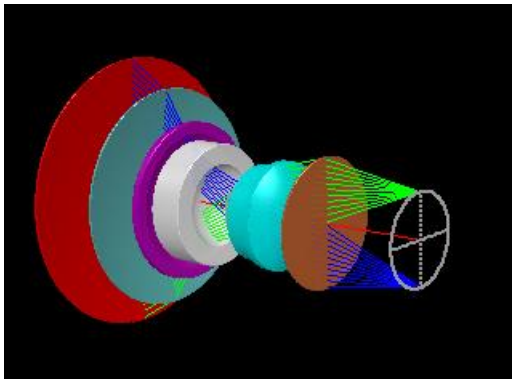
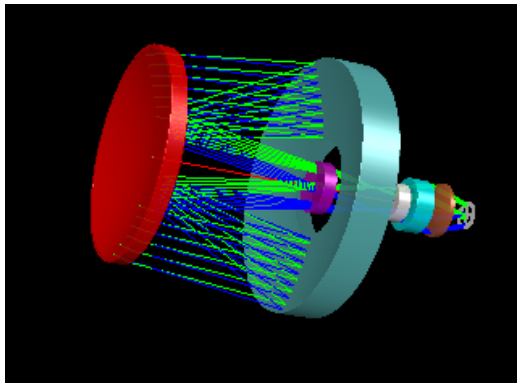
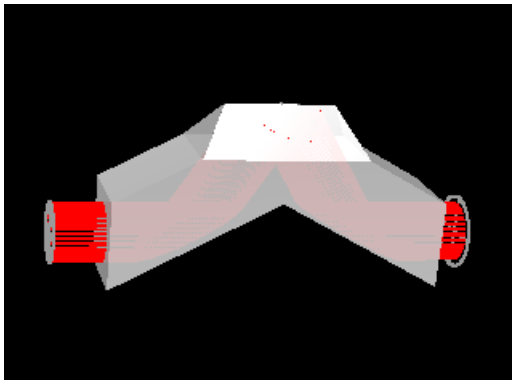
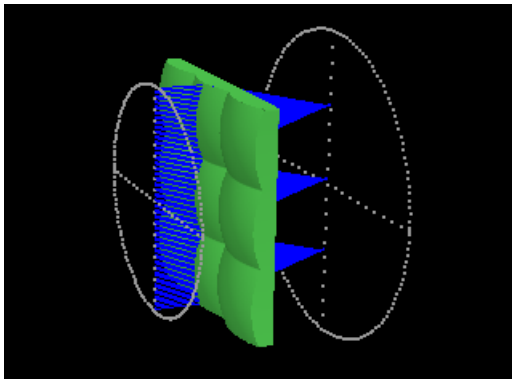
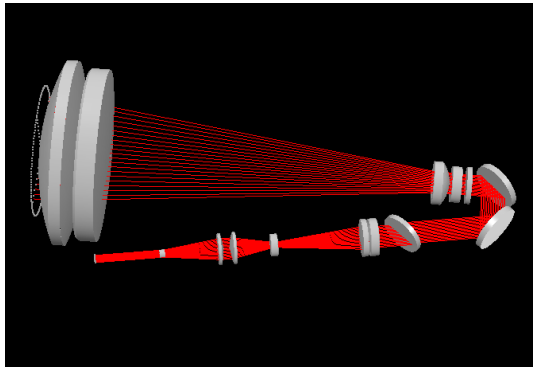
Comparison: SYNOPSYS™ *vs.* Zemax™

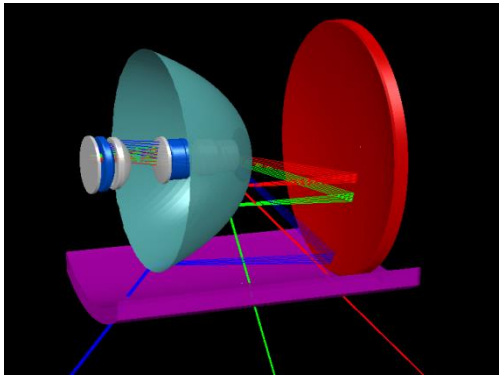








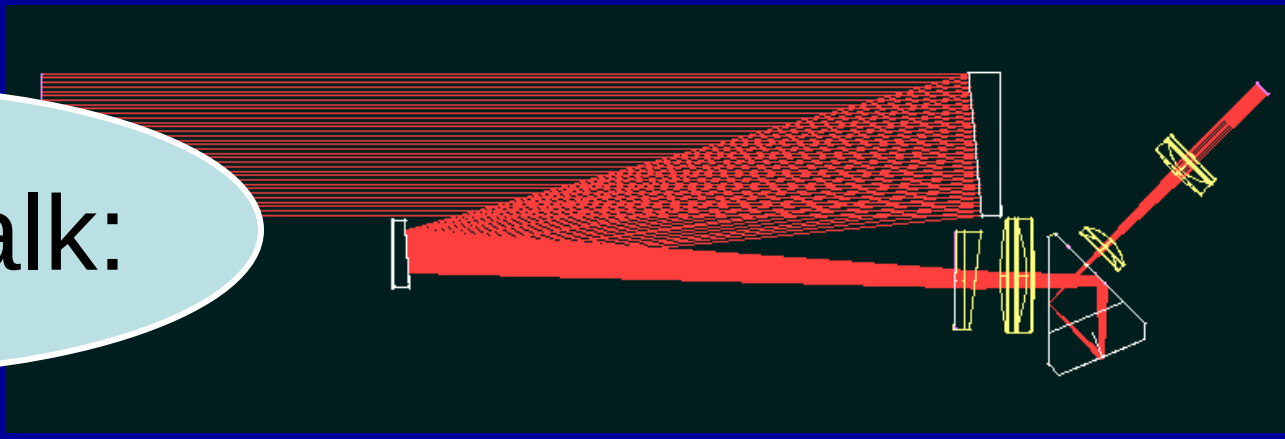




Disclaimer

- All of the information presented here is based on comments we have received from Zemax 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. Zemax™
- 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.

Big difference in concept

- Zemax has no command language.
- Puts merit function and tolerances in the same file as the lens data.
- File can be extremely large.

- SYNOPSYS™ has a powerful command language.
- The lens file is just a lens file. This is more flexible, smaller, and convenient. You can associate the files easily, if you want, for your records.

Zemax has a serious weakness

- There is no Command Window.
- A powerful resource is missing.
- Those who have experienced the convenience and power of a command window do not like having to do without.

How can *command language* be good?

- Easy.
  - For some tasks, clicking with the mouse is quicker.
  - For others, typing something is quicker
- Wouldn't it be nice to have a choice?
  - SYNOPSYS™ gives you a choice.

Command Language:

- Love it, or
- Hate it …

…here's what you can do with Command Language

- Run most useful features by typing 3 characters.
- Open any dialog with 3 characters.
- Run a feature with a mouse click.
- Return to the *same* dialog with the <Enter> key.
- Define your own command, to do anything you want – with 1 to 3 characters.
- Make a command file, to run it again – with one click. This takes 3 keystrokes.

They wrote a program that can't do that…

… and they're proud of it!

SYNOPSYS can.

Window protocol is different

- Zemax uses a separate window for each kind of picture.
  - Clutter
  - Clutter
  - Clutter
  - Clutter
  - Clutter
  - Clutter
  - Clutter …
- SYNOPSYS™ can reuse graphics windows.
  - Simple and neat
  - Open several if you want to.
  - Monitor optimization in the SketchPad window. One window, five views.
  - Neat.

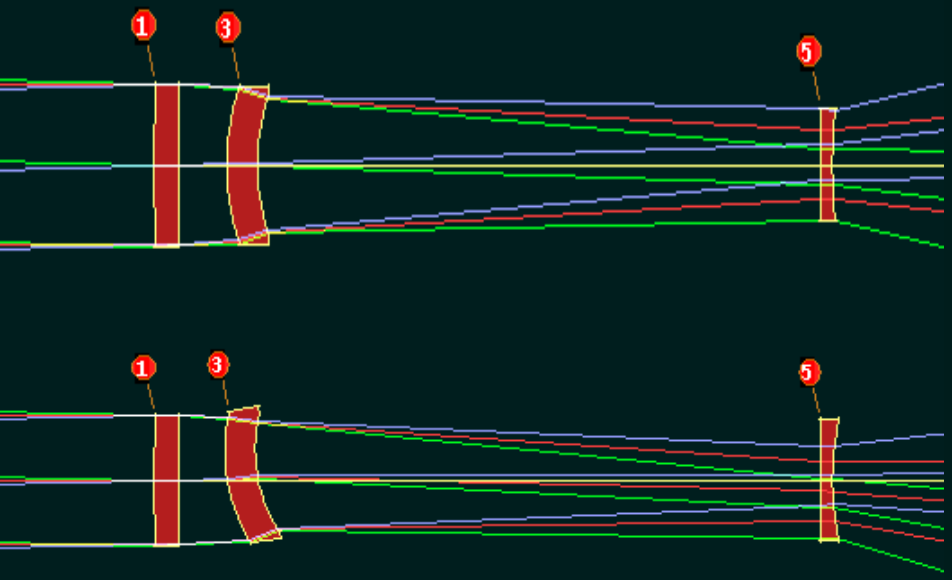
Weaknesses:

- Another weakness in ZEMAX is its handling of tilts and decenters.
  - Cumbersome (although it works)
  - If you use “coordinate breaks”, you get lots of extra dummy surfaces.
  - You can also tilt a surface, if you choose to. Users have told us, in their opinion, SYNOPSYS™ makes it easier.

SYNOPSYS coordinates:

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

Relative tilts:



To tilt the second element

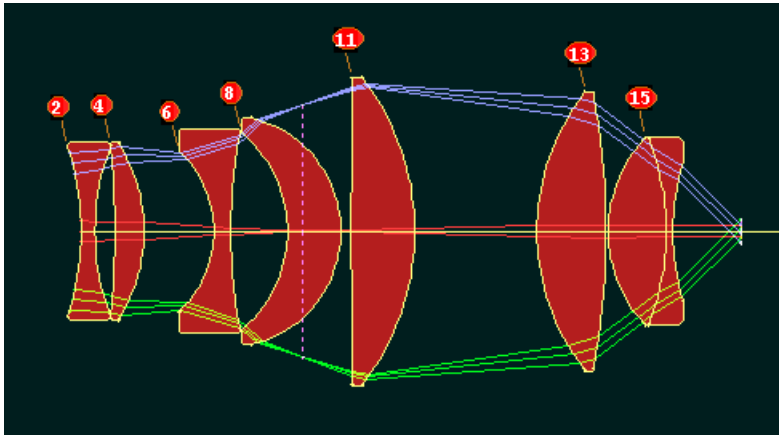
You tilt the *element*,
not a dummy surface.

Surface 3, 10 degrees
2 surfaces. The reverse
tilt is *automatic*.

3 AT 10 0 2

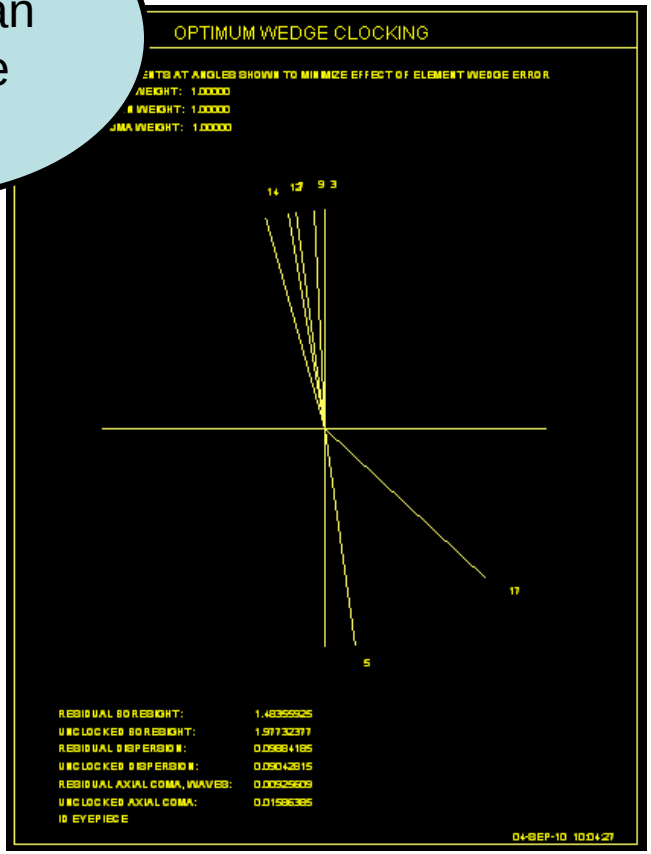
This is simple
and friendly.

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 very easy.

Try this with Zemax, and let us know if you succeed.

SYNOPSYS doesn't need any dummies.

Documentation:

- SYNOPSYS has two manuals:
  - User's Manual – to be read on the monitor
  - Tutorial Manual – to be printed out

The SYNOPSYS™ online manual is more friendly.

- 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 Zemax online manual is less convenient.

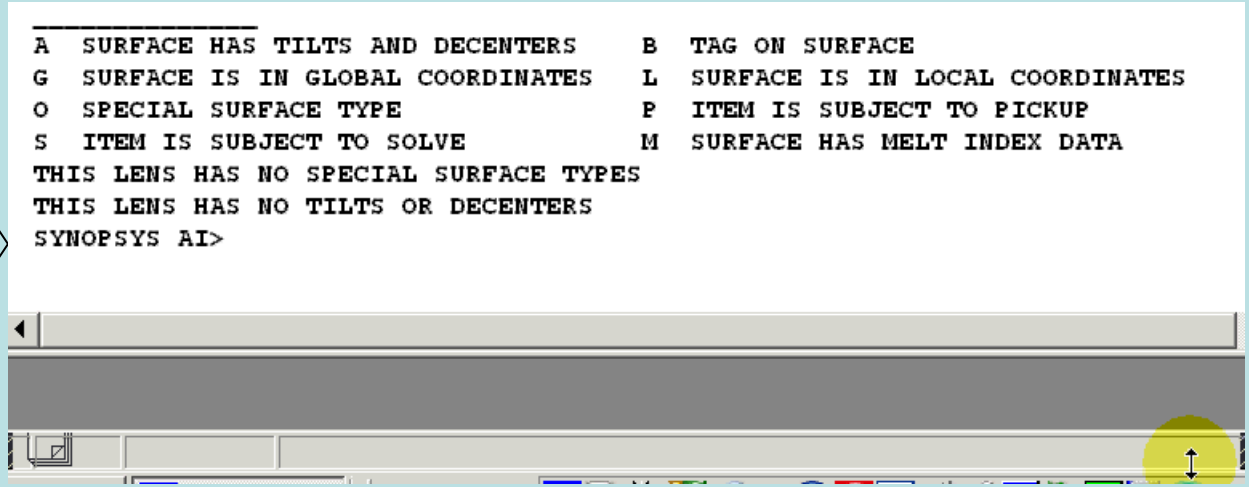
Watch the Instant Help in action

1. Type 3 characters of a command.

2. Look at the Tray

3. It remembers the command syntax for you.

Click



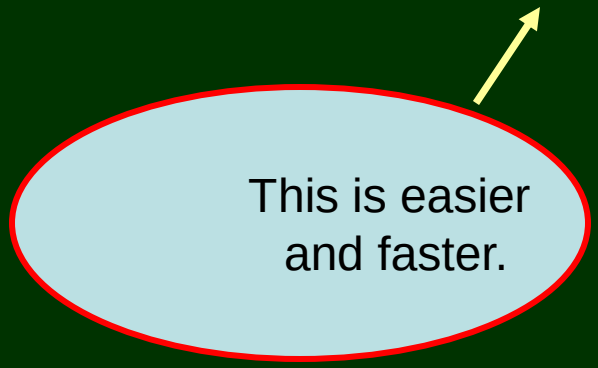
Press F2 and the manual opens.

ZOOM lenses

- ZEMAX must do zoom lenses with the multiconfiguration feature.
  - No native zoom.
  - No automatic undo
  - No cam curve feature
  - No zoom slider
- 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 with ZSEARCH™

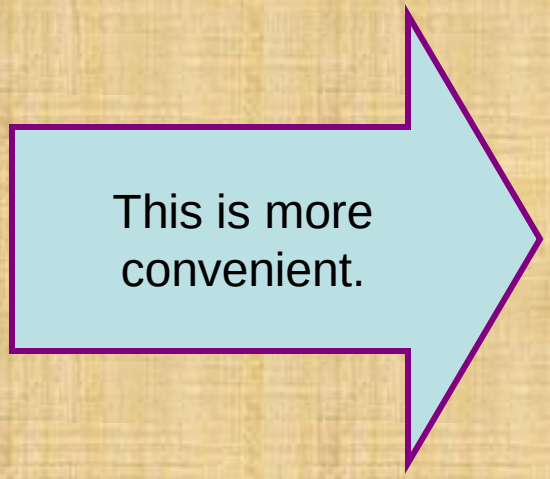
Difference in multiconfiguration philosophy

- In Zemax, all configurations are *the same* unless you declare differences.
- In SYNOPSYS™, all configurations are *different* unless you declare similarities.
  - Which you can do with about 3 commands.



Zemax stores a list of field points

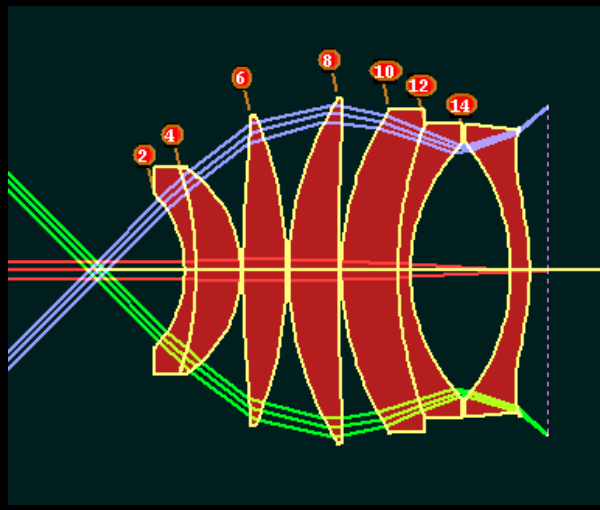
SYNOPSYS stores the *definition* of “full field”.



Then you can request any field point you want with the parameters HBAR and GBAR

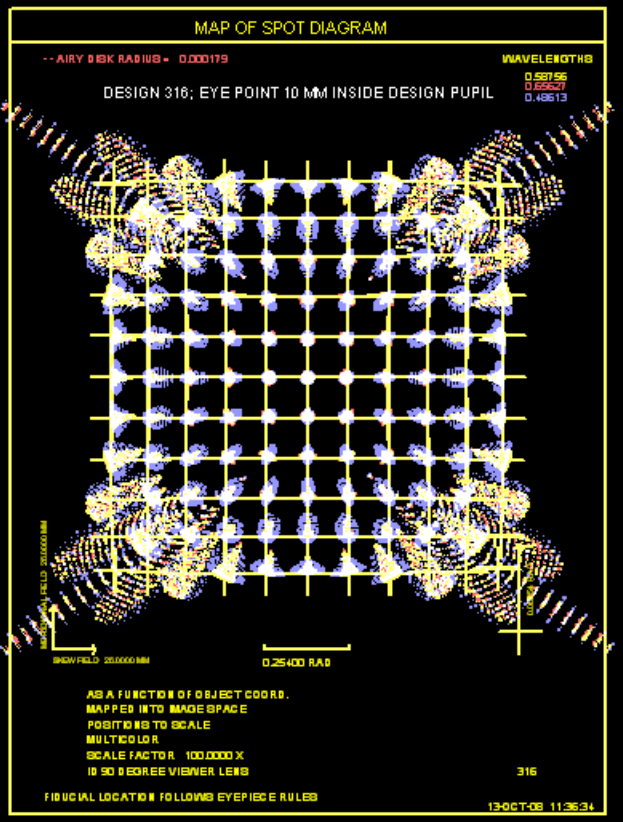
MAP feature:

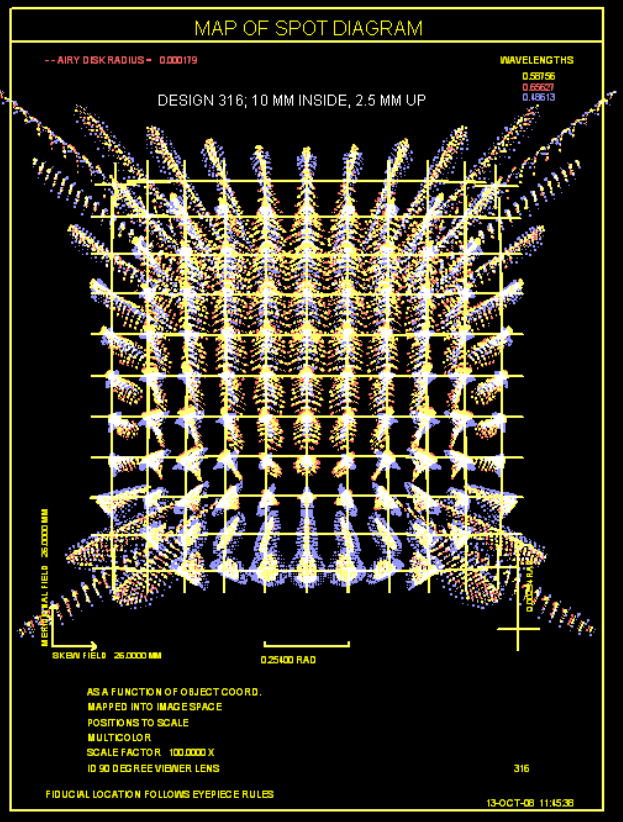
Spot diagram mapped over the field



When you look at the center you see this.

When you look near the bottom you see this.

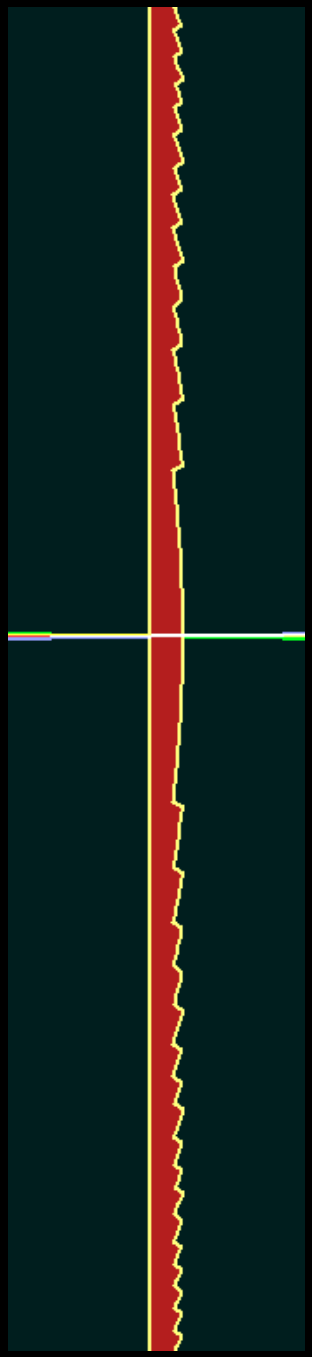




That's one of 19 things MAP can show.

More unique features:

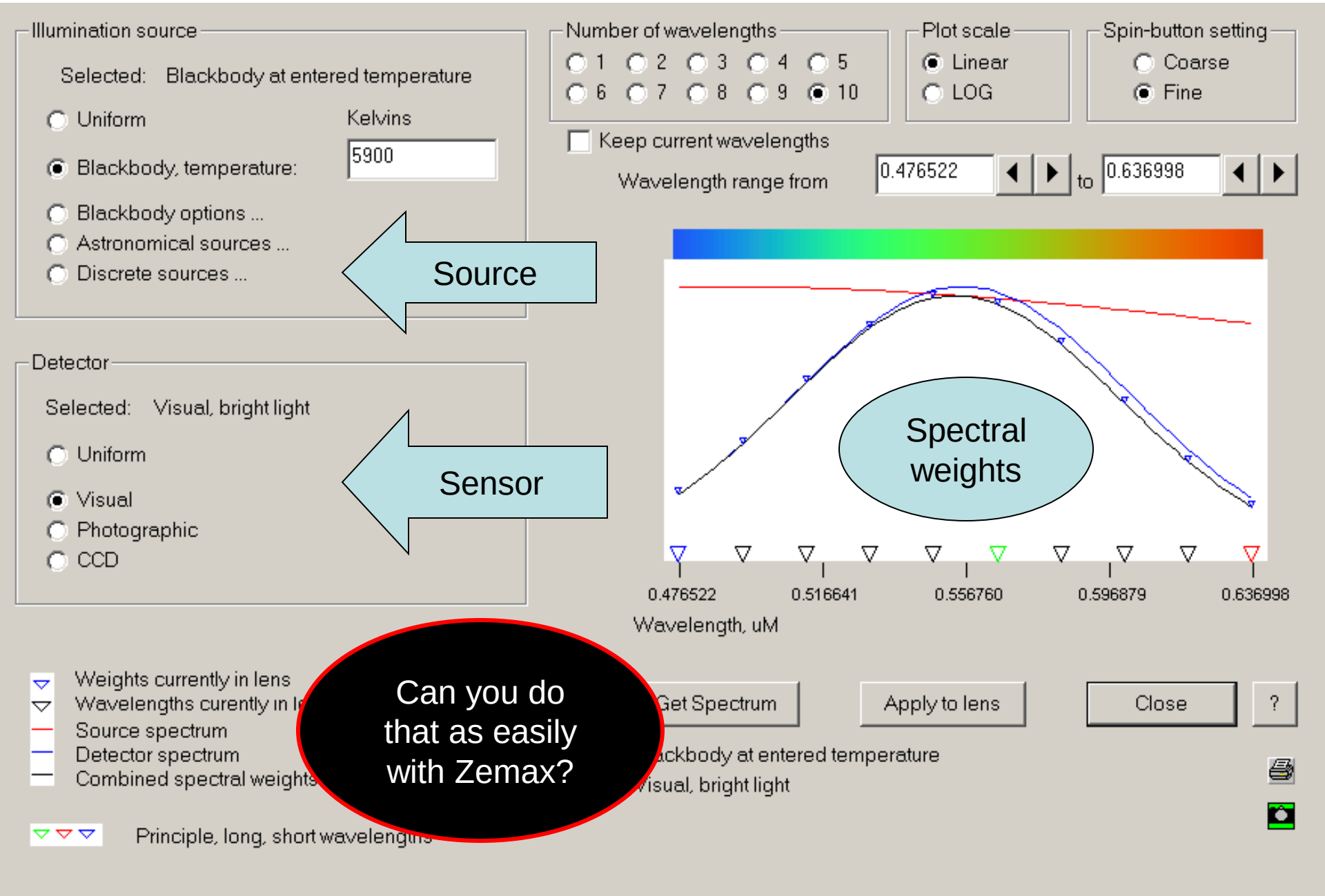
- Hologram efficiency
- Explicit Fresnels
  - Sequential raytrace
- Longitudinal PSF
- Coating design program
- 3-D stereo display
- PSD optimization



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.
- Tolerance desensitization, from 3rd-order theory.
- Images displayed in realistic colors
  - Geometric
  - Diffraction-based
  - Coherent
- Spectrum Wizard

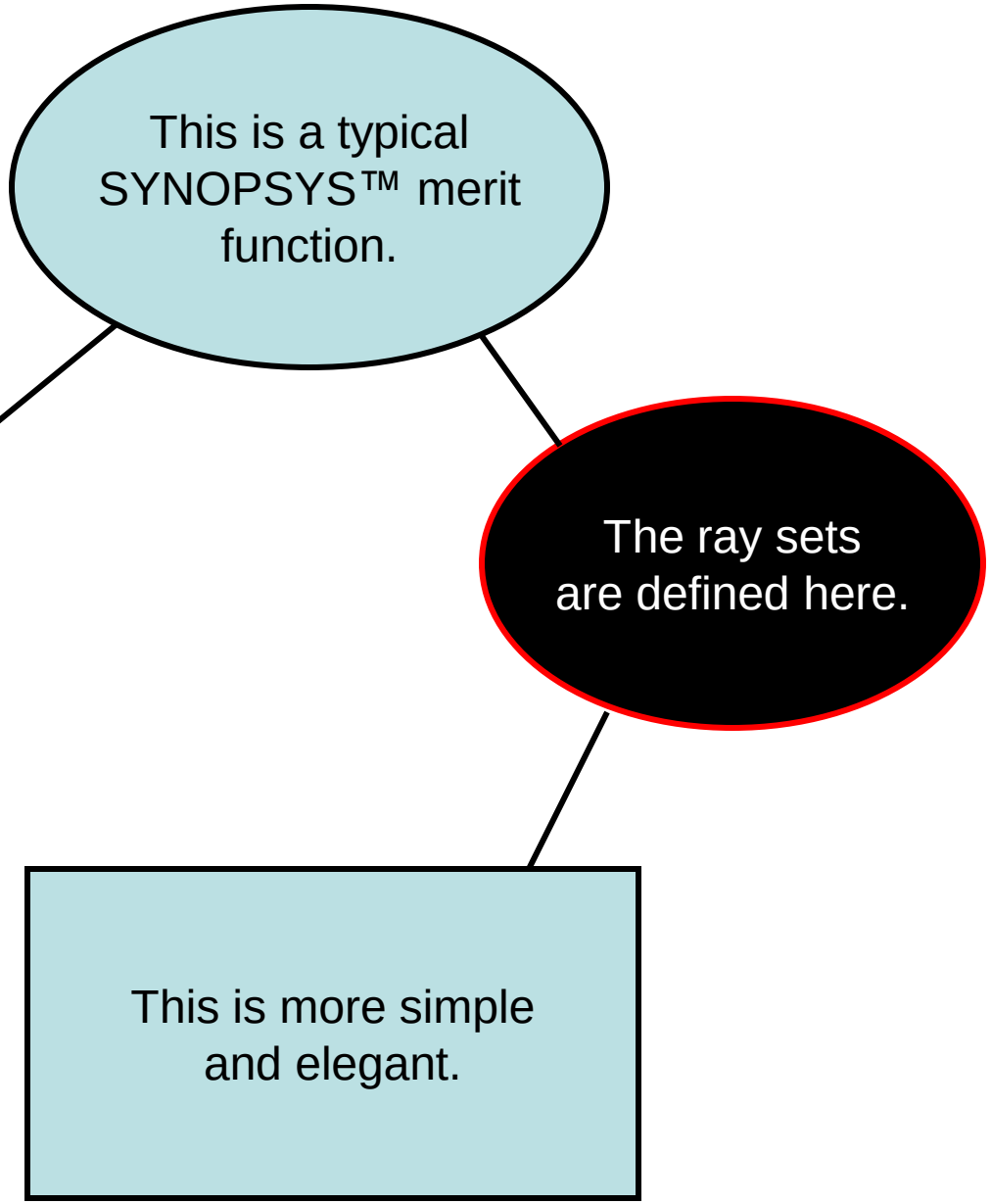
The Spectrum Wizard can find spectral weights for you.



```
PANT
VLIST RAD ALL
VY 1 TH 20 3
VY 2 TH
VY 3 TH 20 3
VY 5 TH
VLIST GLM 1 3
END

AANT
AEC
ACC
GNR .5 1 3 2 0
GNR .5 1 3 2 .5
GNR .5 1 3 2 .7
GNR .5 1 3 2 1.
GNR .5 1 2 1 0
GNR .5 1 2 3 0
GNR .5 1 2 1 1
GNR .5 1 2 3 1
END

SNAP
SYNO 25
```

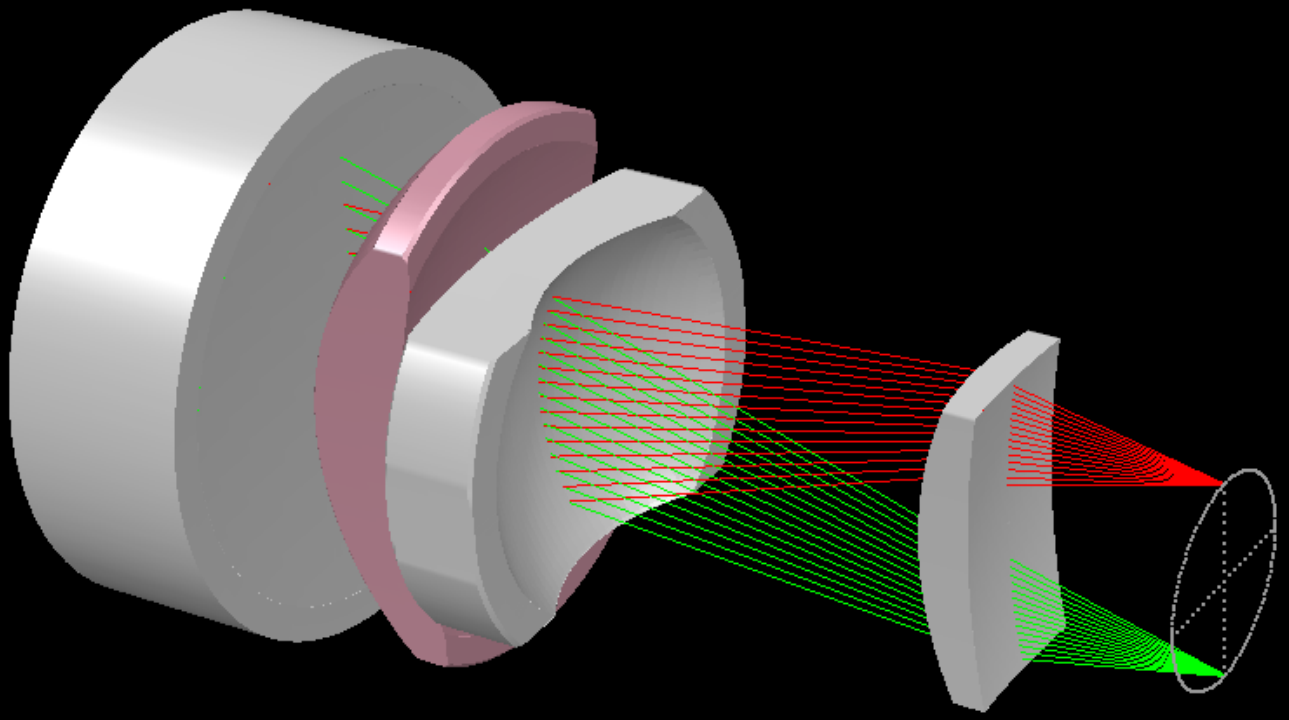


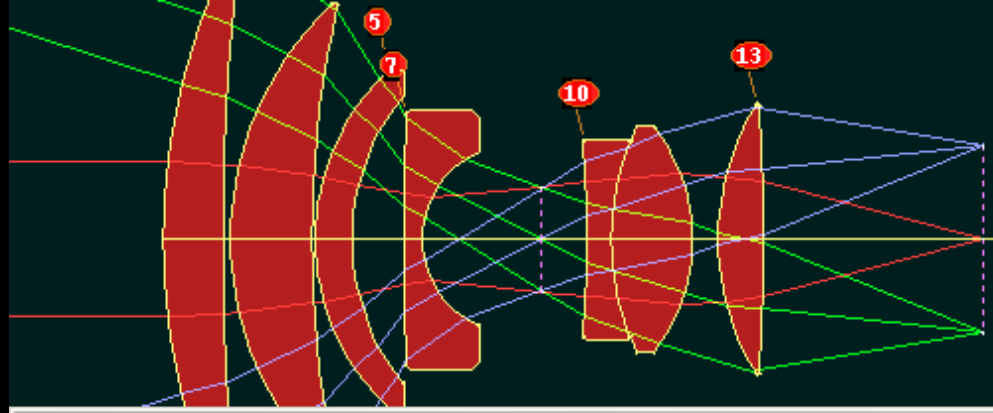
SYNOPSYS can monitor the system during optimization, to

- keep all default apertures less than a desired limit
- keep refraction angles from getting too close to the critical angle
- maintain a minimum edge thickness for glass and air spaces
- keep elements from getting too thick or too thin
- prevent surface curves from getting too steep.

Edge geometry

- Zemax has none
- 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

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

Prev. el. <- -> Next el.

Spin increment: 0.127000

Add rectangular edge to EFILE circular apertures

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

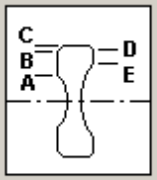
Angle 1 0 — Angle 2 0

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

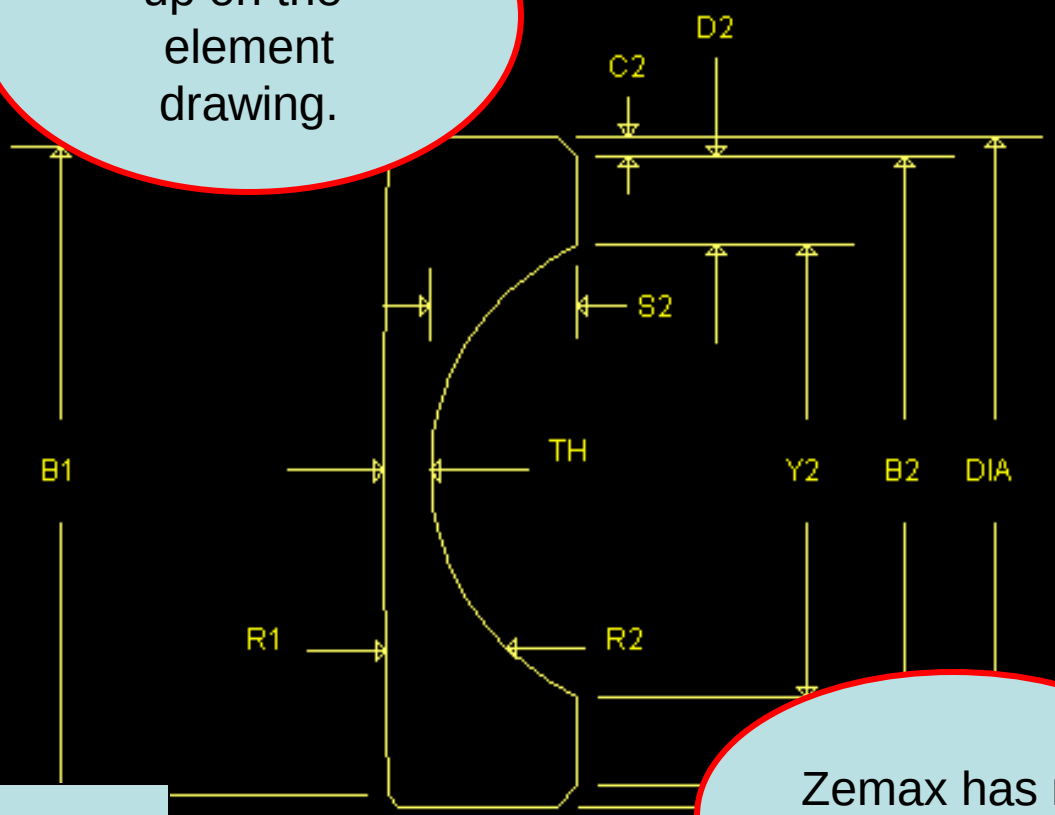
(Use negative number to flip)

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.



Zemax has no edge wizard

Tolerances too.

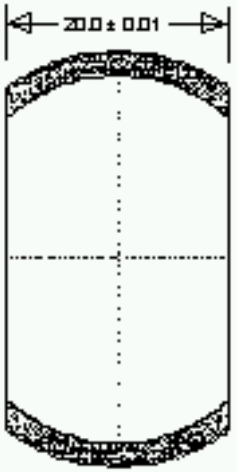
2.000 X	JMBER	
DATE 07-SEP-10	REV.	
DESIGNER	APPROVED	
CHECKER		
TEST WAVL		
DIMENSIONS MM		SYNOPSYS LOG 21571

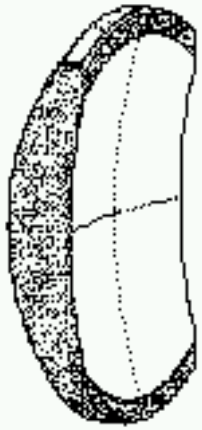
SAMPLE LEN

ELEMENT 4

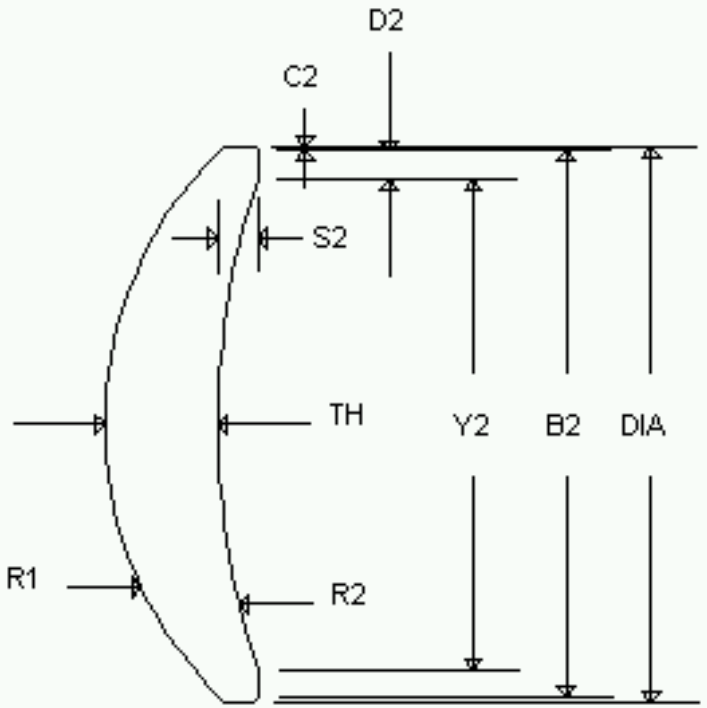
OSD, INC

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.

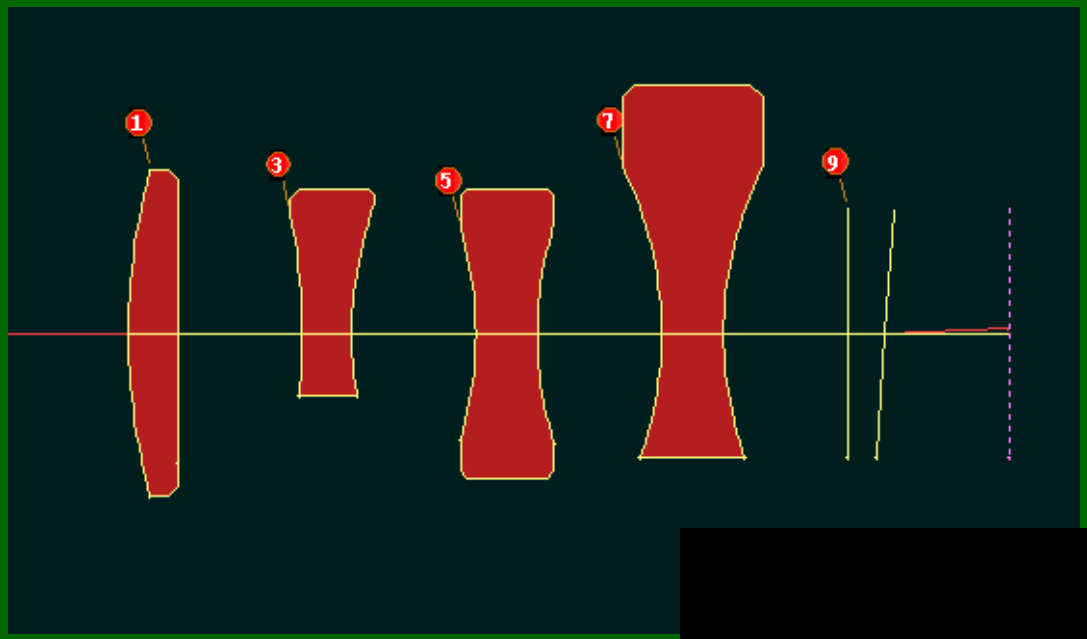


SCALE 2.000 X	NUMBER	
DATE 03-OCT-05	REV.	
DESIGNER	APPROVED	
CHECKER		
TEST WAVL		
DIMENSIONS MM		SYNOPSYS LOG 1861

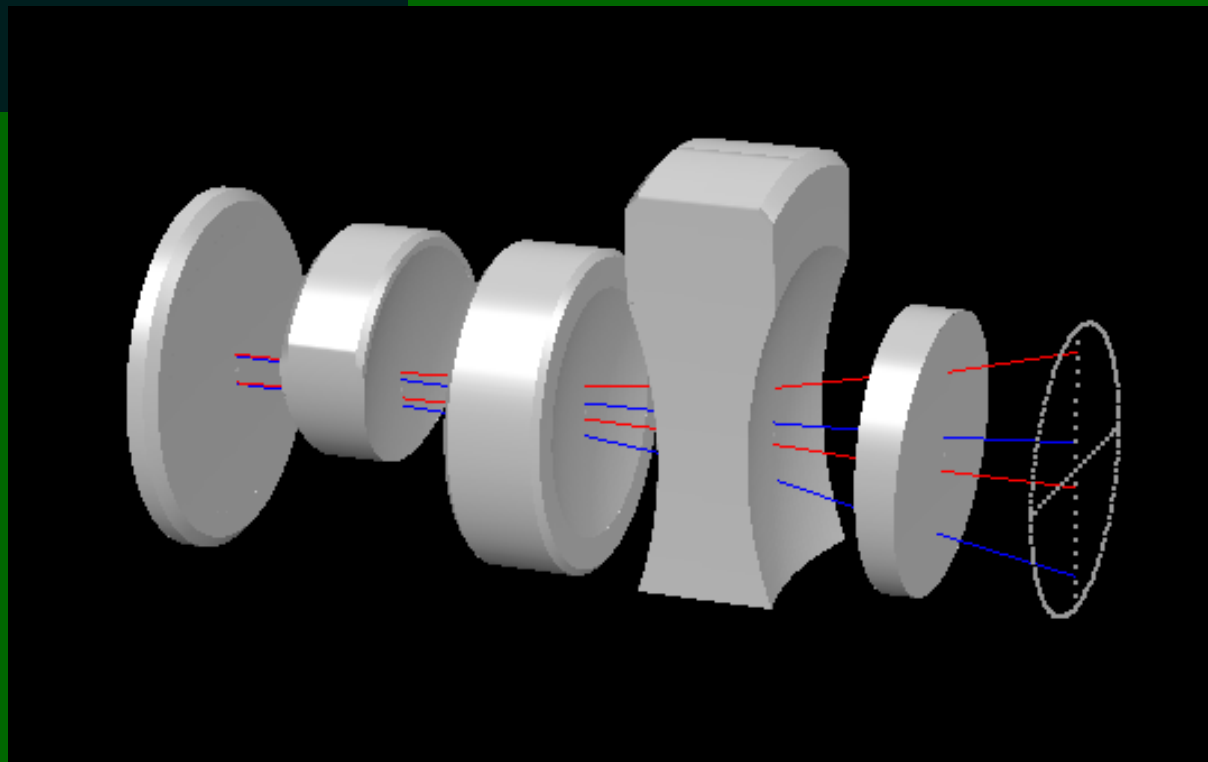
ELD EXAMPLE
COMPLEX APERTURE

OSD. INC.

Edges can be simple or complex.



Can you do
that
with Zemax?



Optimization methods:

Zemax

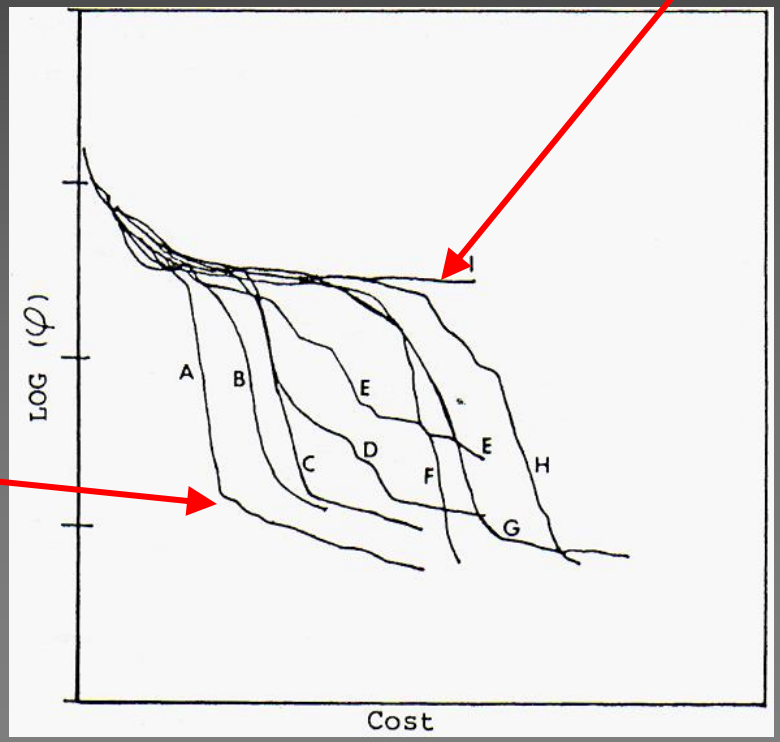
- Several modes
  - DLS
  - orthogonal descent
  - genetic

SYNOPSYS

- PSD III

DLS

PSD III

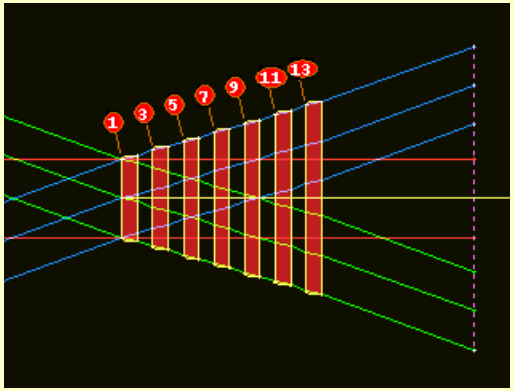


Is PSD III better?

- You bet!

We gave SYNOPSYS™ and Zemax 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.

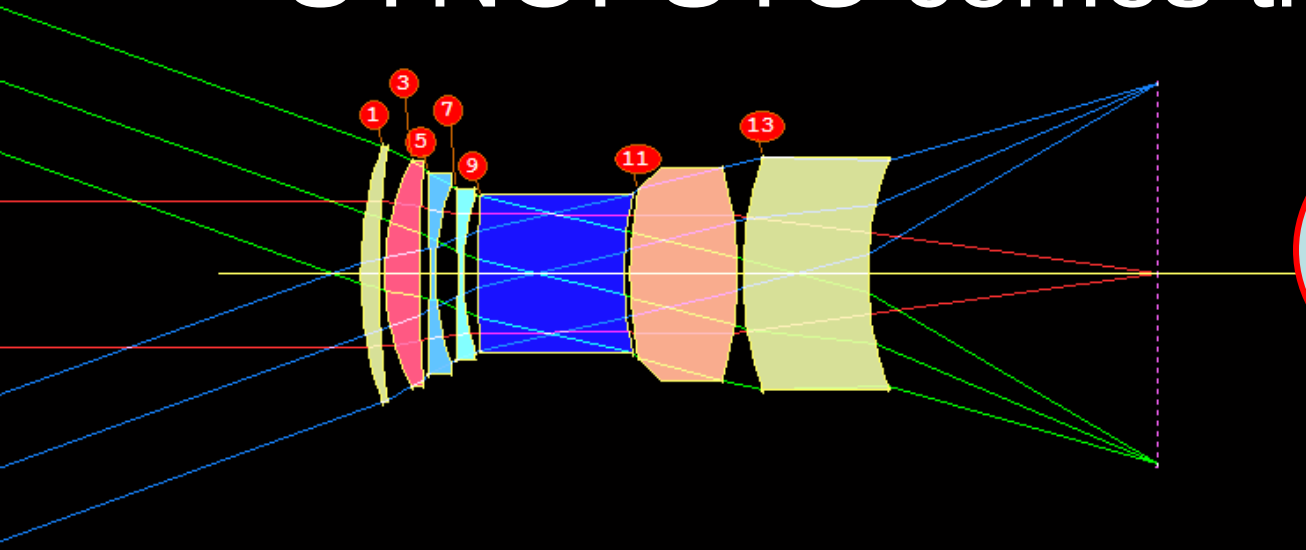


Optimization time
no more than
15/S, where
S is the CPU speed.

Those are the rules:

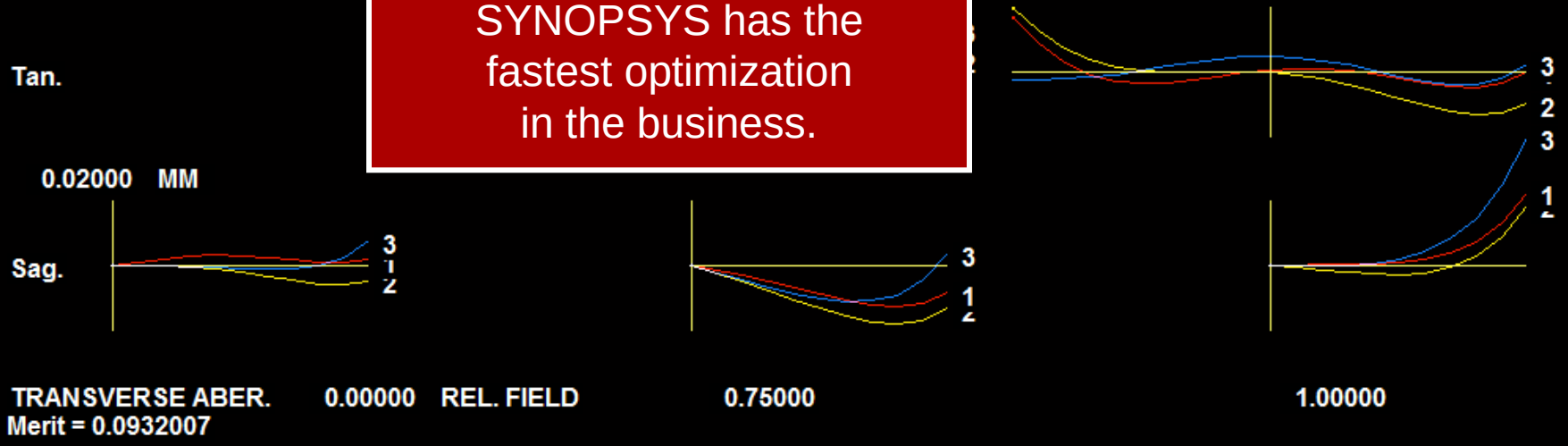
And the results…

SYNOPSYS comes through!



SYNOPSYS:
Average RMS spot: 6.9 uM

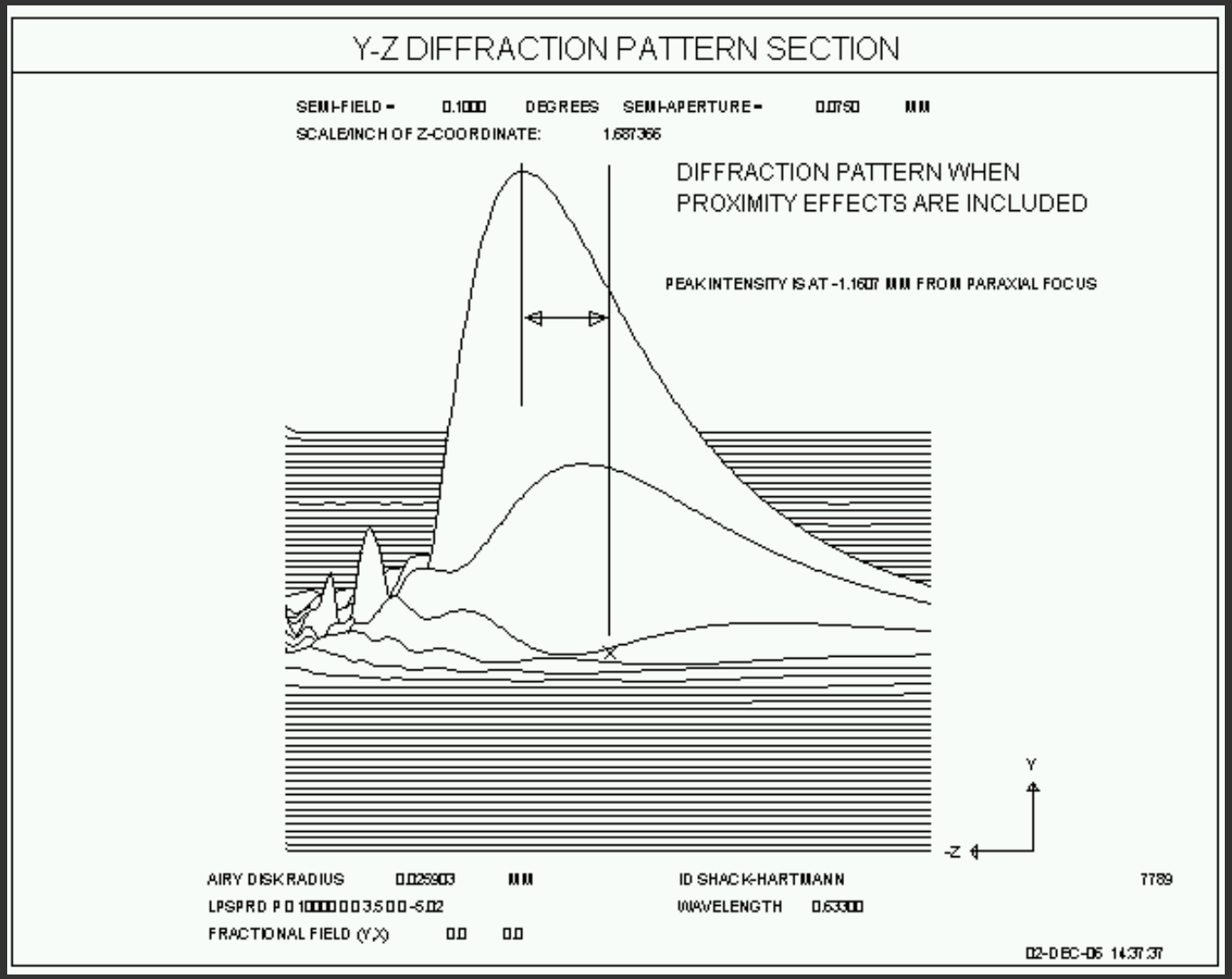
SYNOPSYS has the fastest optimization in the business.



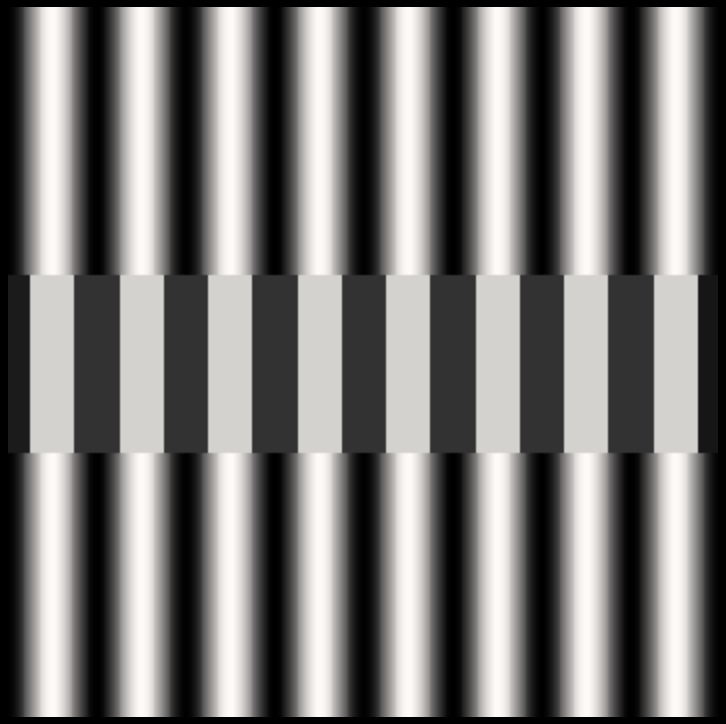
The Scorecard:

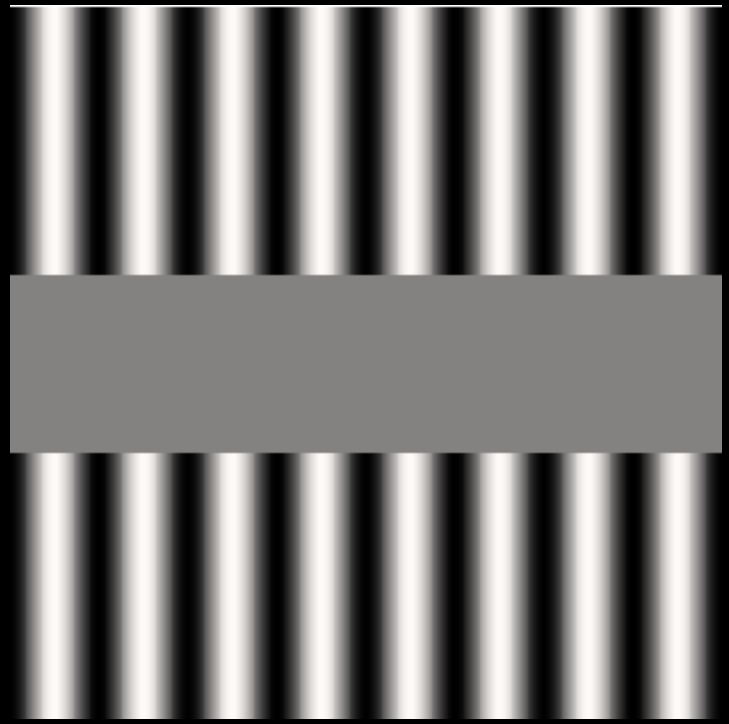
	SYNOPSYS	ZEMAX	CODE-V
CPU speed	2.0 GHz	2.4 GHz	2.0 GHz
Time limit	4.89 sec.	6.25 sec.	7.5 sec.
Ave. RMS	6.9uM	>150	364.7
Time to get this quality	1.88 sec.	3600 sec. (1 hour)	2400 sec. (40 minutes)
Cores used	1	2	2
Times slower	-	1915	320

This is a *longitudinal* PSF



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





One of the Image Tools features

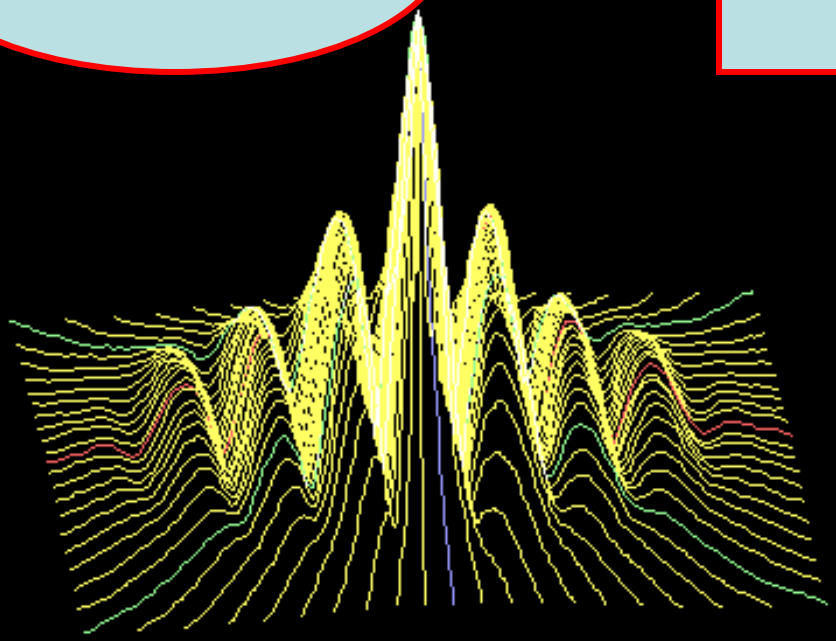
Can you do that as easily with Zemax?

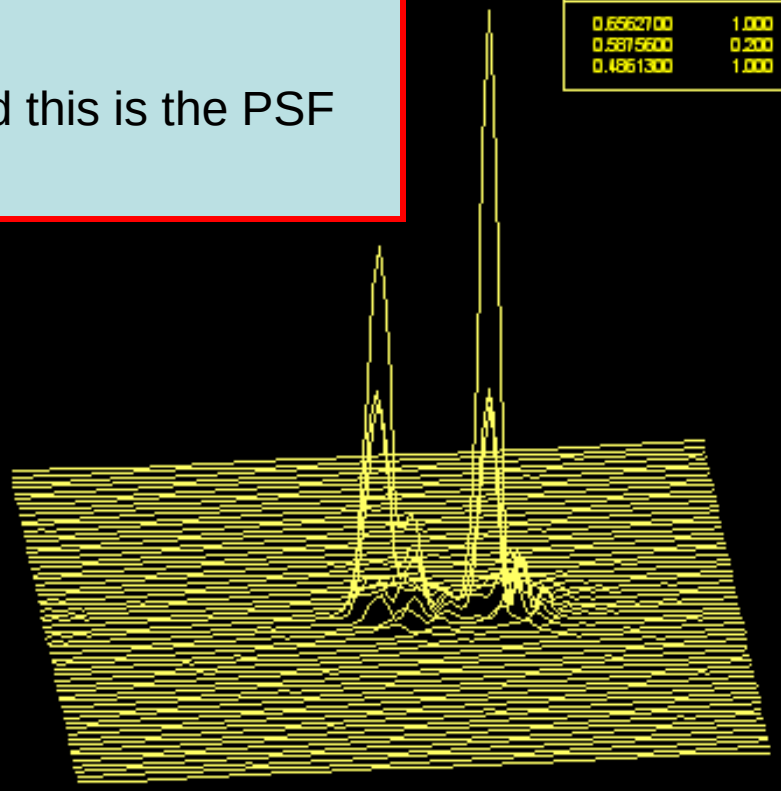
FOURIER-TRANSFORM MTF

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 Zemax?

E = 5.0000 MM

DE

FRACTI

ID TEST LATERAL 2176

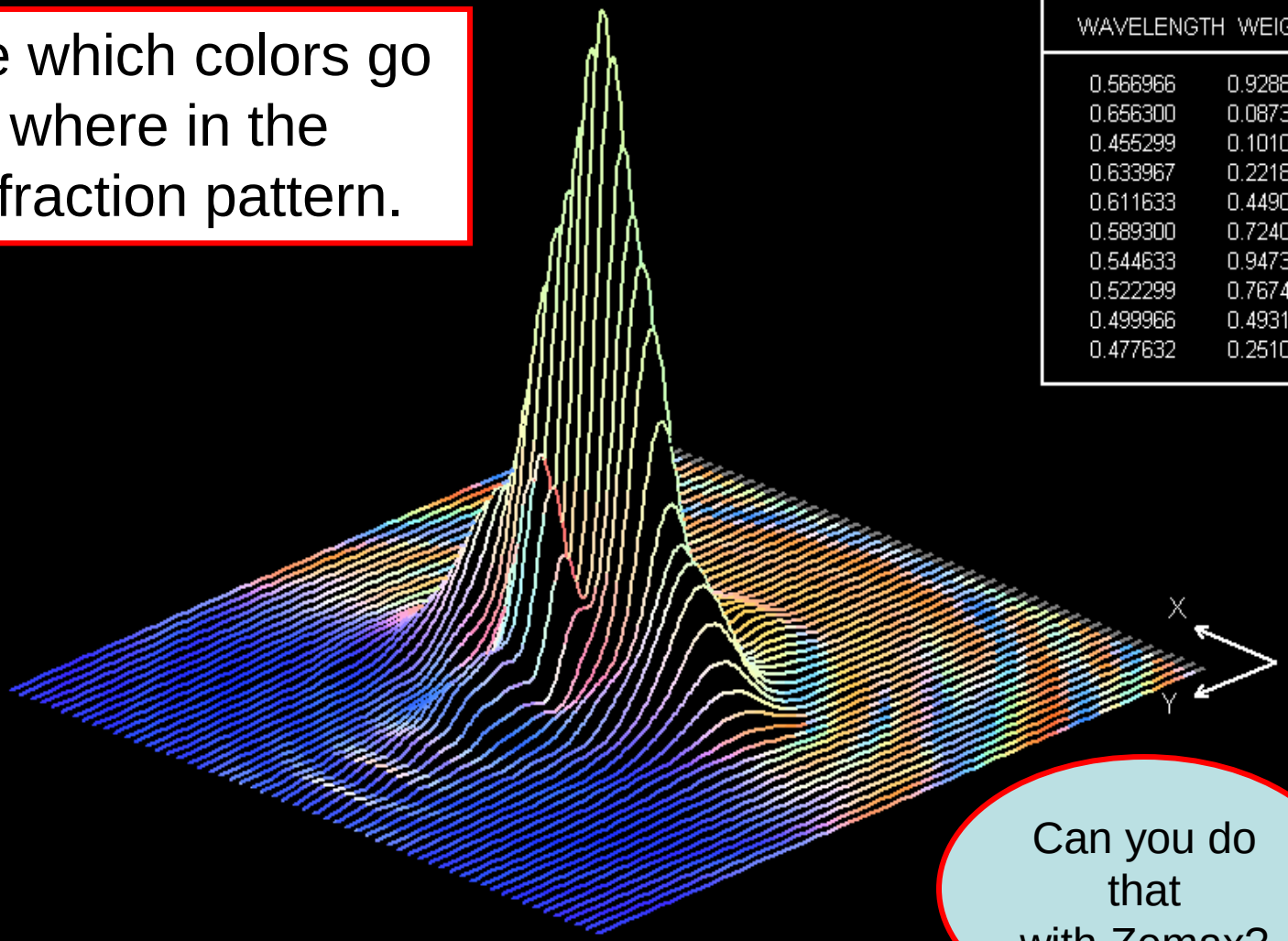
30-AUG-10 14:09:25

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

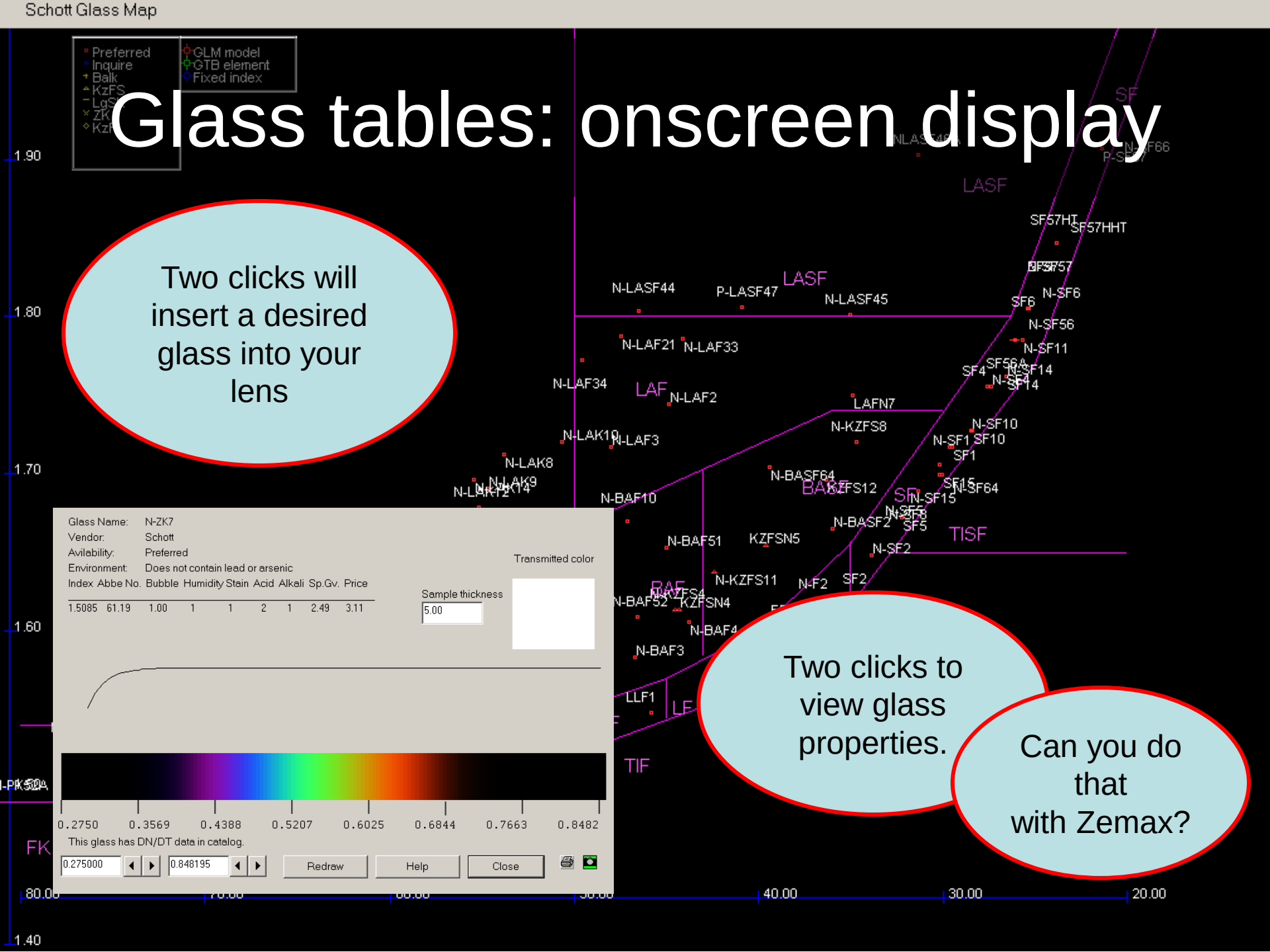


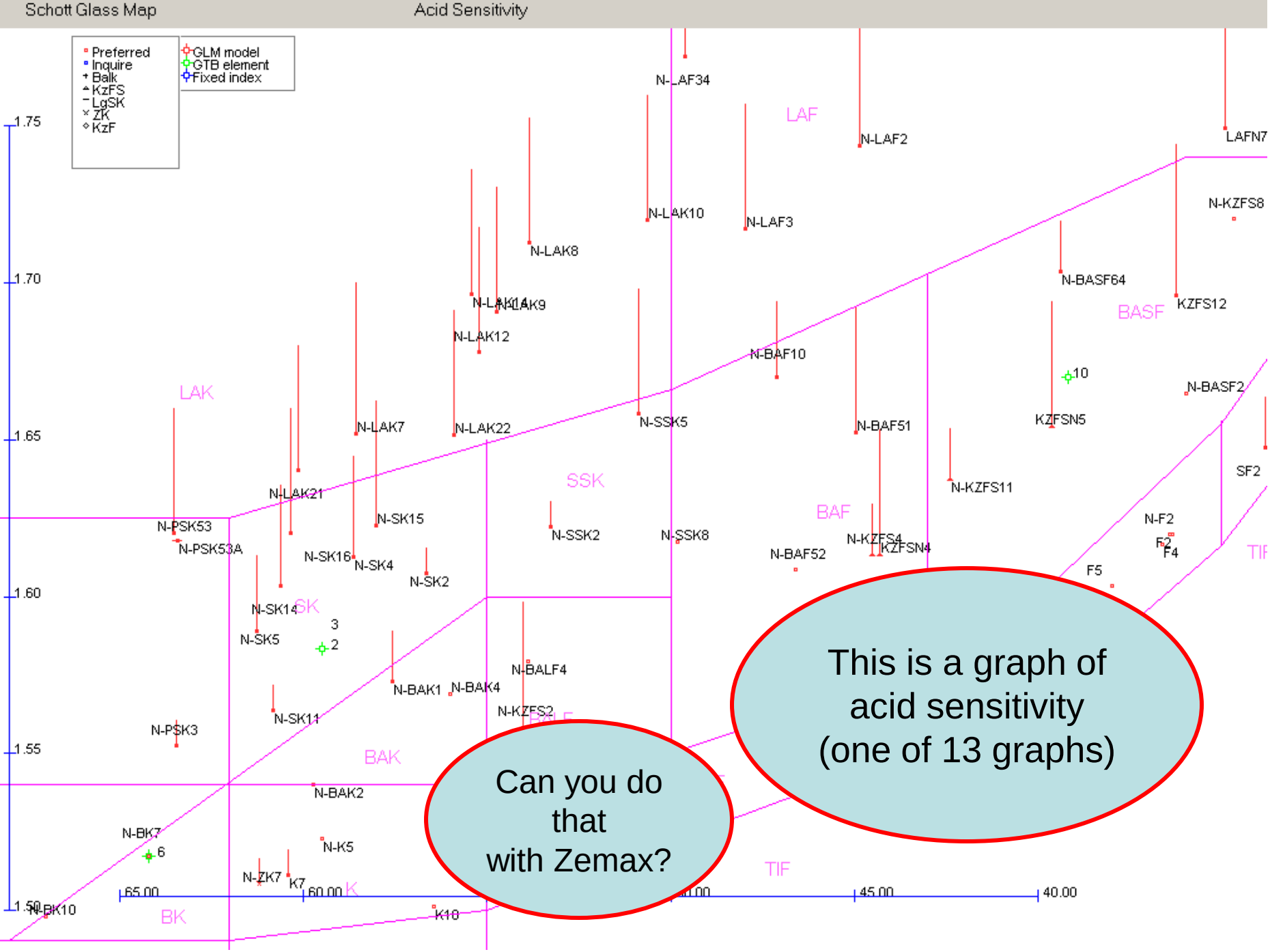
Can you do that with Zemax?

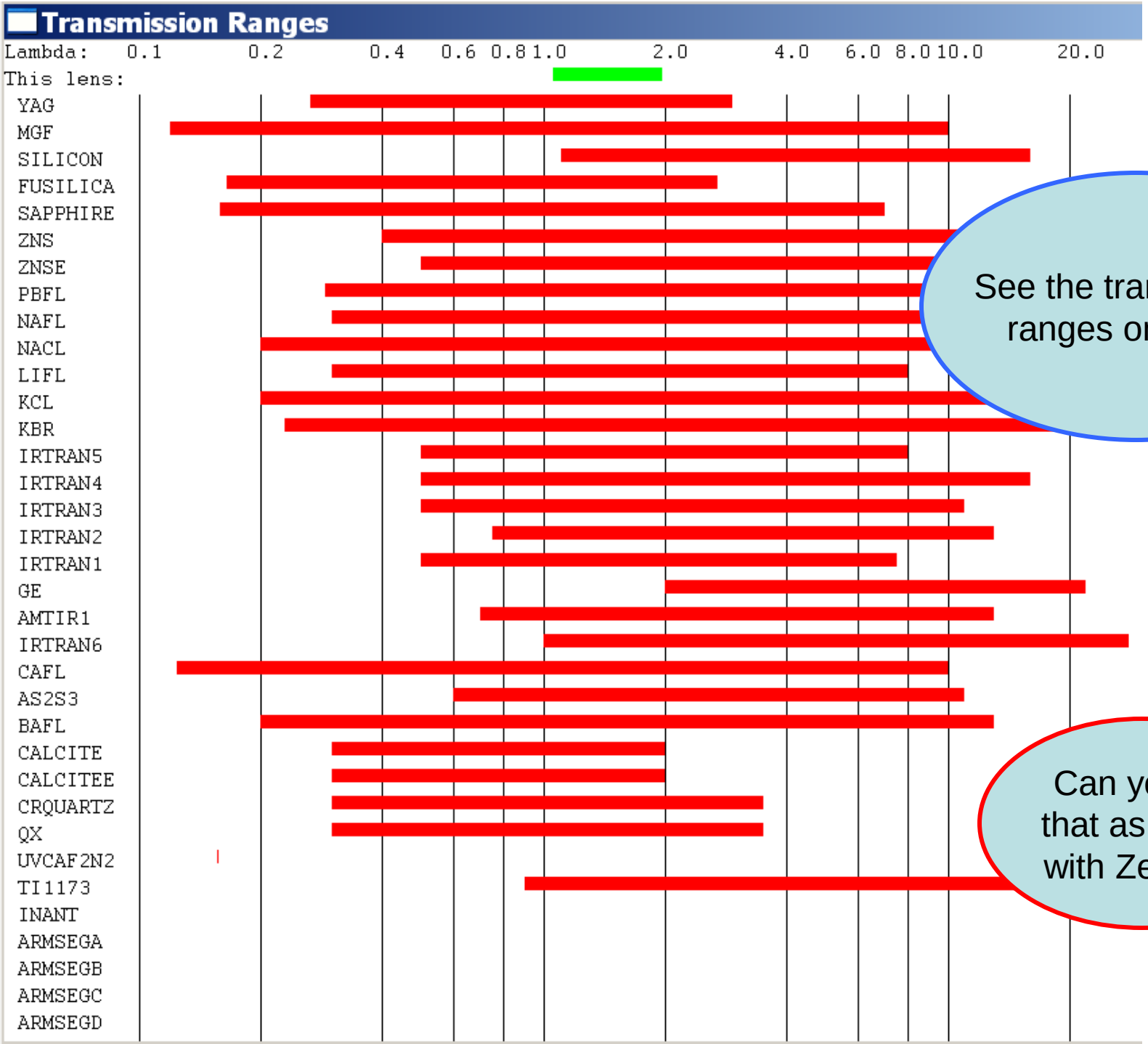
AIRY DISK RADIUS 0.000191 INCH ID RELAY FLAT 10344

PSPRD M 1 2000 0 0 3.5 L C

FRACTIONAL FIELD 1.0000 0.0


Schott Glass Map
Preferred
Inquire
Balk
KzFS
GLM model
GTB element
Fixed index
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 Zemax?
Glass Name: N-ZK7
Vendor: Schott
Avilability: Preferred
Environment: Does not contain lead or arsenic
Index Abbe No. Bubble Humidity Stain Acid Alkali Sp.Gv. Price
1.5085 61.19 1.00 1 1 2 1 2.49 3.11
Transmitted color
Sample thickness
5.00
0.2750 0.3569 0.4388 0.5207 0.6025 0.6844 0.7663 0.8482
This glass has DN/DT data in catalog.
0.275000
0.848195
Redraw
Help
Close
LASF
LAF
BASF
BAF
SF
TISF
TIF
FK
N-LASF44
P-LASF47
N-LASF45
N-LAF21
N-LAF33
N-LAF34
N-LAF2
N-LAF3
LAFN7
N-KZFS8
N-LAK10
N-LAK8
N-LAK9
N-BAF10
N-BASF64
N-KZFS12
N-BAF51
KZFSN5
N-BASF2
N-SF2
N-KZFS11
N-F2
SF2
N-BAF52
KZFSN4
N-BAF4
N-BAF3
LLF1
SF57HT
SF57HHT
N-SF6
SF6
N-SF56
N-SF11
SF4
N-SF14
N-SF10
SF10
N-SF1
SF1
N-SF15
N-SF64
SF5
1.90
1.80
1.70
1.60
1.40
80.00
40.00
30.00
20.00


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
SK
BAK
BK
TIF
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
KZFSN5
N-BAF51
SF2
N-LAK21
N-KZFS11
N-SK15
N-SSK2
N-SSK8
N-F2
N-PSK53
N-PSK53A
N-SK16
N-SK4
N-BAF52
N-KZFS4
KZFSN4
F2
F4
F5
N-SK2
N-SK14
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 Zemax?



See the transmission ranges onscreen

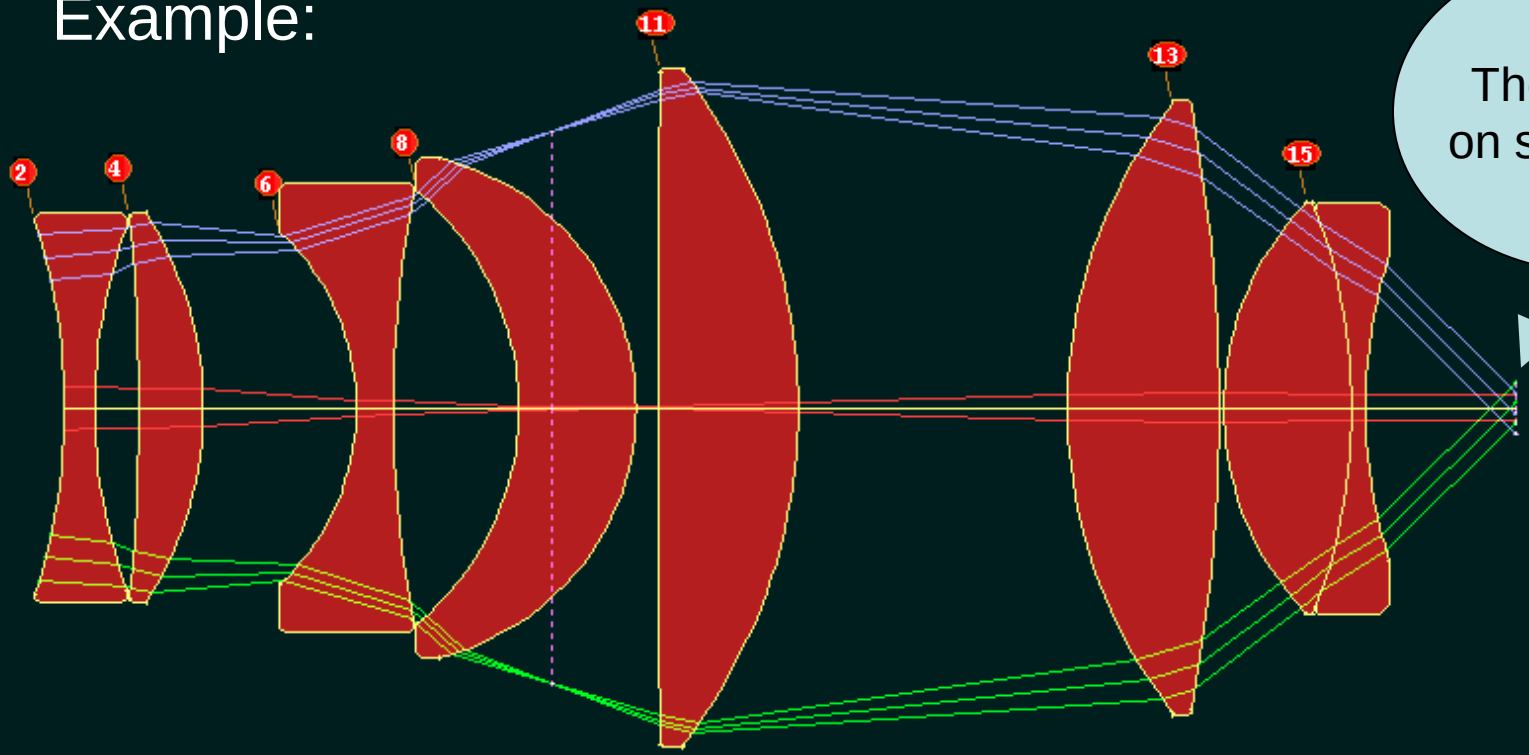
Can you do that as easily with Zemax?

Artificial Intelligence

- What if you want a feature that is not in the program?
- Zemax: 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:



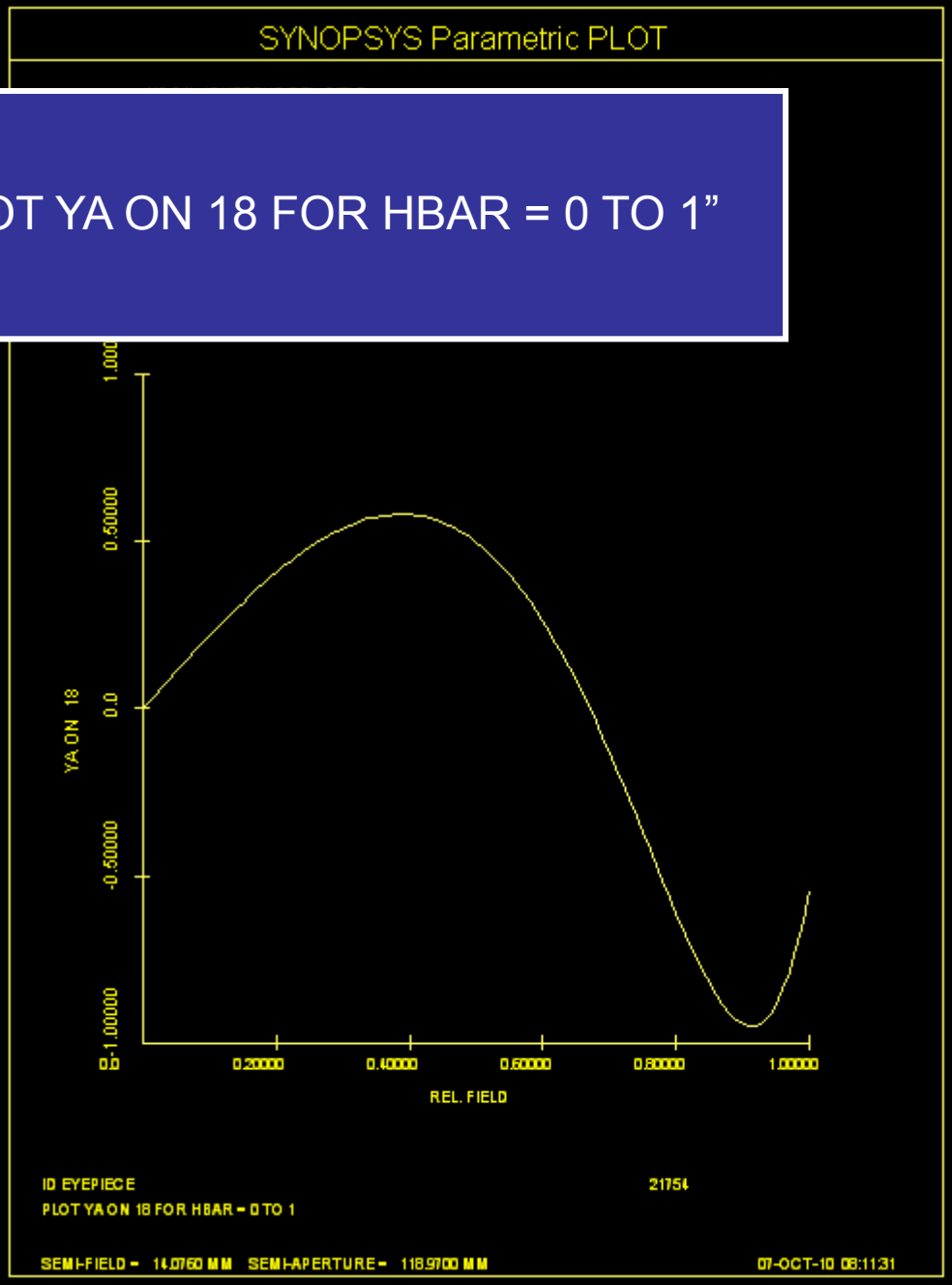
The pupil is on surface 18

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 Zemax?

Artificial Intelligence

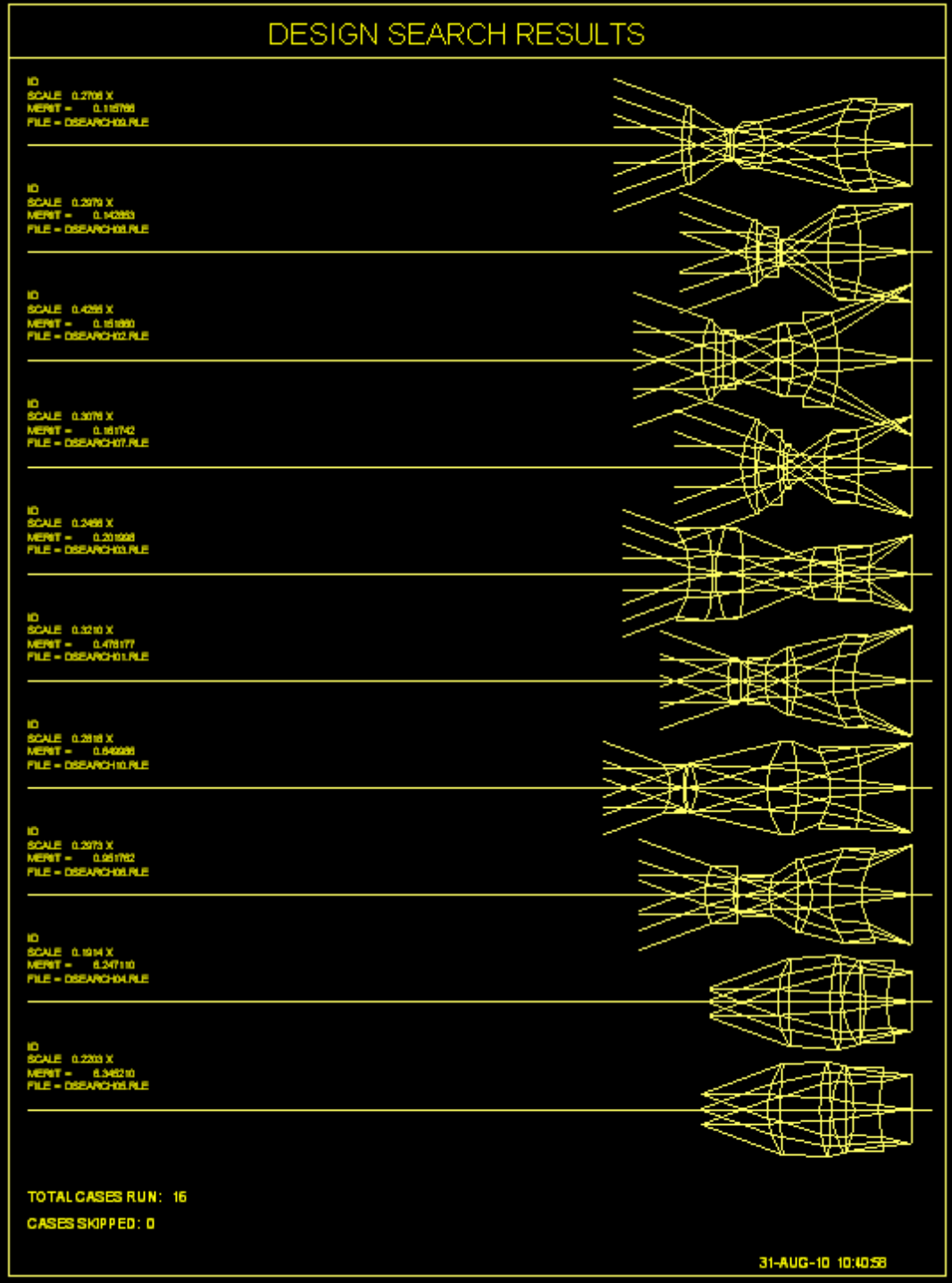
- Make up your own commands
  - in plain English.
- Define a symbol to execute that command
  - (examples) QQ: RAY P 0 0 1 SURF
  - XX: PLOT YA ON 18 FOR HBAR = 0 TO 1
- Hate typing? Only type it once!
- Then use that symbol whenever you want.

Can you do that with Zemax?

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.

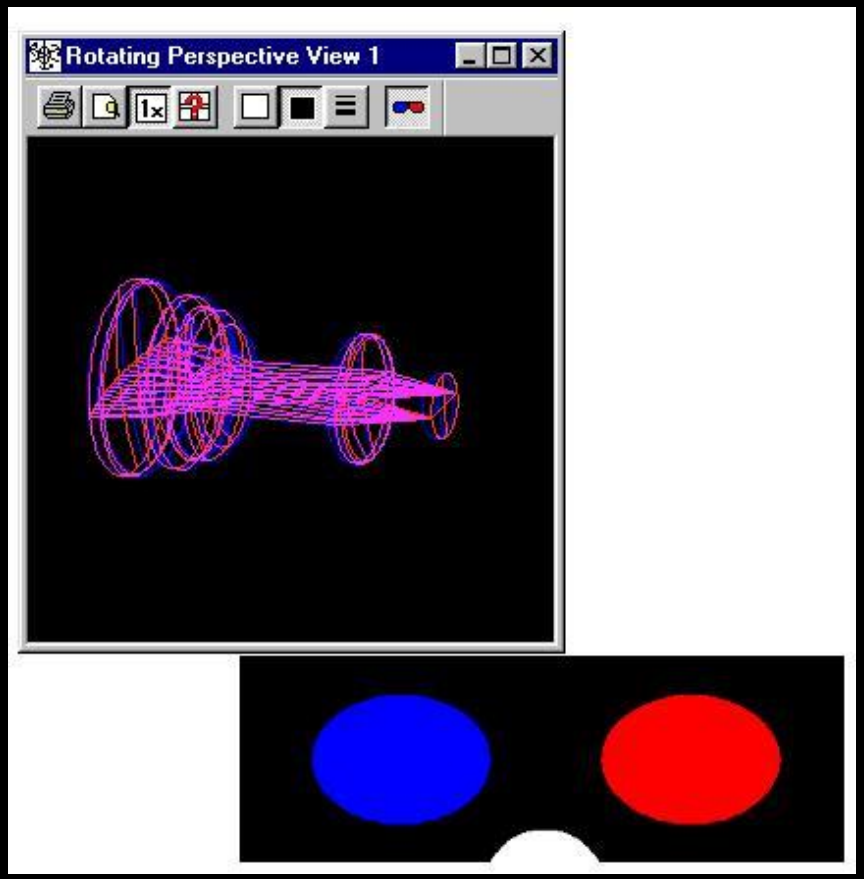


SYNOPSYS™ can tell you:

- 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)

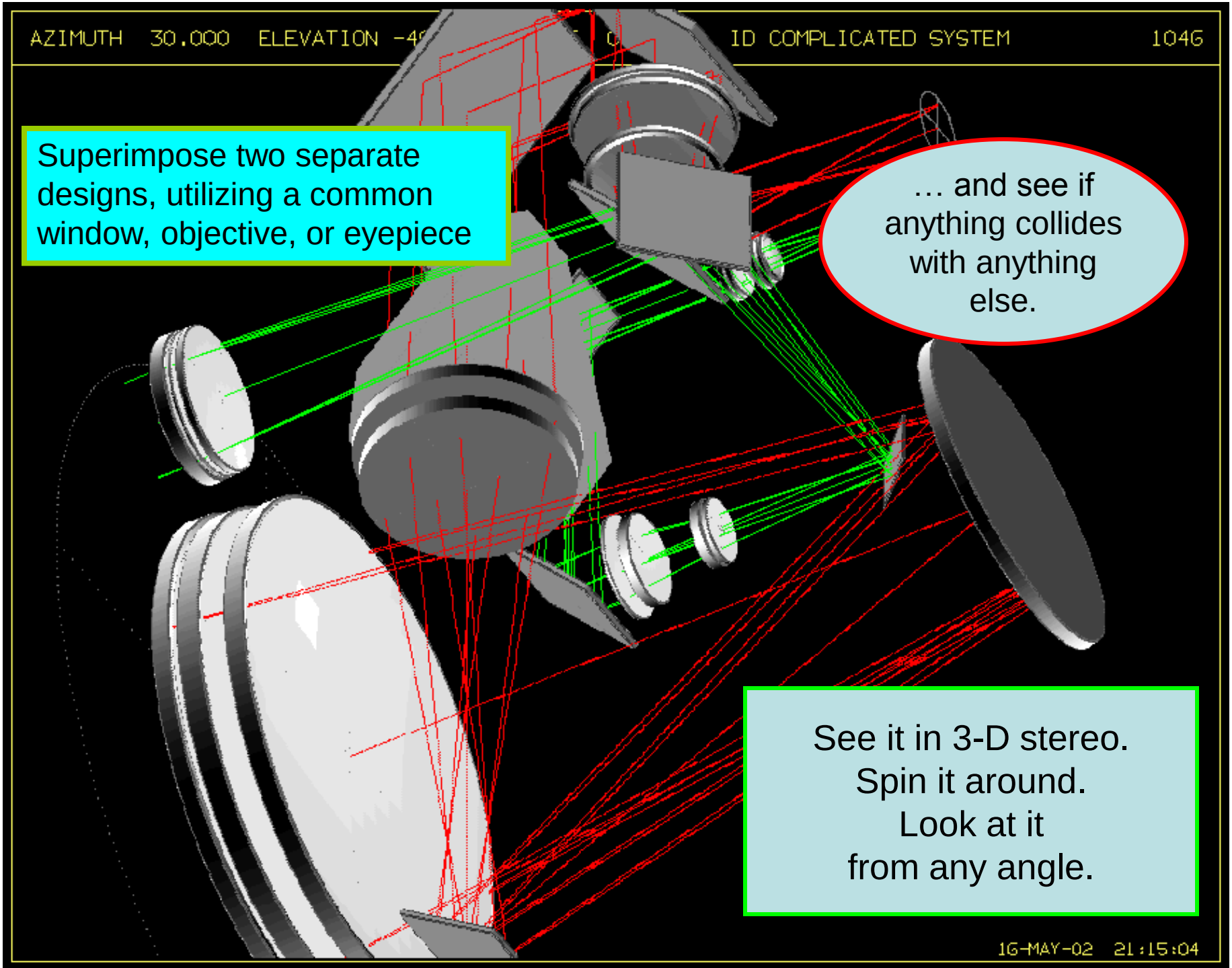
Can you do that as easily with Zemax?

3D Stereo display



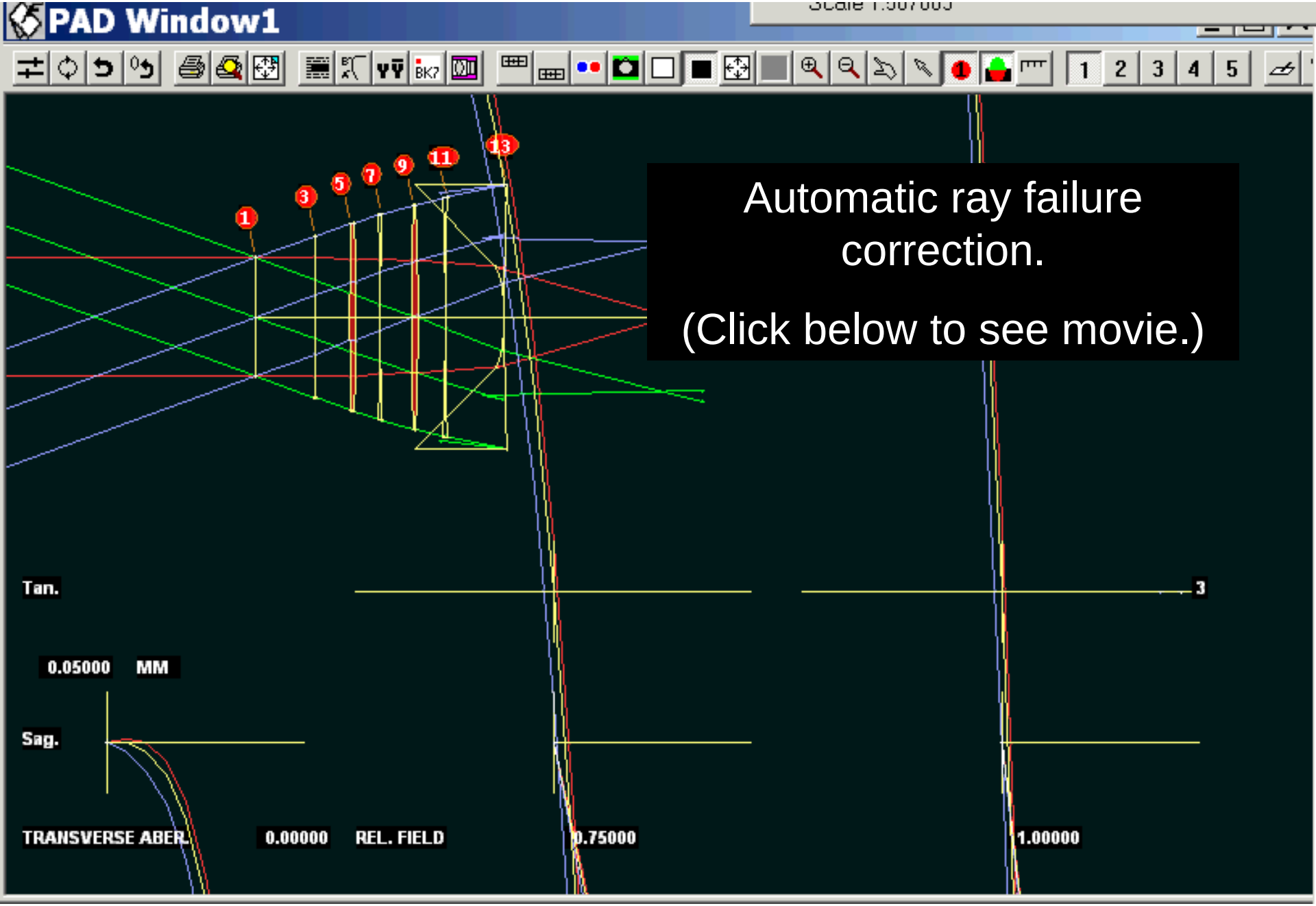
Great for complex systems. See what is in front of what.

Can you do that with Zemax?

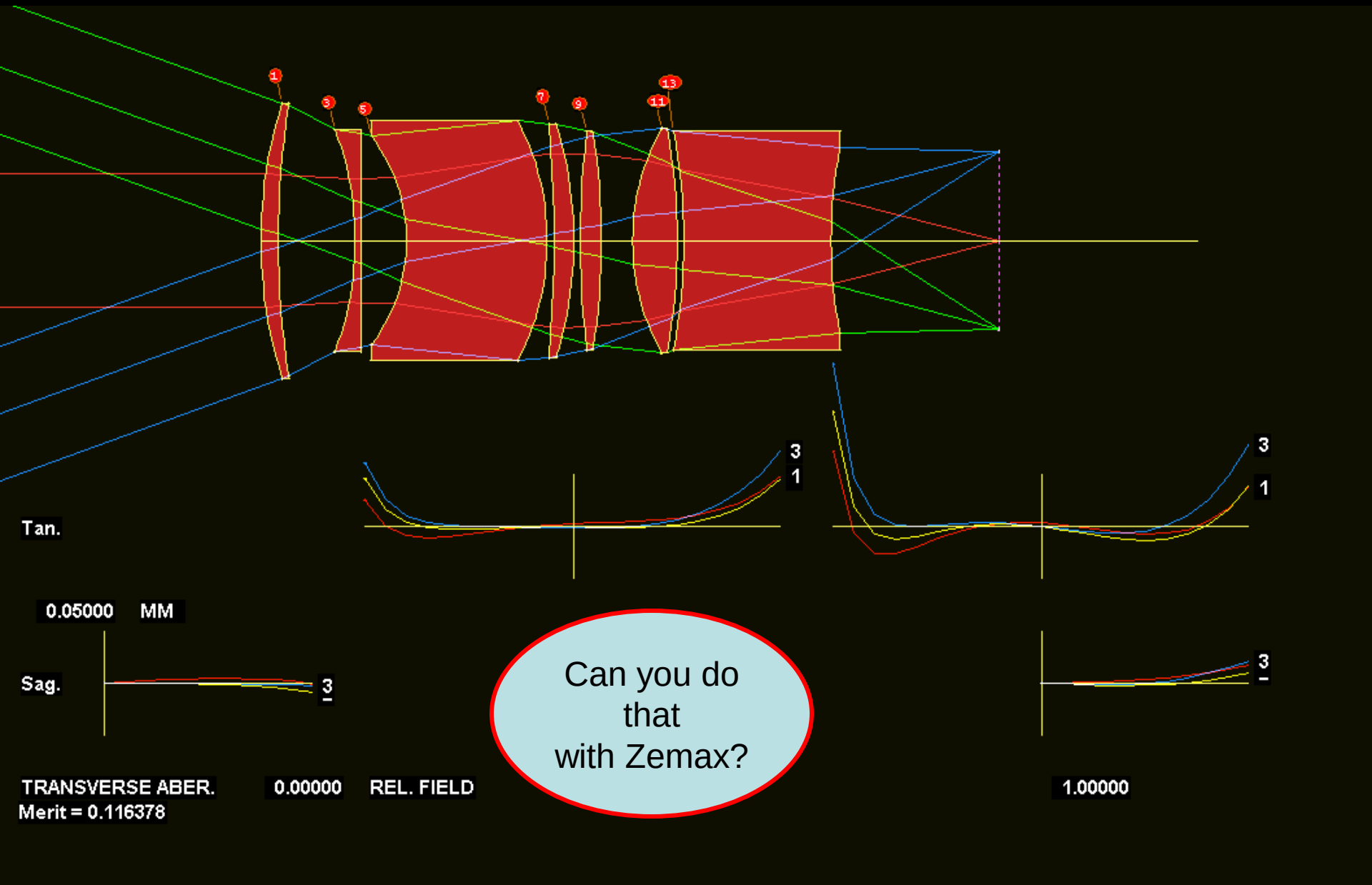

AZIMUTH 30.000 ELEVATION -4
ID COMPLICATED SYSTEM 1046
Superimpose two separate designs, utilizing a common window, objective, or eyepiece
… and see if anything collides with anything else.
See it in 3-D stereo.
Spin it around.
Look at it
from any angle.
16-MAY-02 21:15:04

Ray Failures?

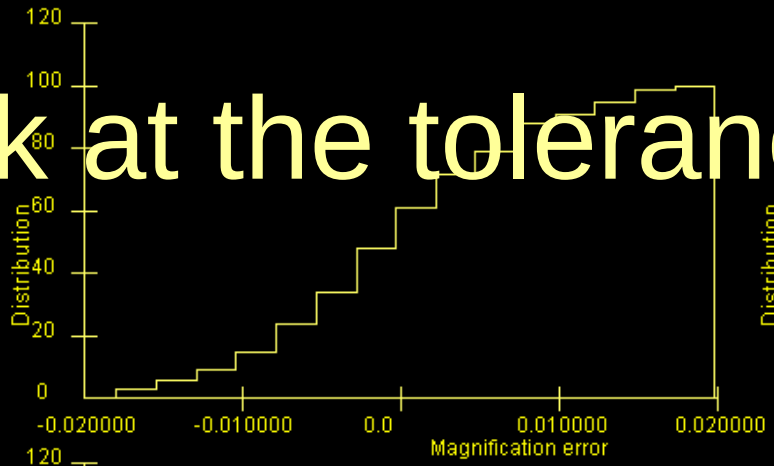
- What does Zemax do if a ray fails to trace through the starting system?
  - It quits
  - It gives up
  - It cannot optimize.
- What can SYNOPSYS do?
  - Watch the next movie to find out.

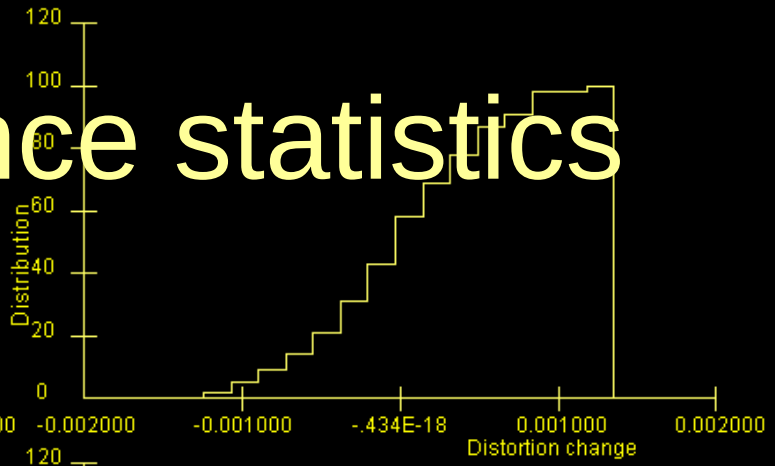

PAD Window1
1
2
3
4
5
1
3
5
7
9
11
13
Automatic ray failure correction.
(Click below to see movie.)
Tan.
0.05000 MM
Sag.
TRANSVERSE ABER
0.00000
REL. FIELD
0.75000
1.00000
3

Here's another example, starting with ray failures

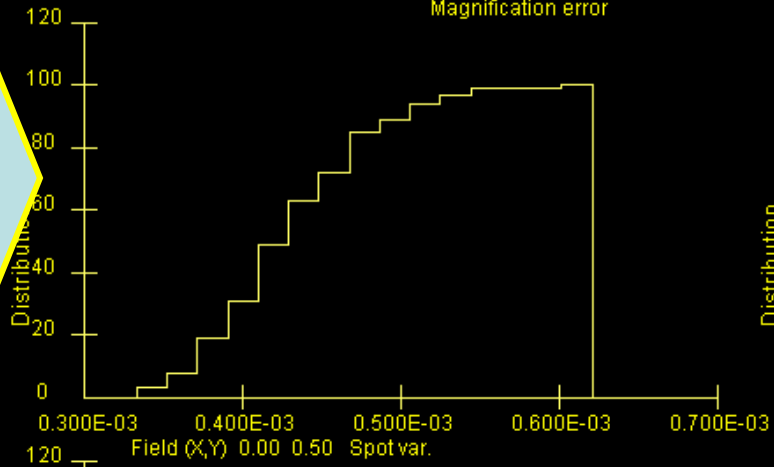


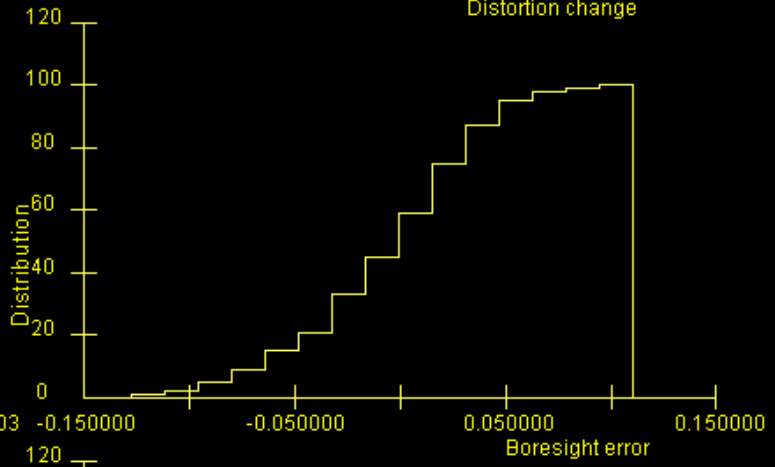
Look at the tolerance statistics



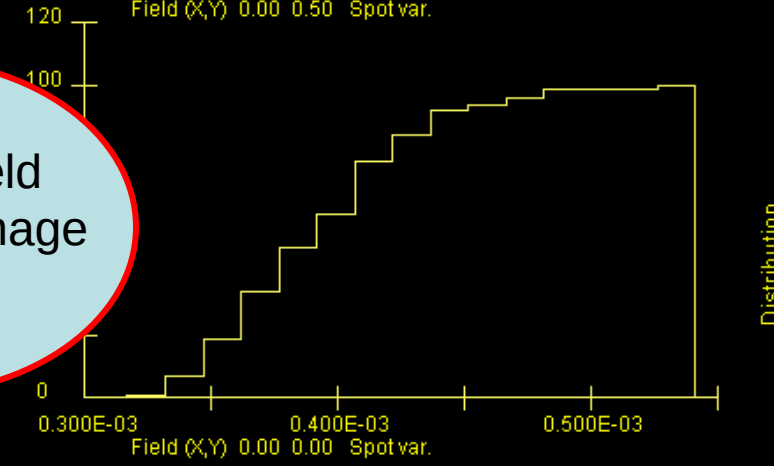


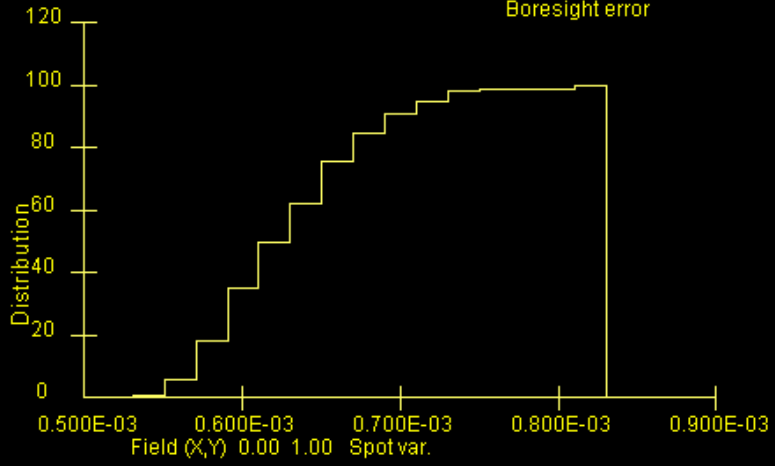
This is a *distribution* function.





See the yield for a given image quality.

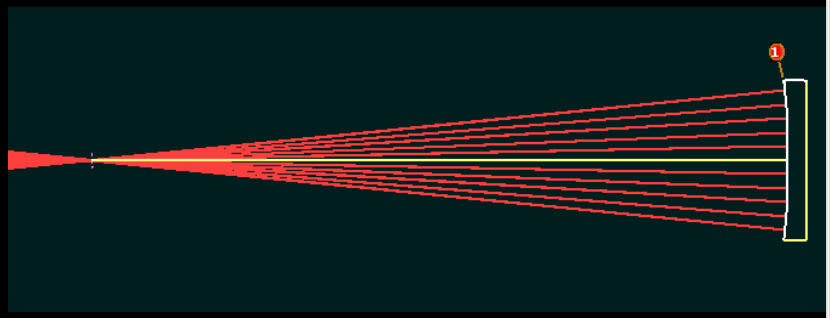




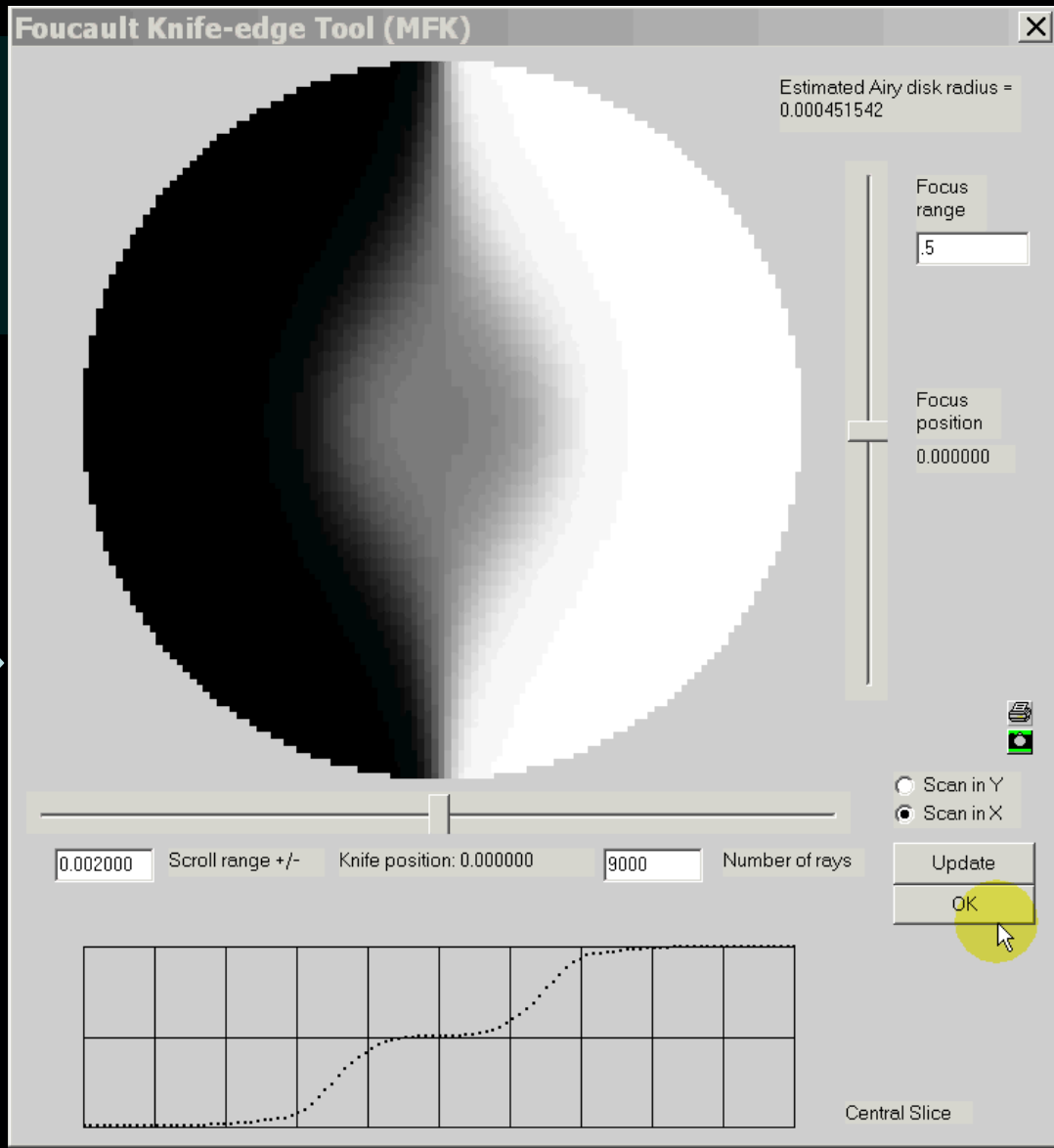
THICKNESS TOLERANCE DISTRIBUTION IS UNIFORM

WEDGES ARE RANDOM

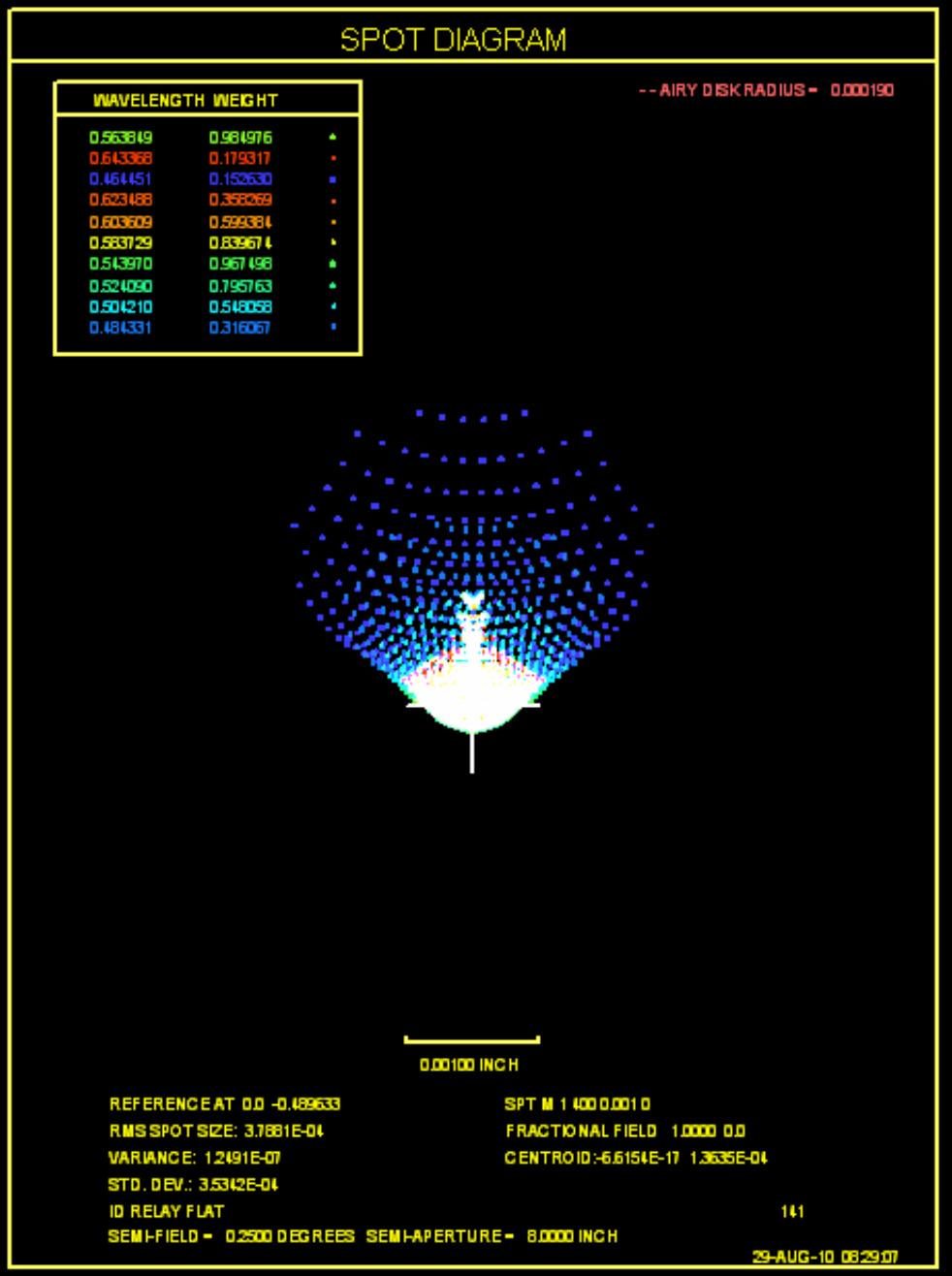
Foucault test emulator



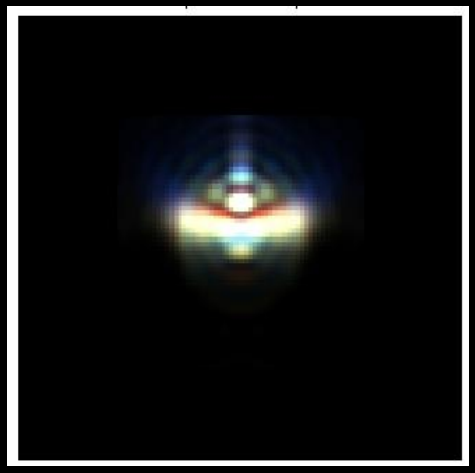
Click to play

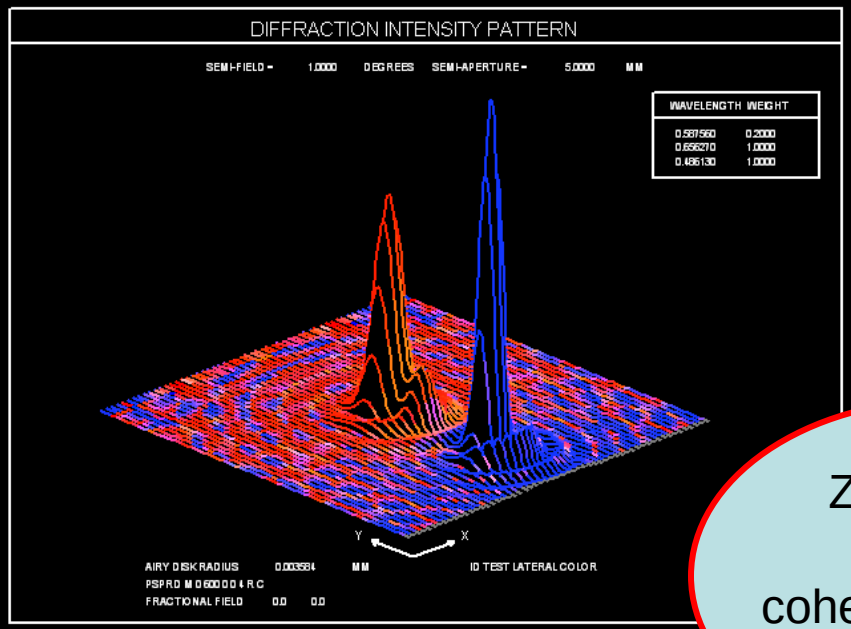


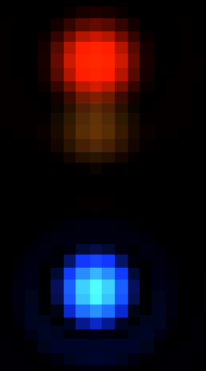
- Geometric images show realistic colors



Diffraction images are also shown in realistic colors.

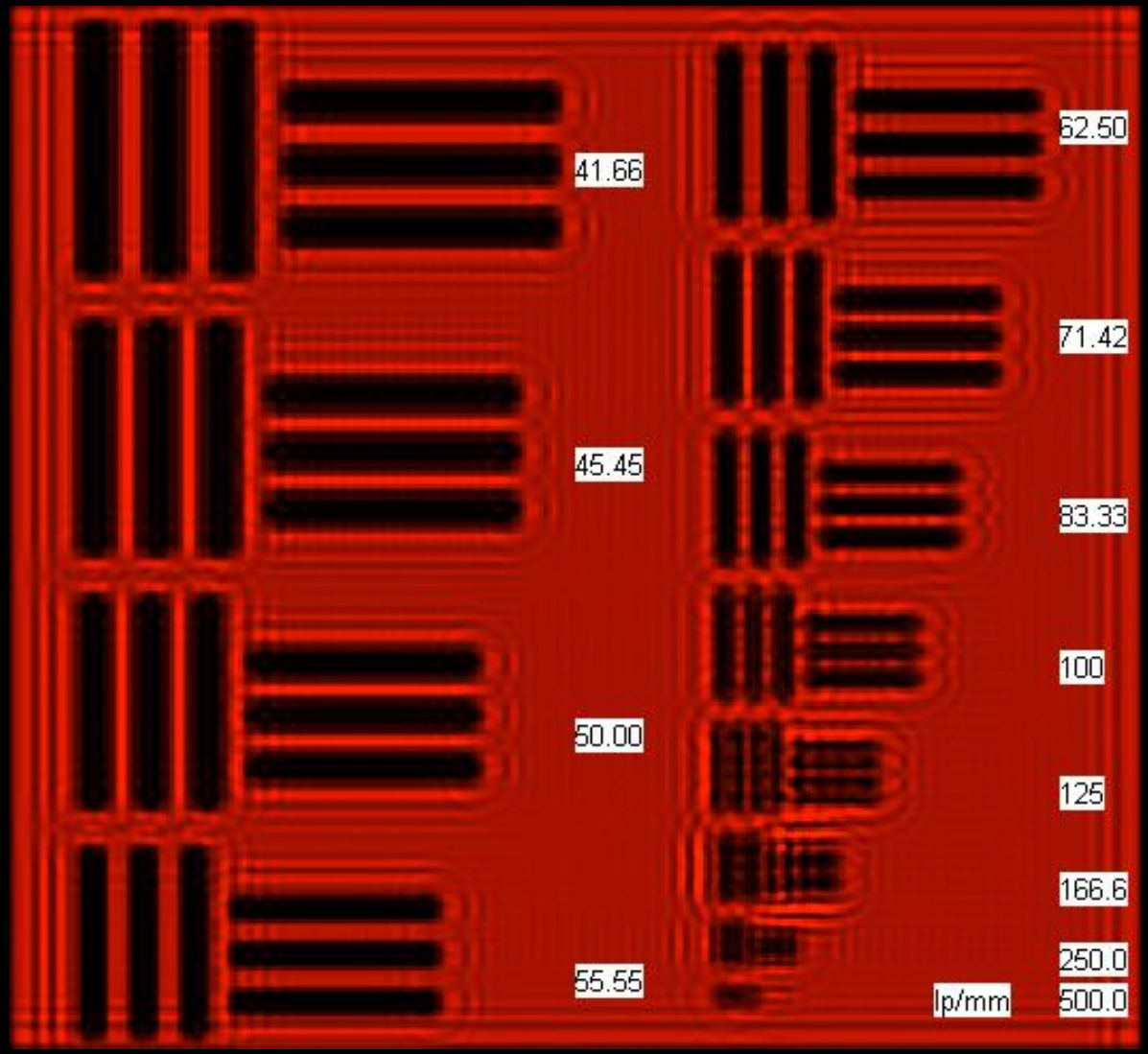




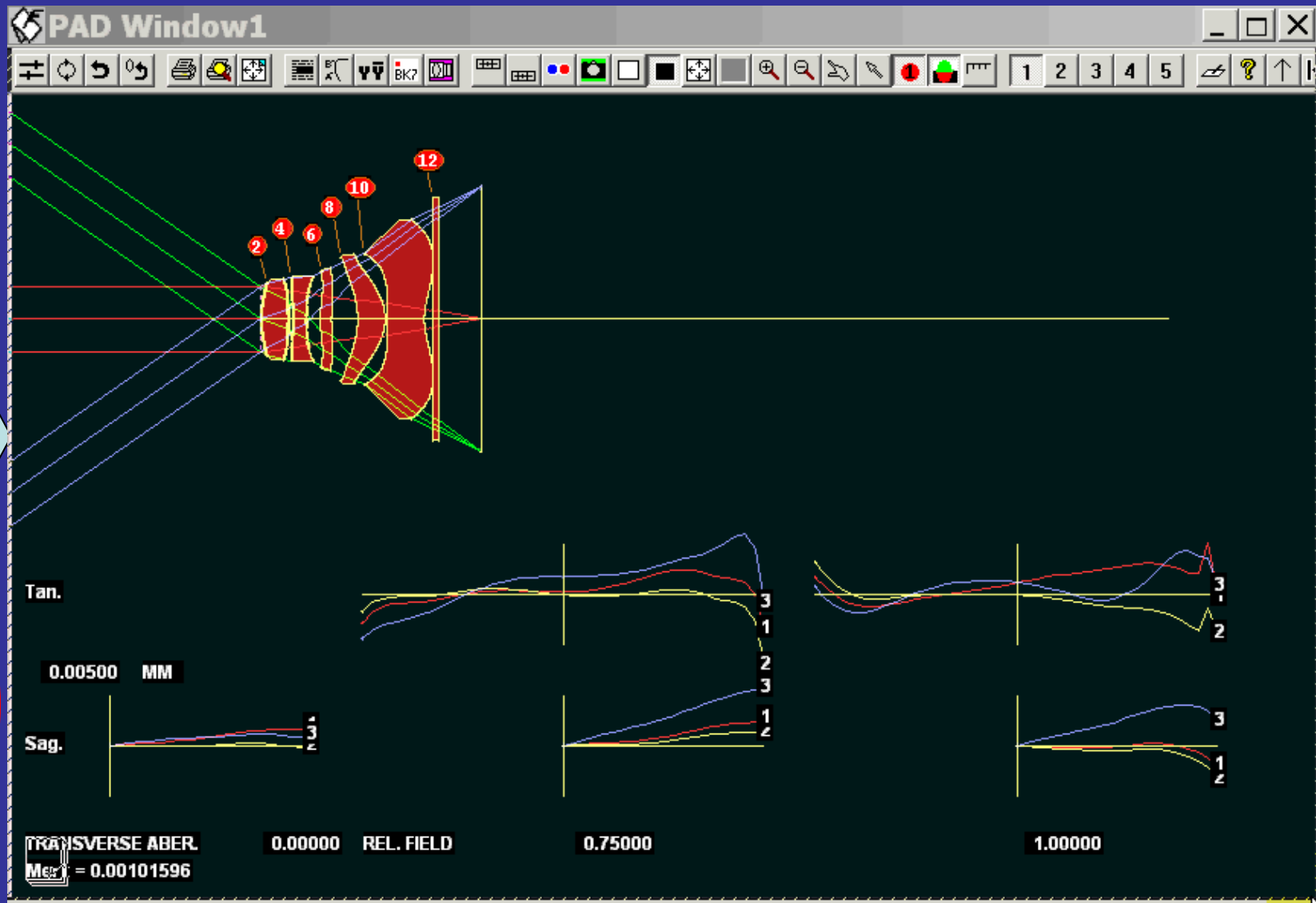


Zemax can do this in coherent analysis only.

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



PAD scan button: see performance over the field

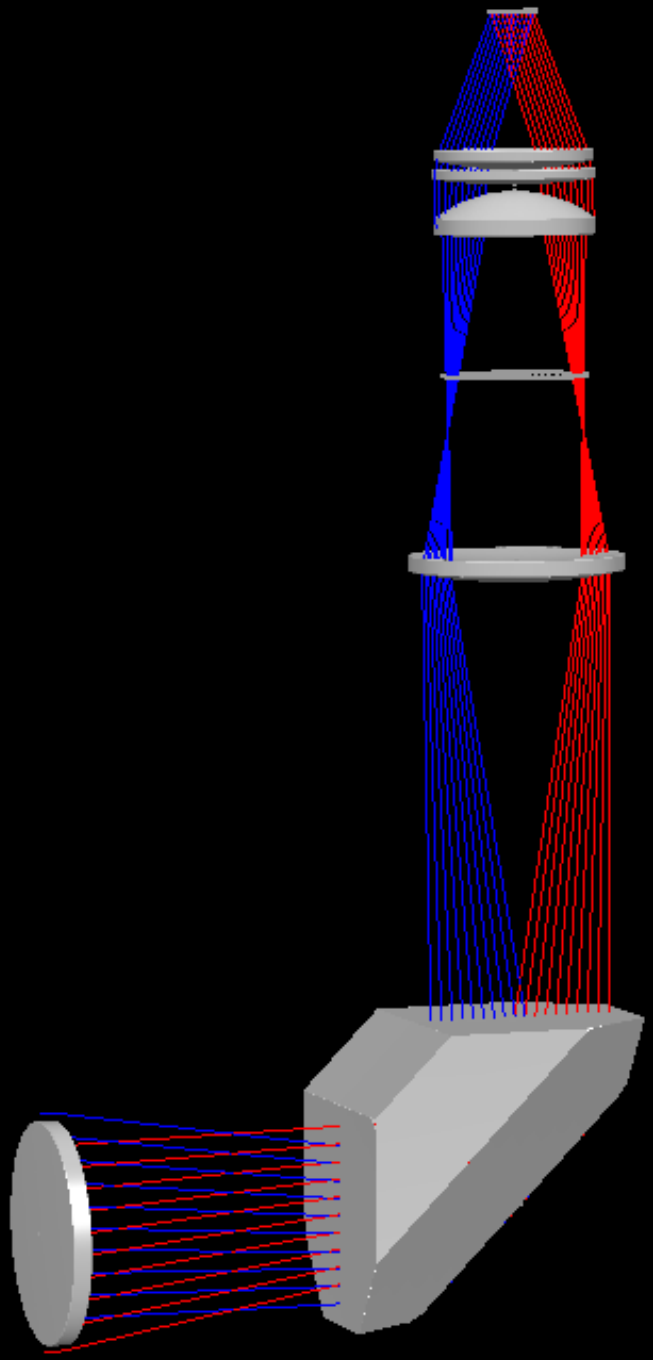


Click

Can you do that with Zemax?

- Option to trace nonsequential systems in sequential mode (but the tolerance program BTOL does the prism right anyway).

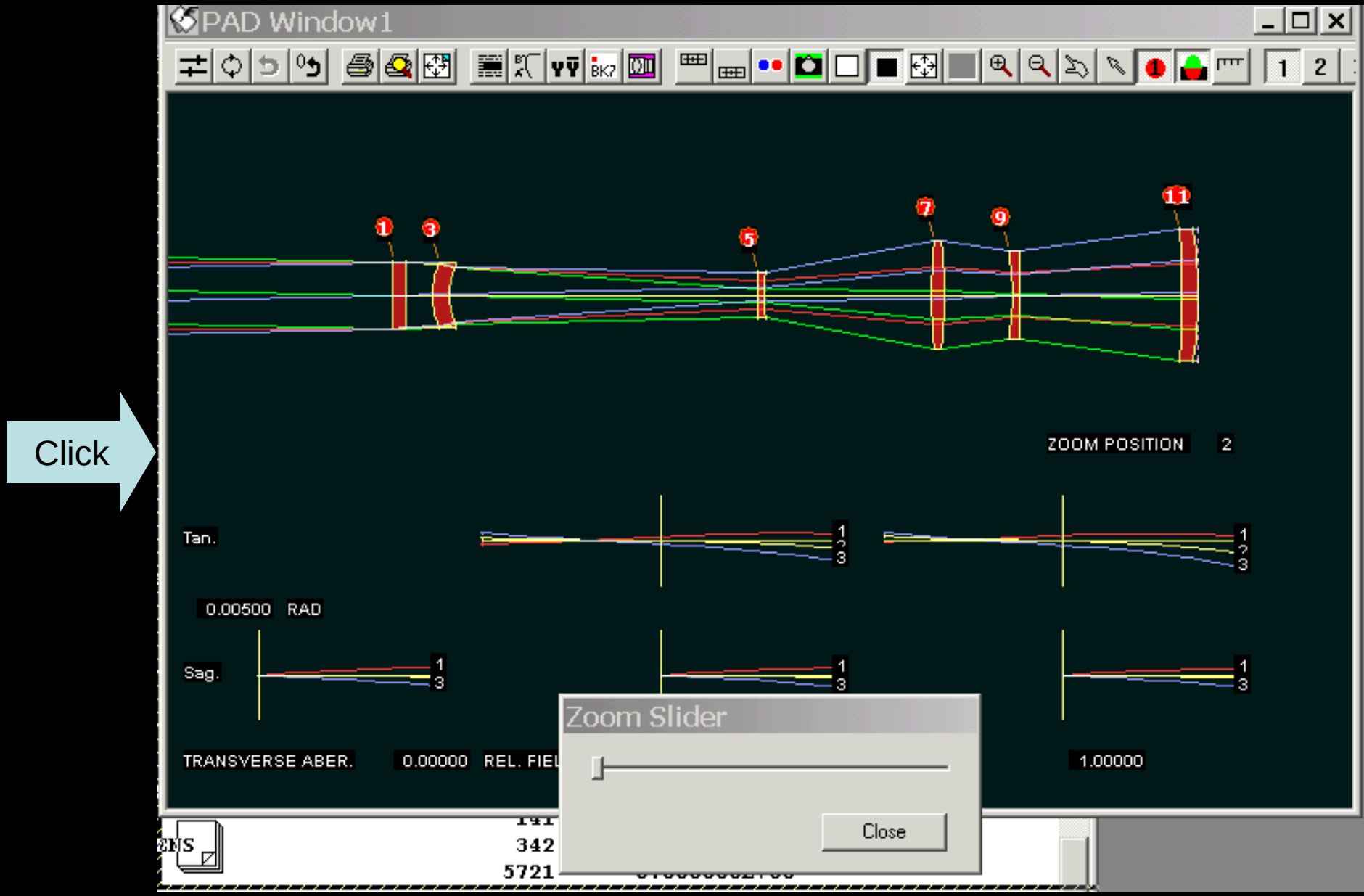
Much faster!



SYNOPSYS™ has *many sliders*!

- Change a lens parameter and watch the effect in real time.
- Slide over the zoom range. Examine the image quality at 100 positions.
- Select a ray to see on the drawing – by moving two sliders.
- Change the tilt angle of a fold mirror, to control beam clearance elsewhere.

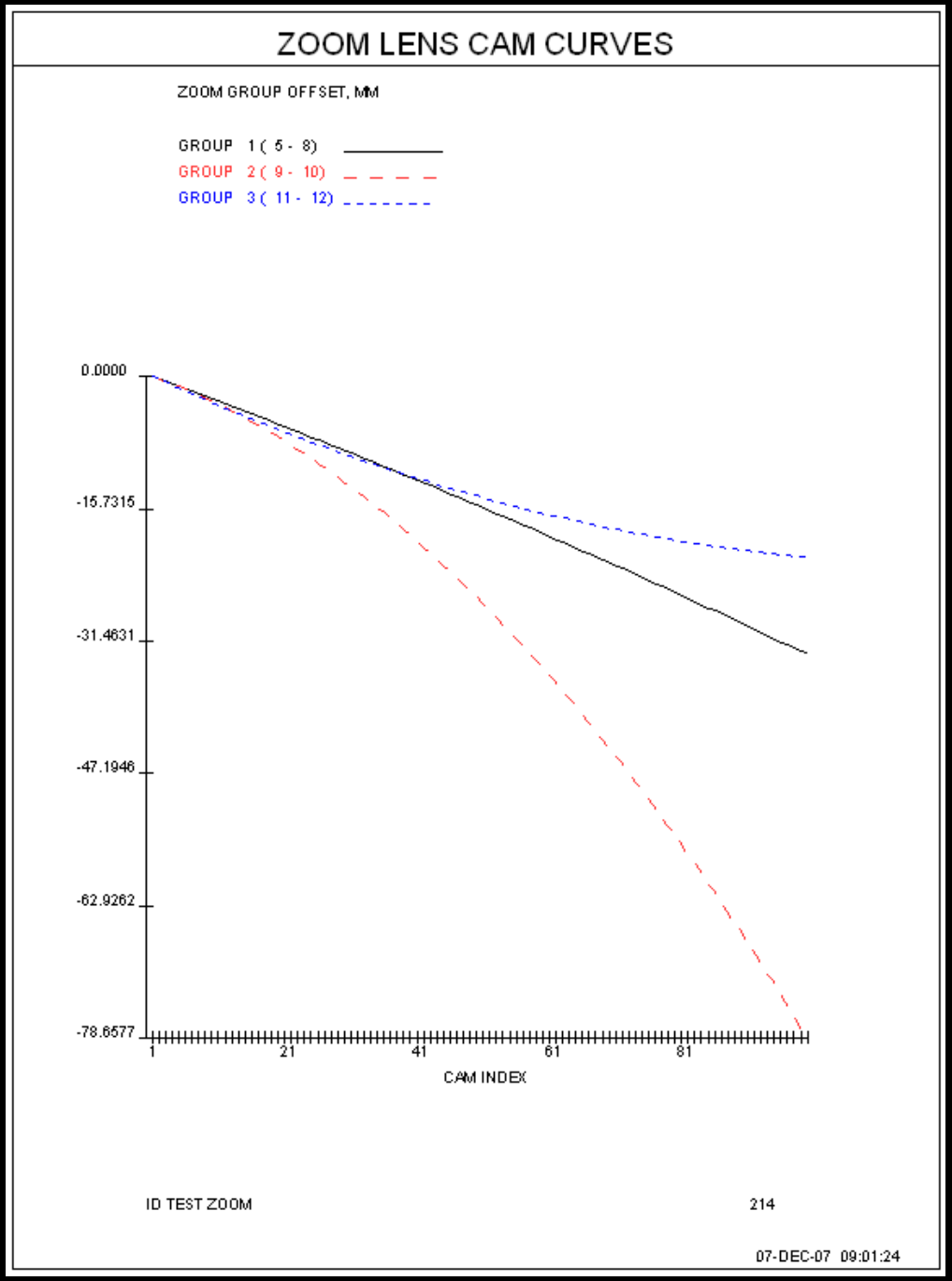
ZOOM slider: One configuration. Automatic undo.



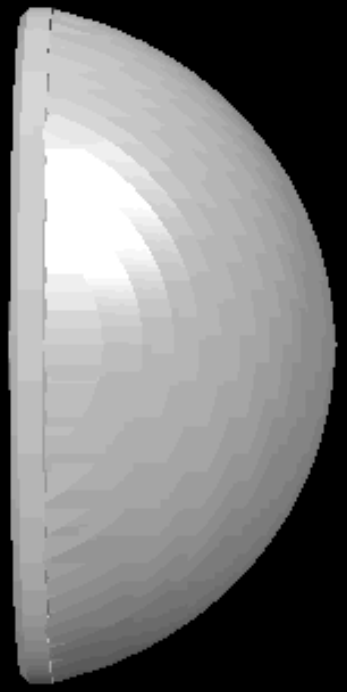
Need a CAM curve?

- Test your cam curve with a slider
  - 100 positions

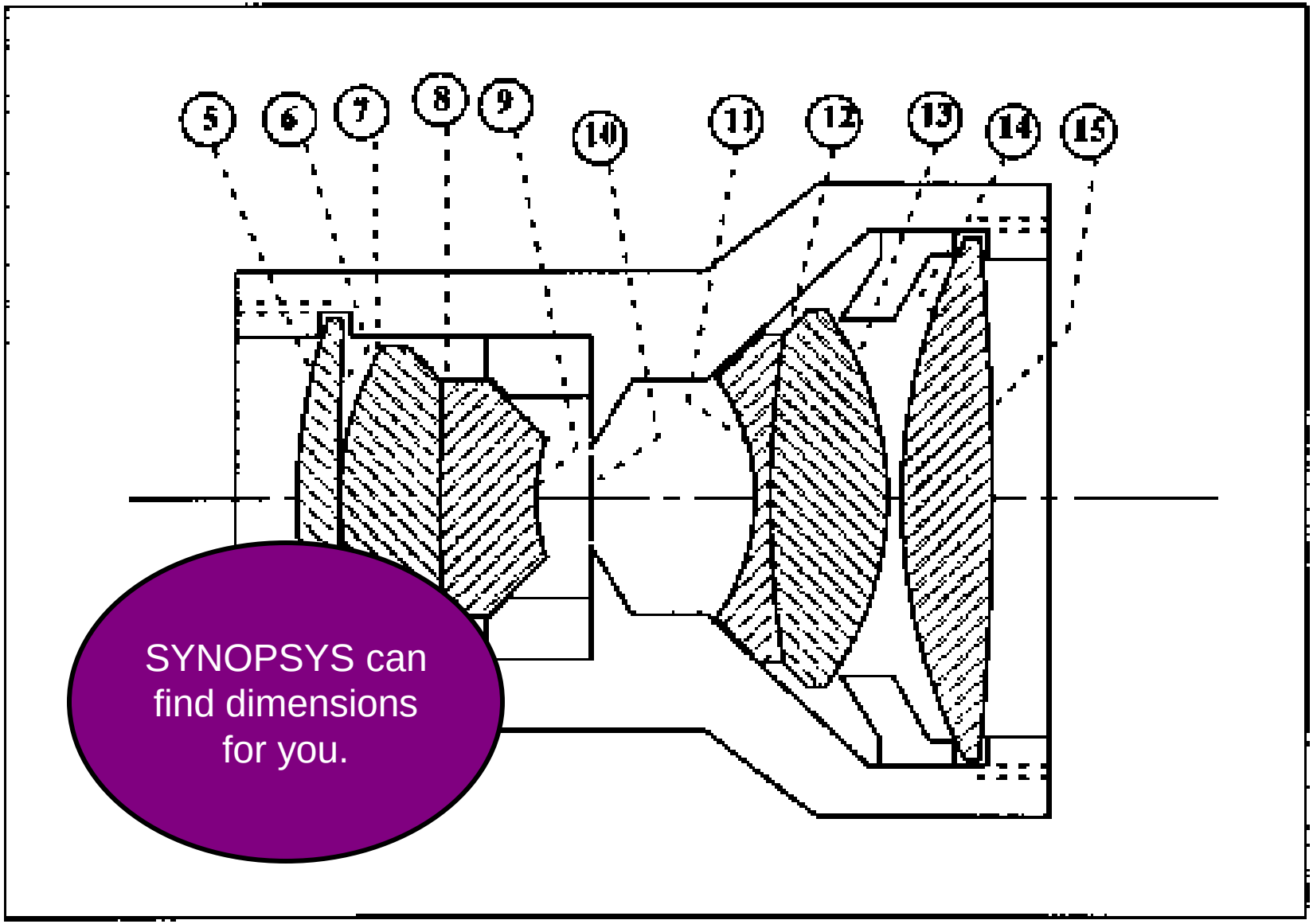
Can you do that with Zemax?



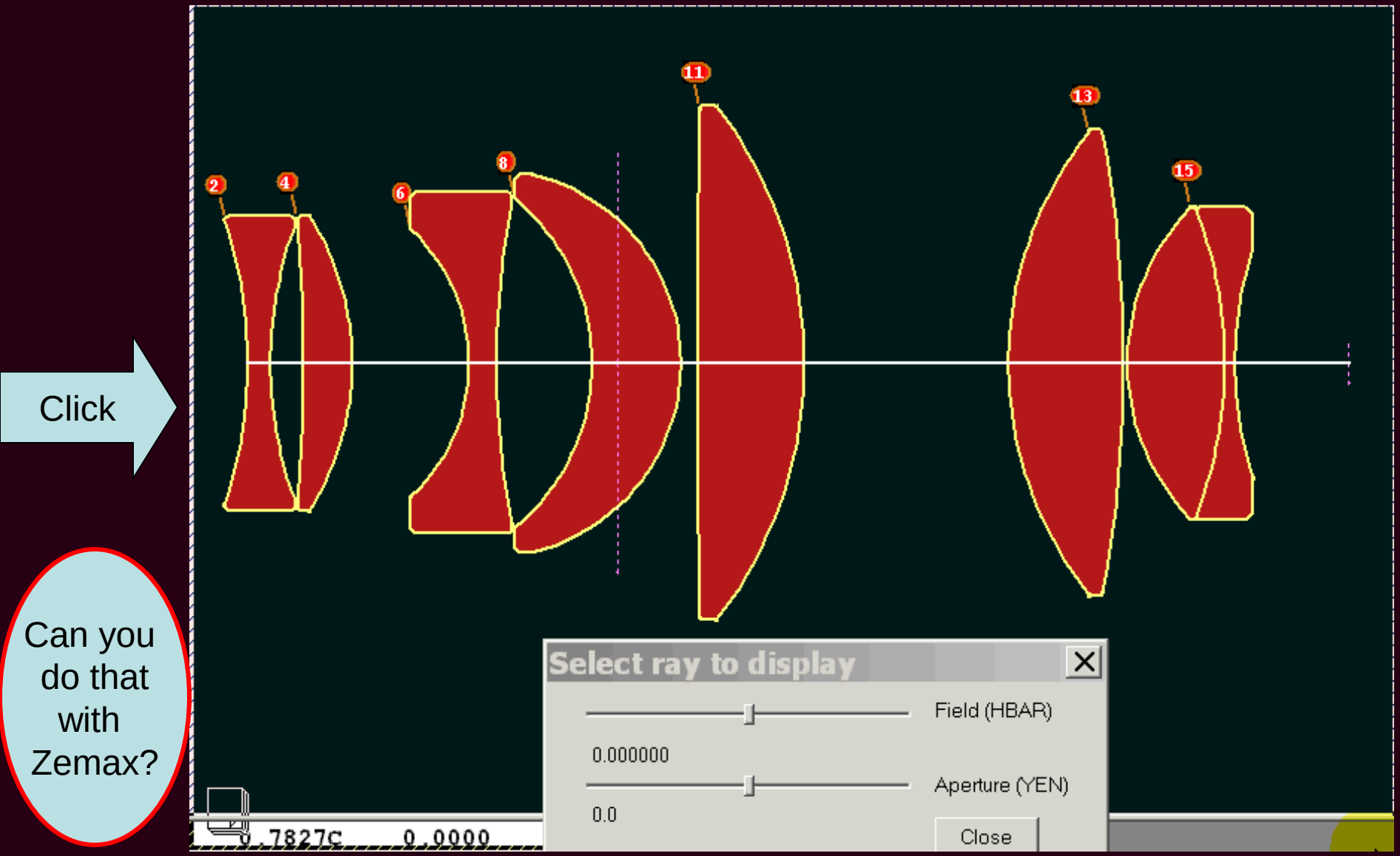
Command GCOST estimates the cost of lens blanks, either flat or molded.



Spacer calculation



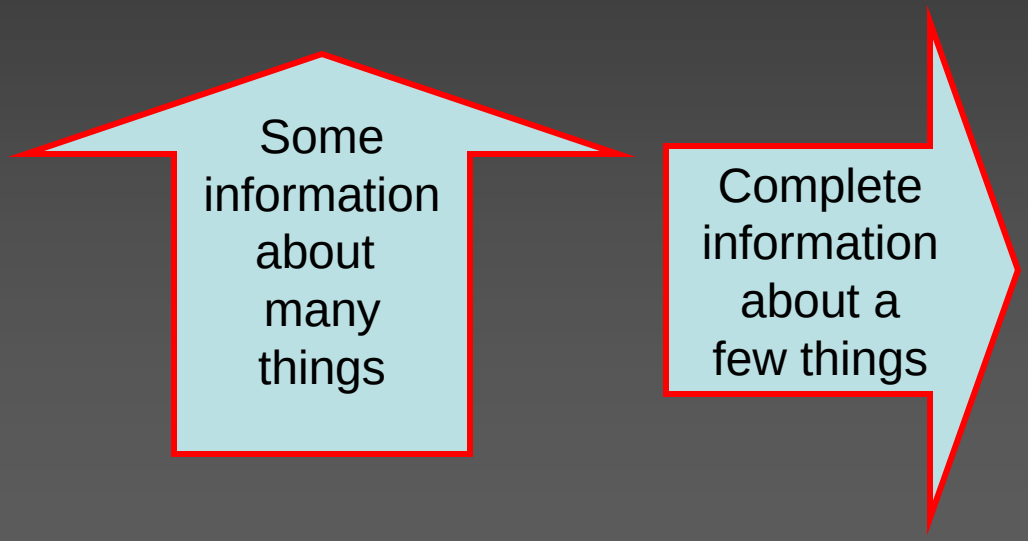
Single ray option in SketchPad



Spreadsheet *vs*. WorkSheet

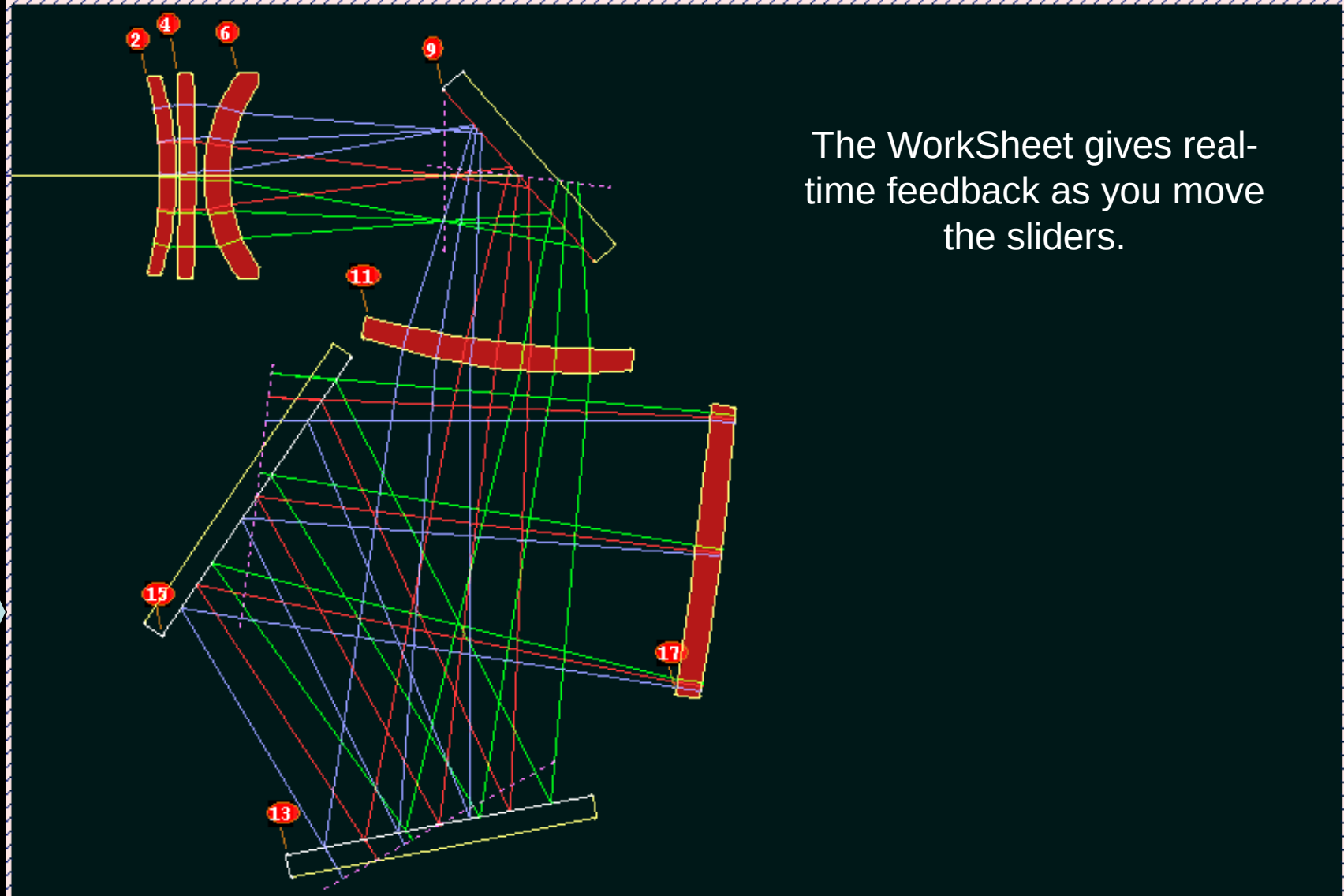
Zemax

- Spreadsheet entry only



- SYNOPSYS
- Spreadsheet option
- WorkSheet option
  - Graphical feedback
  - See lens and image
  - Sliders to change anything
  - Insert, delete, flip, etc.

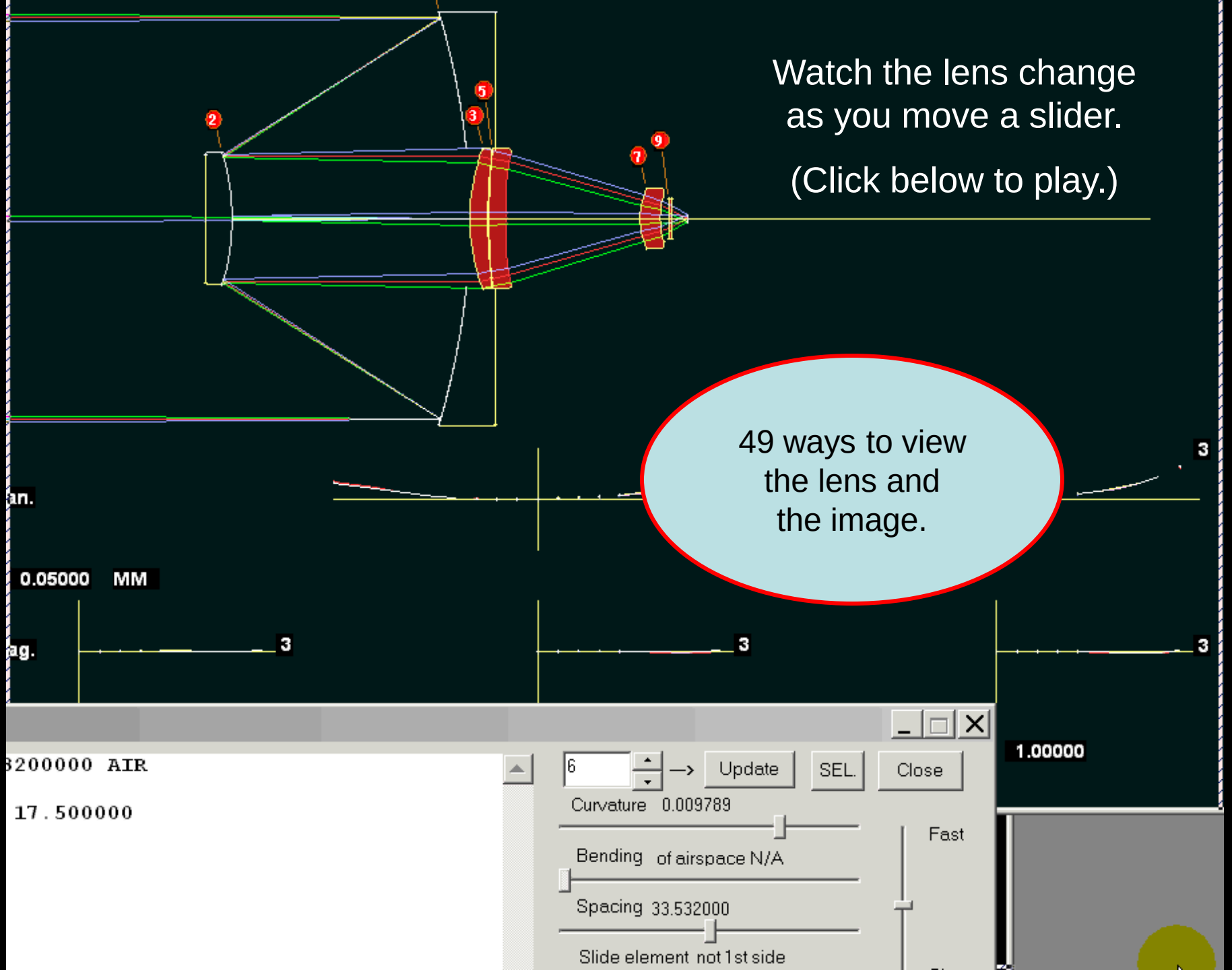
Click



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

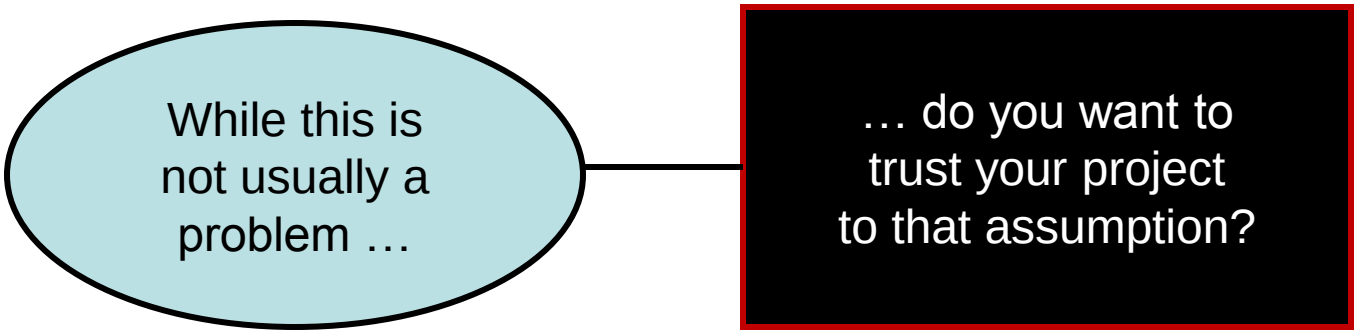
0 0.00000000 0.00000000
.00000000 AIR
00 0.00000000 100

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


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

Here's a blunder:

- To analyze the image, Zemax finds a set of rays, by iteration, to fit a perfect grid at the stop.
- If there are any pupil aberrations, this is not accurate. And it is very *slow.*
- SYNOPSYS™ starts with a uniform grid in object space. So you get the right answer.
  - The grid might *not* be uniform at the stop.



Here are some comments from those who have used Zemax:

"I am relatively new to the field of lens/optical design and so far I have used both SYNOPSYS and Zemax. My first impression is that SYNOPSYS is far superior when it comes to lens optimization, and more versatile in editing lenses. I am very impressed by the fact that when editing a lens in SYNOPSYS, one can use either the radius or the curvature of the surface. As for the optimization, it is faster, robust, and easier with SYNOPSYS."

... Jean Michel Taguenang, PhD
Alabama A&M University
Huntsville AL

Let me commend you on an excellent program. Before finding SYNOPSYS, I had a look at KDE (hard-to-learn interface, not windows oriented, …), Zemax (not nearly as easy to use as SYNOPSYS, Beam 3/4 (nowhere near enough features) and Optics Lab (again, not enough features).

…R. Lee Hawkins, NC

"The young people at ___ are trying to create ZEMAX models of my SYNOPSYS systems. With global coordinates in SYNOPSYS and only "coordinate breaks" in ZEMAX, they are getting a new appreciation for their chosen tool. The system has no plane of symmetry *and* includes a K-mirror to de-rotate the image seen through the high power laser pointer/tracker. SYNOPSYS handles the problem very nicely, of course."

… William Swantner, NM

"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."

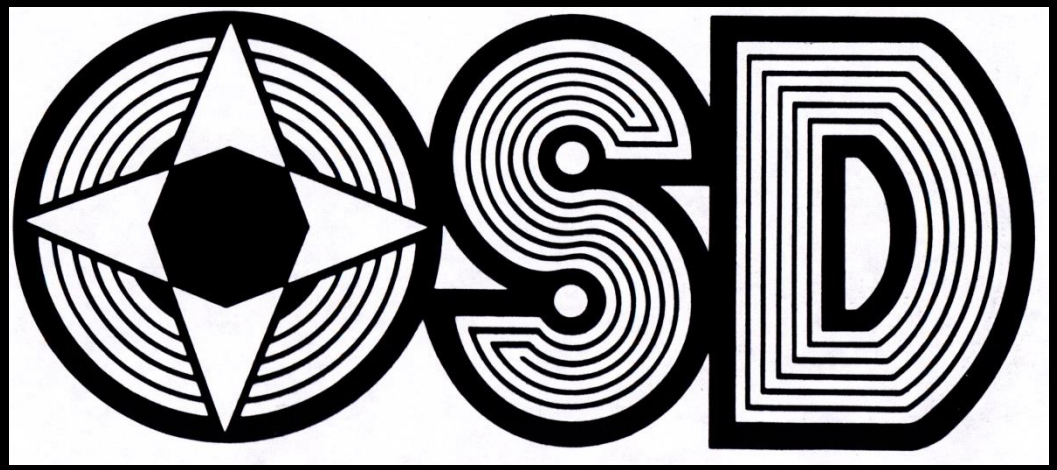
…Roger Whitmer, Pittsfield MA

"While I am used to OSLO and other programs, yours has by far and away the best tolerancing. I hate having to create a sensitivity table etc. I love being able to just put in a drop of Strehl of 0.25 and go. I built a 5-element lens using your tolerancing and it seemed to be right on the money. On my Athlon, tolerancing takes less than a minute to do everything …."

…John A Gibson, USA

Don Dilworth

Optical Systems Design, Inc.



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