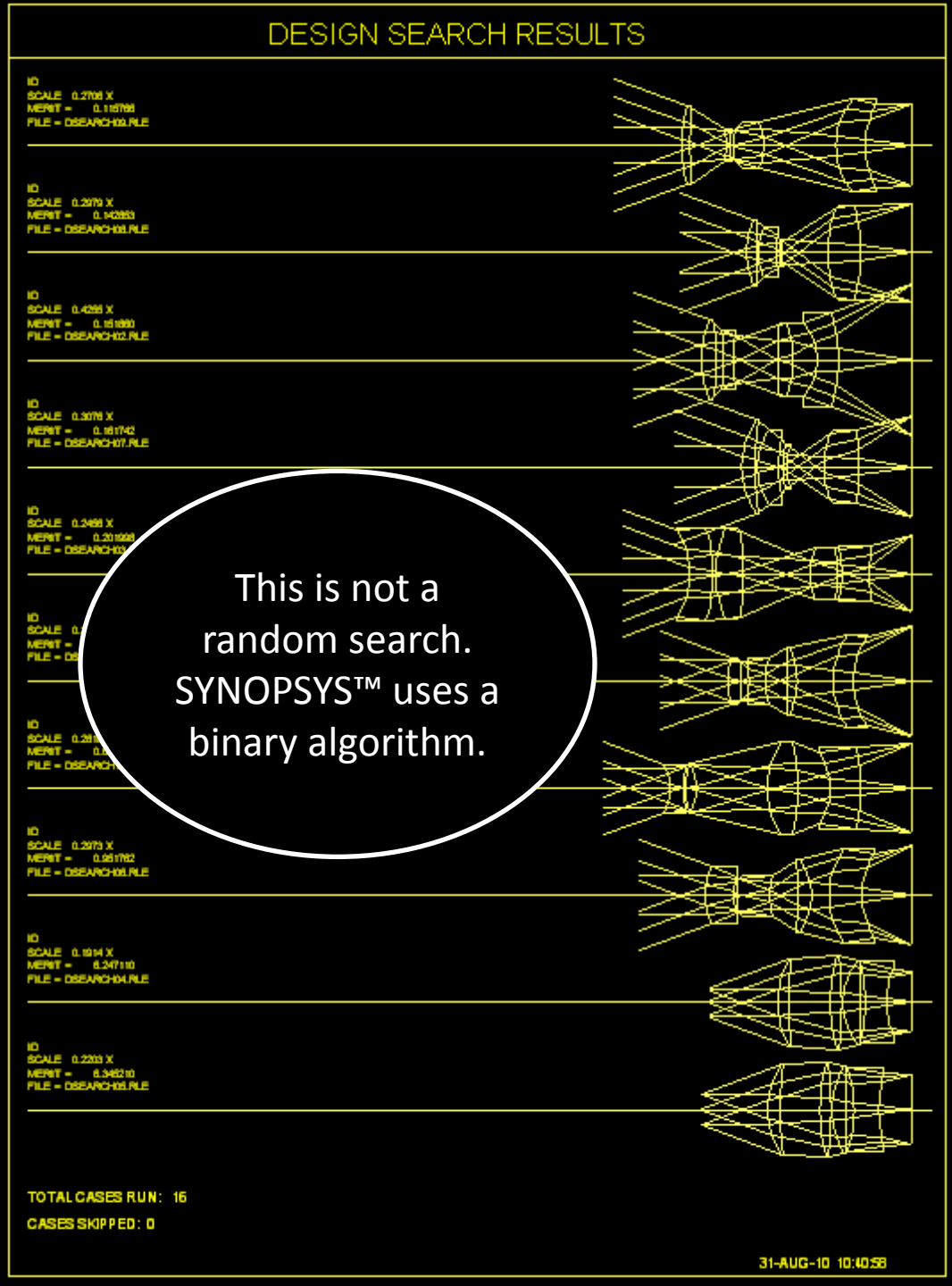
- Make up your own commands
  - in plain English.
- Define a symbol to execute that command
  - (examples) QQ: RAY P 0 0 1 SURF
  - XX: PLOT YA ON 18 FOR HBAR = 0 TO 1
- Hate typing? Only type it once!
- Then use that symbol whenever you want.

Can you do that with Code-V?

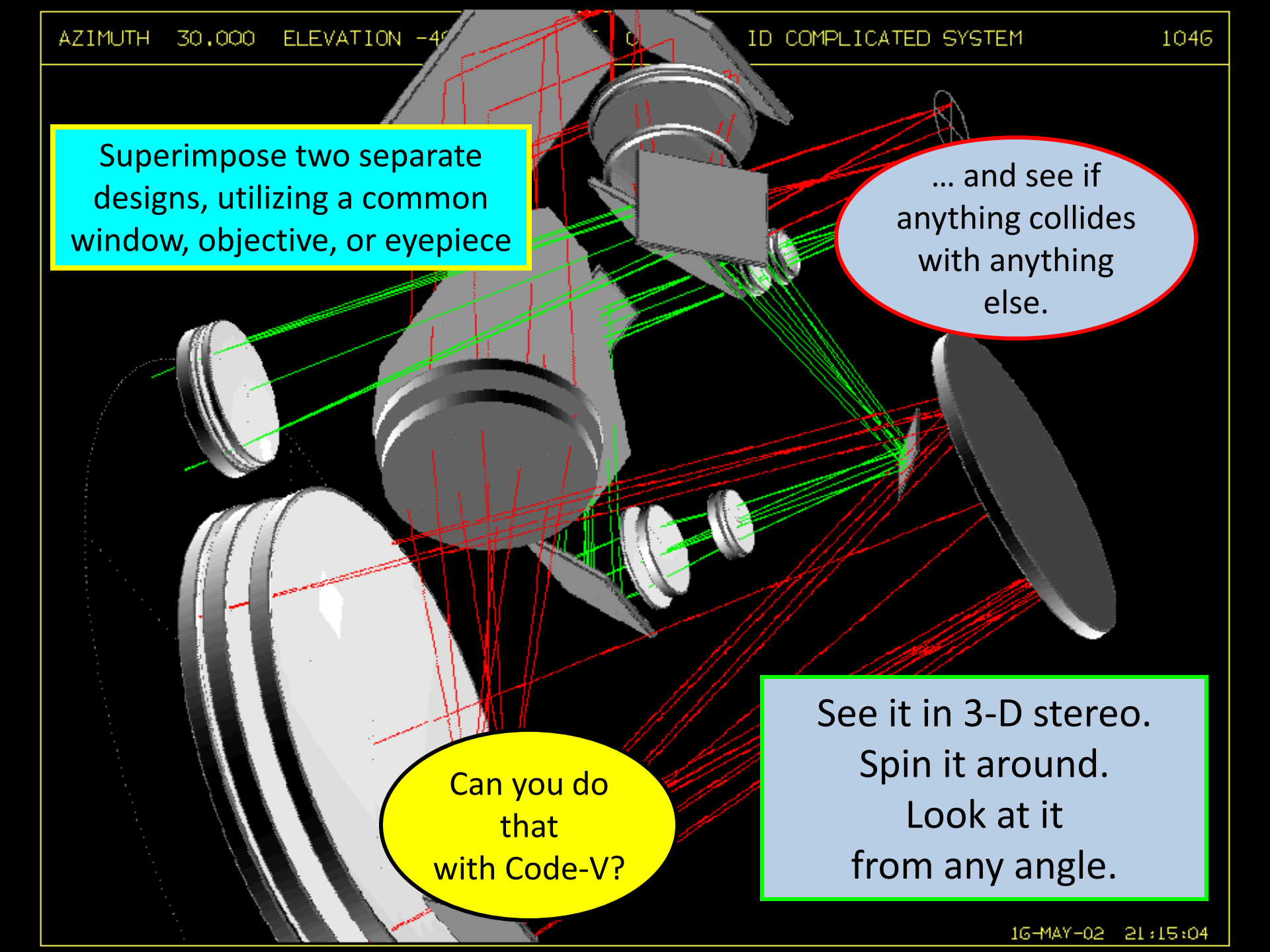
SYNOPSYS has a design search feature. You give it some goals and the number of elements you want. Then it looks for the best starting points automatically.

Here we asked for a four-element lens with a 40-degree field of view

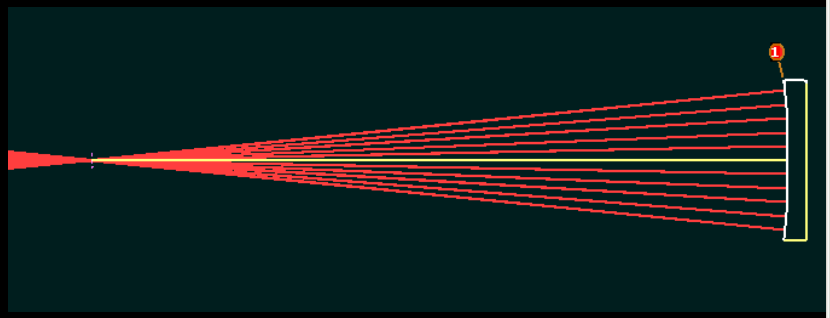
Some of these lenses are good starting points.



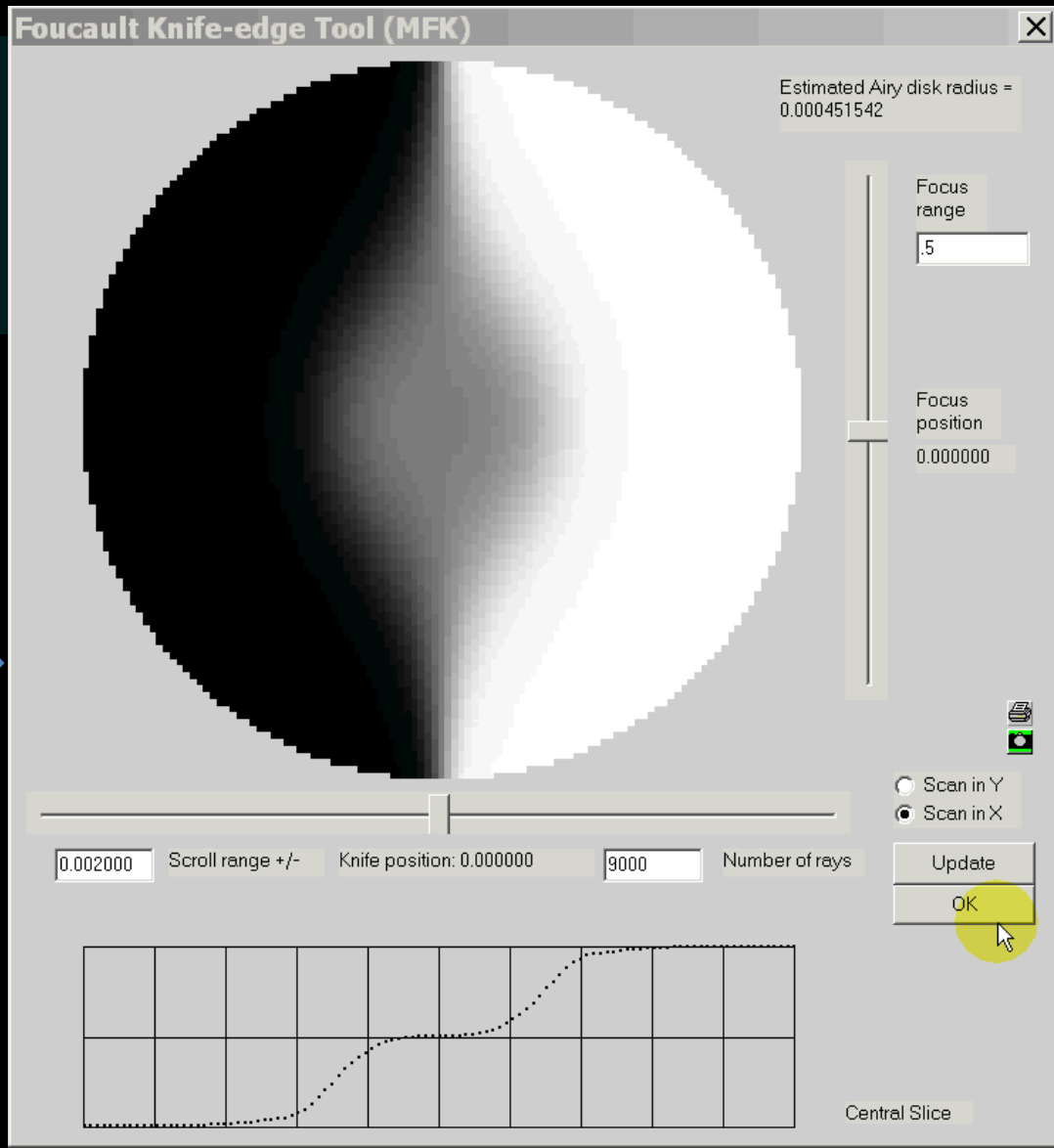
This is not a random search. SYNOPSYS™ uses a binary algorithm.


AZIMUTH 30.000 ELEVATION -4
ID COMPLICATED SYSTEM 1046
Superimpose two separate designs, utilizing a common window, objective, or eyepiece
… and see if anything collides with anything else.
Can you do that with Code-V?
See it in 3-D stereo.
Spin it around.
Look at it from any angle.
16-MAY-02 21:15:04

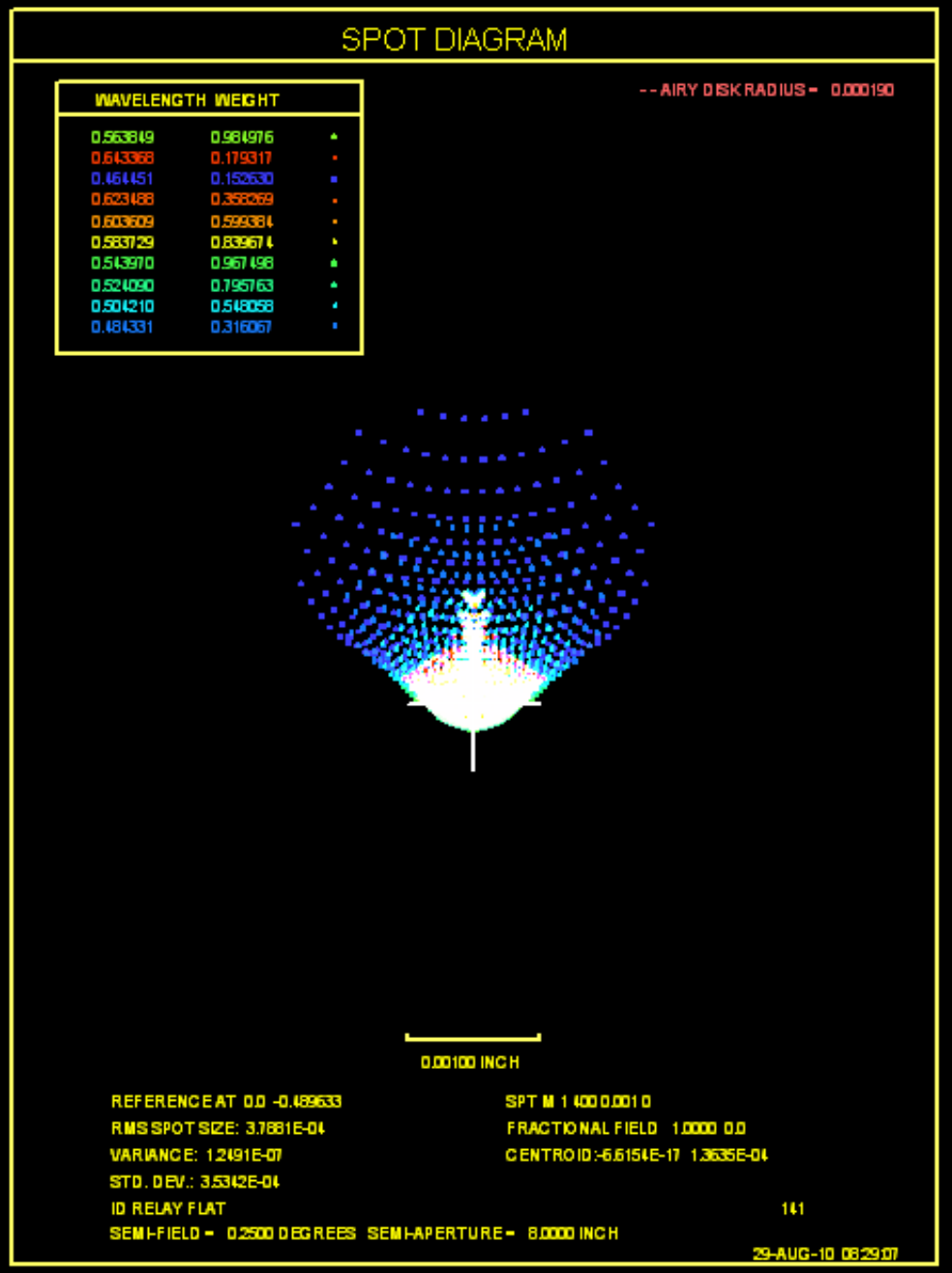
Foucault test emulator



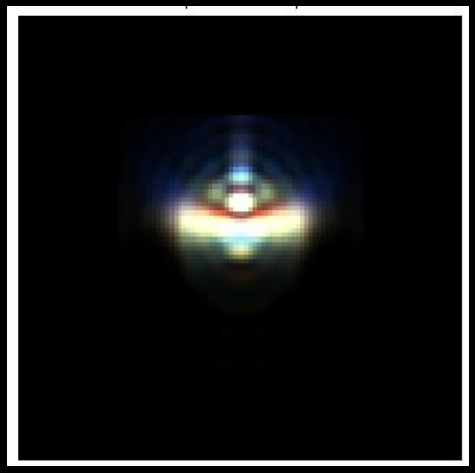
Click to play

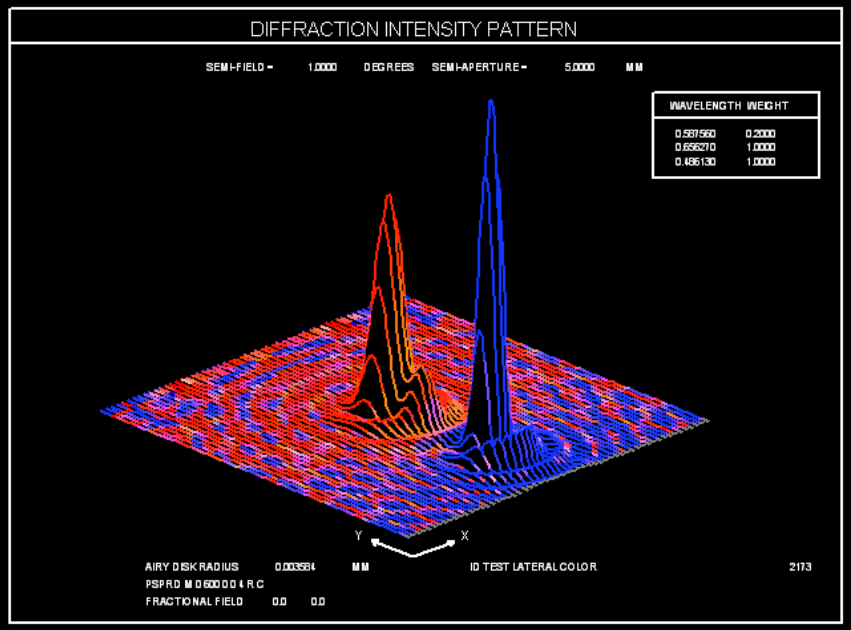


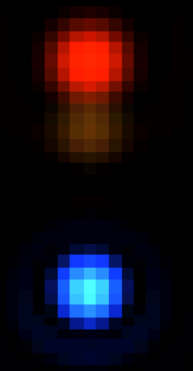
- Geometric images show realistic colors



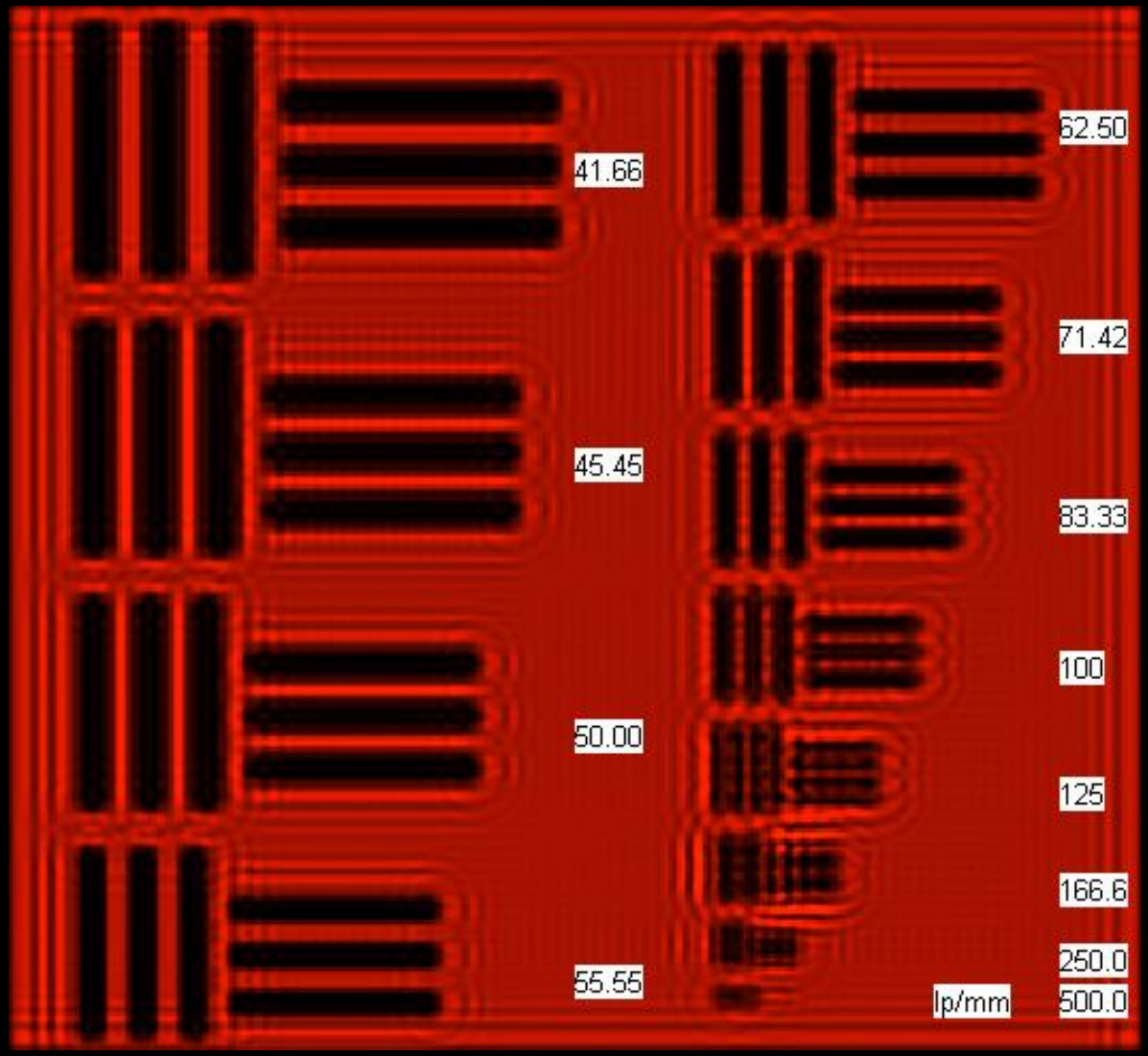
Diffraction images are also shown in realistic colors.







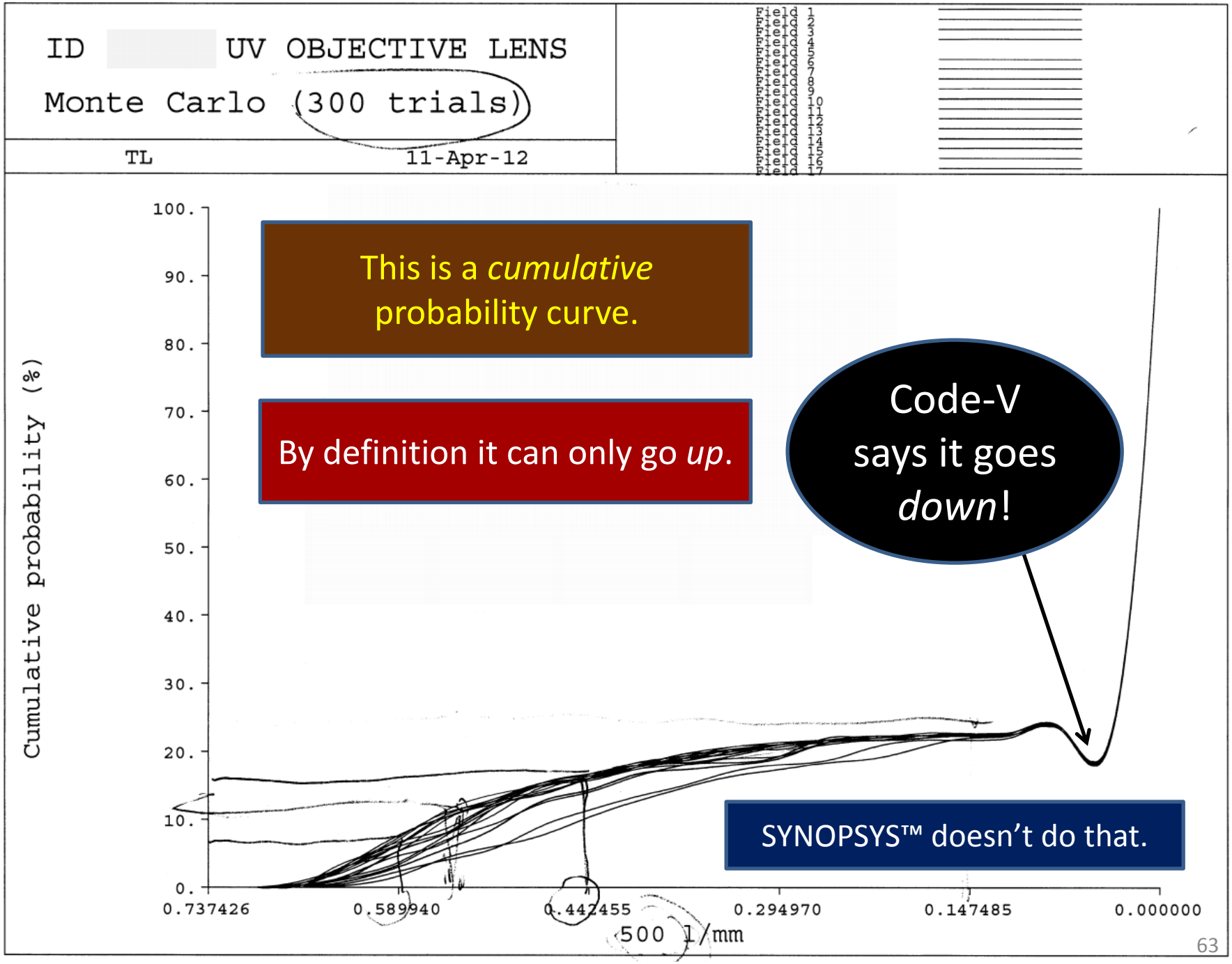
- Image Tools (MIT) has 2-D coherent analysis



Here's a Blunder:

- Code-V smooths all kinds of plotted output
- This gives a *false impression* of high accuracy
- But the result is misleading…

… and sometimes plain wrong.


ID UV OBJECTIVE LENS
Monte Carlo (300 trials)
TL
11-Apr-12
Field 1
Field 2
Field 3
Field 4
Field 5
Field 6
Field 7
Field 8
Field 9
Field 10
Field 11
Field 12
Field 13
Field 14
Field 15
Field 16
Field 17
This is a *cumulative* probability curve.
By definition it can only go *up*.
Code-V says it goes *down*!
SYNOPSYS™ doesn't do that.
Cumulative probability (%)
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.
0.737426
0.589940
0.442455
0.294970
0.147485
0.000000
500 l/mm

You've seen how the features and speed compare.

Now compare the cost…

Code-V claims the highest benefit/cost ratio

Does it deliver?

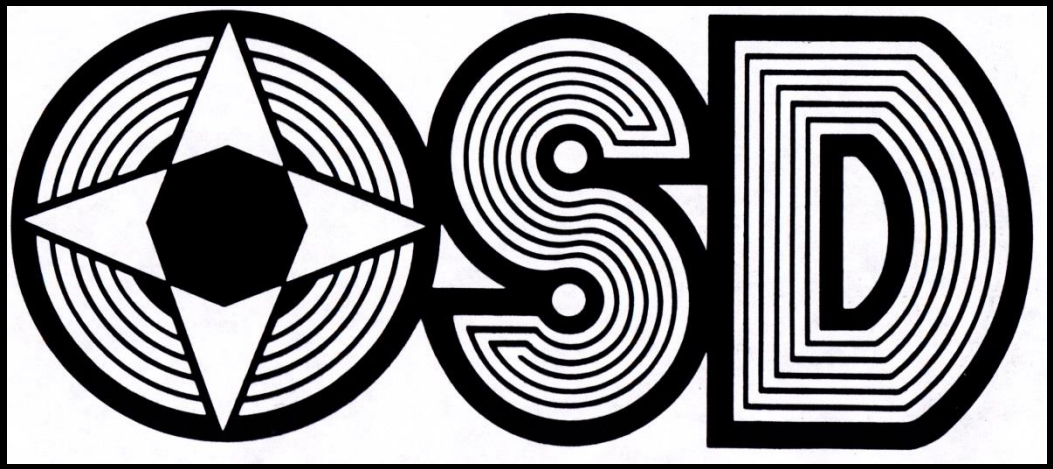
"I have used six different optical design programs; yours has won the competition. I am studying the published work of David Shafer. The graphics front end of SYNOPSYS lends itself very well to his approach. … The net effect is lower cost."

…Roger Whitmer, Pittsfield MA

Check out our website:
www.osdoptics.com
And click on
"Comments"

Don Dilworth

Optical Systems Design, Inc.



www.osdoptics.com

dilworth@osdoptics.com