



**Institute of
Applied Physics**

Friedrich-Schiller-Universität Jena

Optical Design with Zemax

Lecture 6: Advanced Handling

2012-11-27

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5 Aberrations II

Time schedule

1	16.10.	Introduction	Introduction, Zemax interface, menus, file handling, preferences, Editors, updates, windows, Coordinate systems and notations, System description, Component reversal, system insertion, scaling, 3D geometry, aperture, field, wavelength
2	23.10.	Properties of optical systems I	Diameters, stop and pupil, vignetting, Layouts
3	30.10.	Properties of optical systems II	Materials, Glass catalogs, Raytrace, Ray fans and sampling, Footprints, Types of surfaces, Aspheres
4	06.11.	Properties of optical systems III	Gratings and diffractive surfaces, Gradient media, Cardinal elements, Lens properties, Imaging, magnification, paraxial approximation and modelling
5	13.11.	Aberrations I	Representation of geometrical aberrations, Spot diagram, Transverse aberration diagrams, Aberration expansions, Primary aberrations,
6	20.11.	Aberrations II	Wave aberrations, Zernike polynomials, Point spread function, Optical transfer function
7	27.11.	Advanced handling	Telecentricity, infinity object distance and afocal image, Local/global coordinates, Add fold mirror, Vignetting, Diameter types, Ray aiming, slider, multiconfiguration, universal plot, IO of data, Lens catalogs
8	04.12.	Optimization I	Principles of nonlinear optimization, Optimization in optical design, Global optimization methods, Solves and pickups, variables, Sensitivity of variables in optical systems
9	11.12.	Optimization II	Systematic methods and optimization process, Starting points, Optimization in Zemax
10	18.12	Imaging	Fundamentals of Fourier optics, Physical optical image formation, Imaging in Zemax
11	08.01.	Illumination	Introduction in illumination, Simple photometry of optical systems, Non-sequential raytrace, Illumination in Zemax
12	15.01.	Correction I	Symmetry principle, Lens bending, Correcting spherical aberration, Coma, stop position, Astigmatism, Field flattening, Chromatical correction, Retrofocus and telephoto setup, Design method
13	22.01.	Correction II	Field lenses, Stop position influence, Aspheres and higher orders, Principles of glass selection, Sensitivity of a system correction, Microscopic objective lens, Zoom system
14	29.01.	Physical optical modelling I	Gaussian beams, POP propagation, polarization raytrace, polarization transmission, polarization aberrations
15	05.02.	Physical optical modelling II	coatings, representations, transmission and phase effects, ghost imaging, general straylight with BRDF

1. Telecentricity, infinity object distance and afocal image
2. Local/global coordinates
3. Add fold mirror
4. Vignetting
5. Diameter types
6. Material index fit
7. Universal plot
8. Slider
9. IO of data
10. Multiconfiguration
11. Lens catalogs

1. Telecentric object space

- Set in menu General / Aperture
- Means entrance pupil in infinity
- Chief ray is forced to be parallel to axis
- Fixation of stop position is obsolete
- Object distance must be finite
- Field cannot be given as angle

2. Infinity distant object

- Aperture cannot be NA
- Object size cannot be height
- Cannot be combined with telecentricity

3. Afocal image location

- Set in menu General / Aperture
- Aberrations are considered in the angle domain
- Allows for a plane wave reference
- Spot automatically scaled in mrad

1. Coordinate reference

- Fixation of reference in menu: General / Misc
- Every surface vertex can be defined as global reference
- Helpful in constructing 3D-system geometries

2. Scale System

- In menu Tools / Miscellaneous / Scale
- Helpful in exploding/imploding all length scales
- Application: rescale patent systems
- Alternative option in menu Tools / Miscellaneous / Make focal, desired f realized

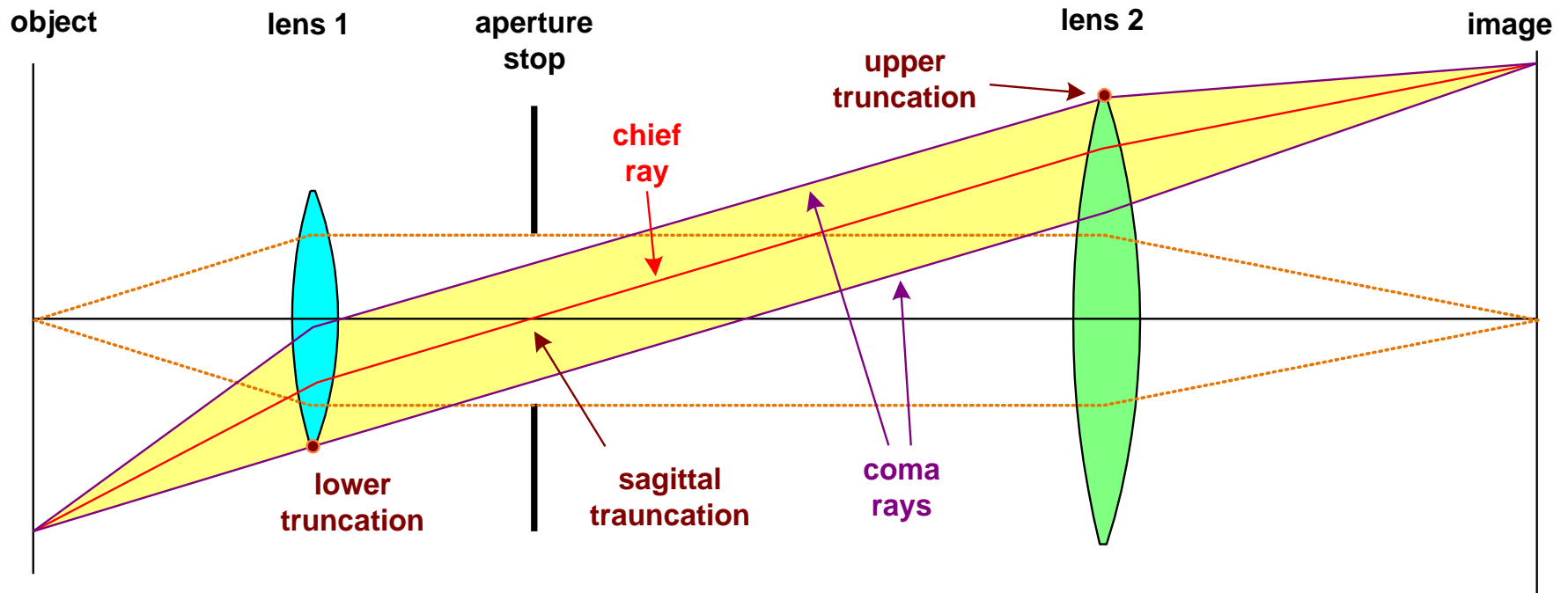
3. Add folding mirror

- Help command in menu Tools / Coordinates / Add fold mirror
- Automatically inserted coordinate break surface

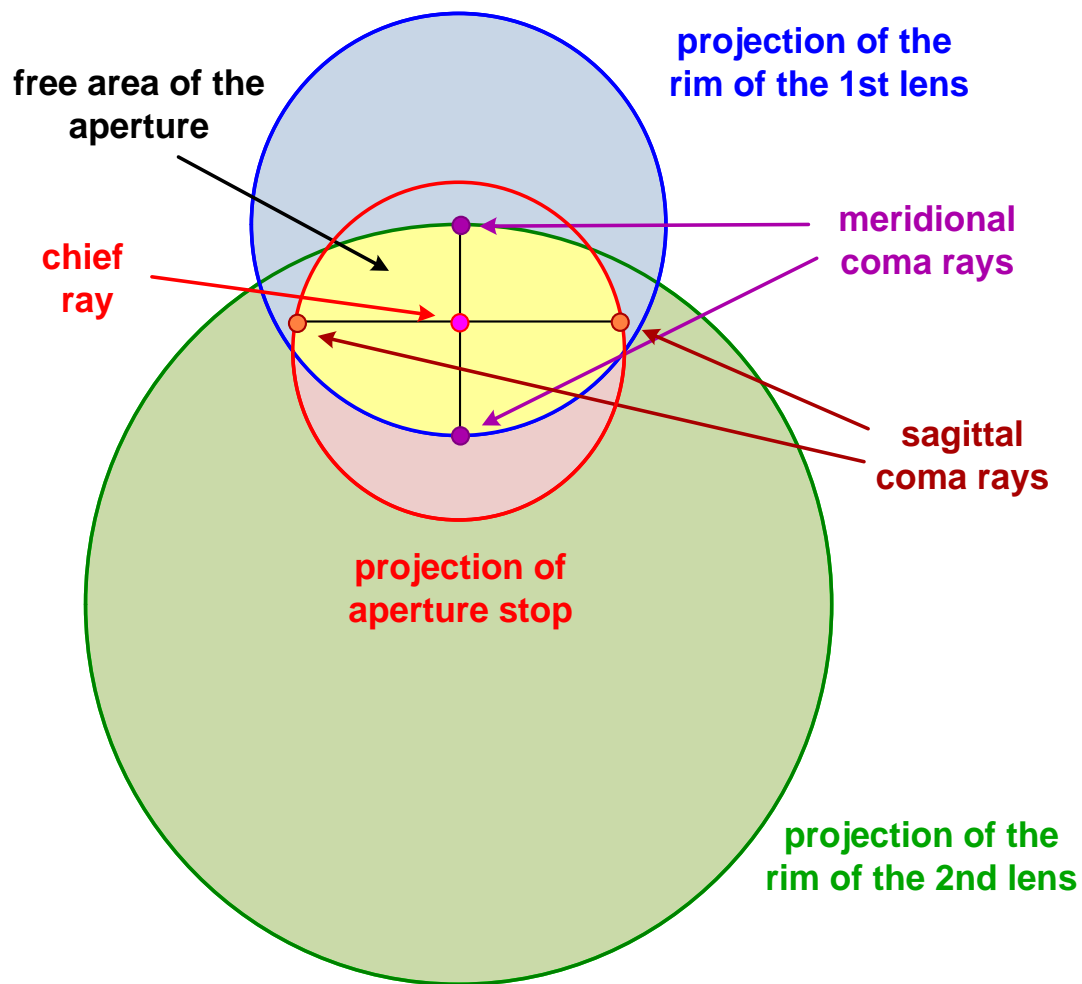
4. Make double pass

- Help command in menu Tools / Miscellaneous / Make double pass
- Folding mirror and reversed system automatically generated

- 3D-effects due to vignetting
- Truncation of the cone at different surfaces for the upper and the lower part of the cone



- Truncation of the light cone with asymmetric ray path for off-axis field points
- Intensity decrease towards the edge of the image
- Definition of the chief ray: ray through energetic centroid
- Vignetting can be used to avoid uncorrectable coma aberrations in the outer field
- Effective free area with extrem aspect ratio: anamorphic resolution

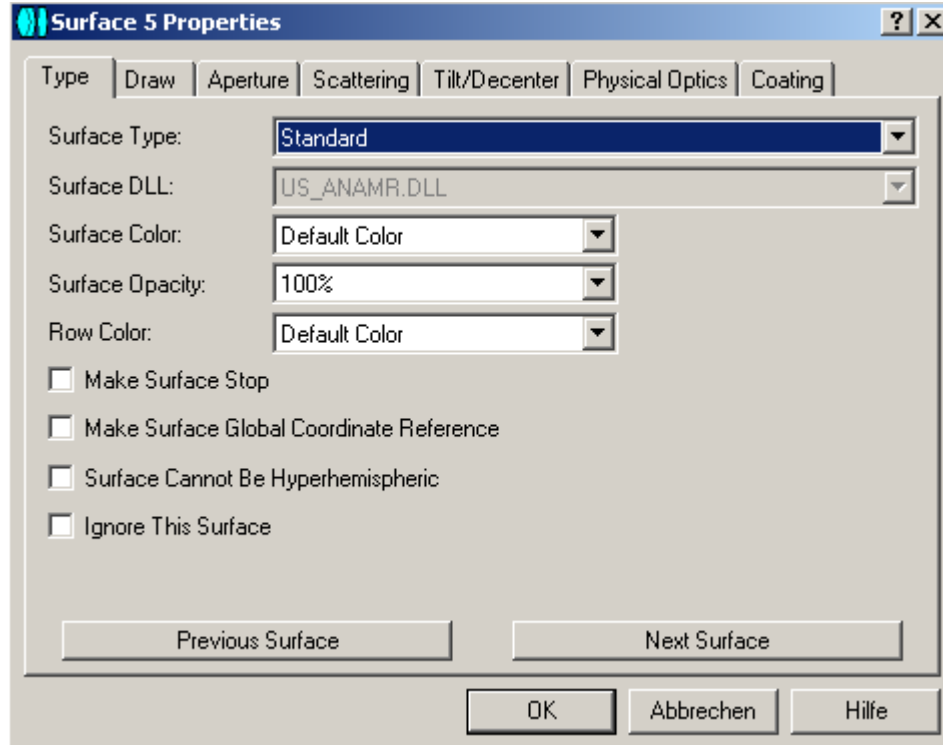


7 Advanced handling Diameters in Zemax

There are several different types of diameters in Zemax:

1. Surface stop

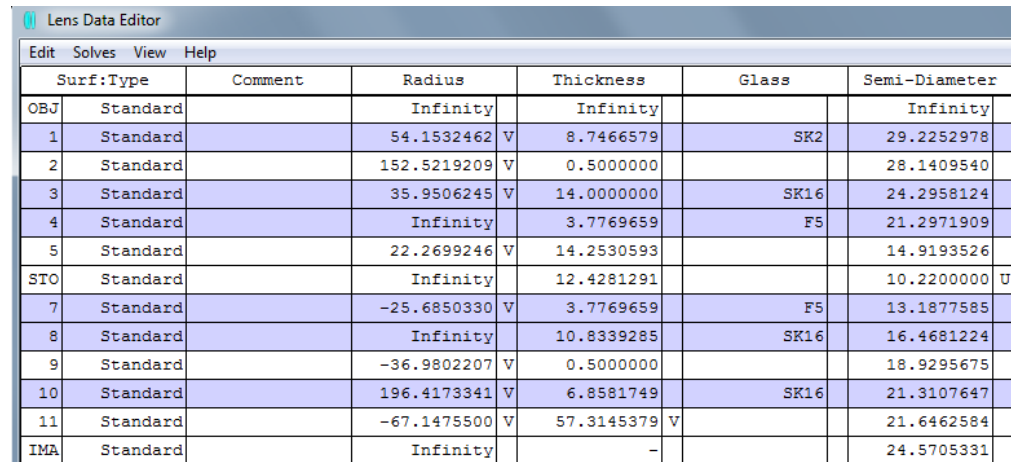
- defines the axis intersection of the chief ray
- usually no influence on aperture size
- only one stop in the system
- is indicated in the Lens Data Editor by **STO**
- if the initial aperture is defined, the size of the stop semi-diameter is determined by marginal raytrace



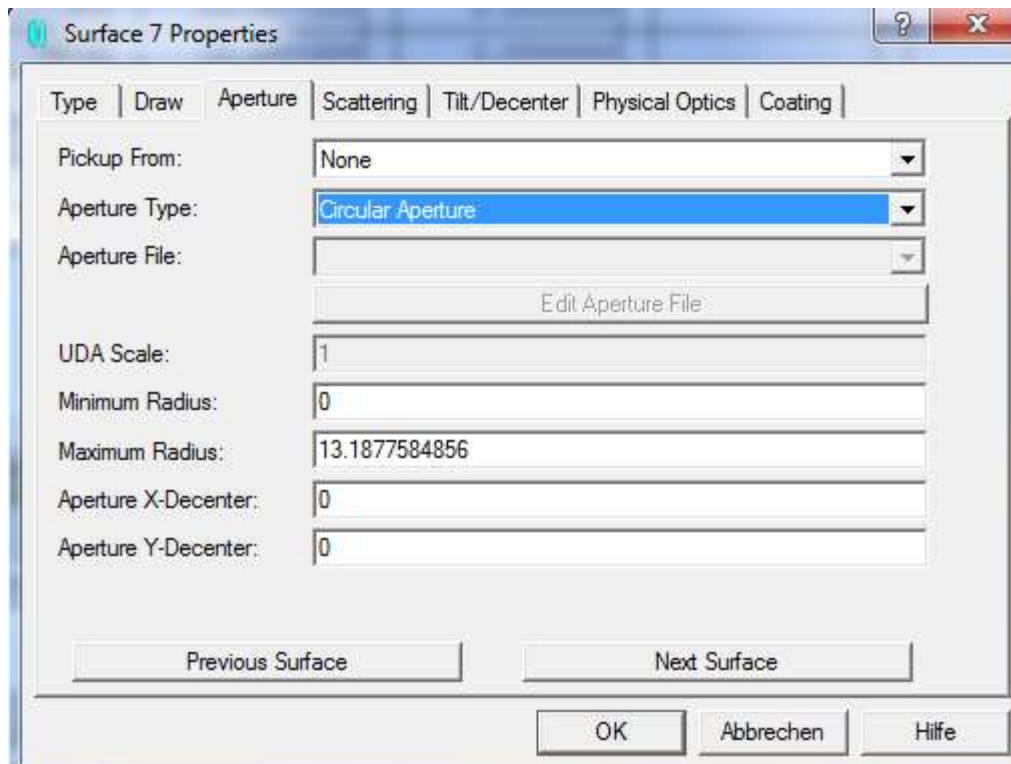
7 Advanced handling Diameters in Zemax

2. Userdefined diameter at a surface in the Lens Data Editor (U)
 - serves also as drawing size in the layout (for nice layouts)
 - if at least one diameter is fixed, the initial aperture can be computed automatically by
General / Aperture Type / Float by Stop Size
This corresponds to a ray aiming

3. Individual diameter of perhaps complicated shape at every surface (,apertures‘)
 - no impact on the drawing
 - is indicated in the Lens Data Editor by a star
 - the drawing of vignetted rays can be switched on/off



Surf	Type	Comment	Radius	Thickness	Glass	Semi-Diameter
OBJ	Standard		Infinity	Infinity		Infinity
1	Standard		54.1532462	V 8.7466579	SK2	29.2252978
2	Standard		152.5219209	V 0.5000000		28.1409540
3	Standard		35.9506245	V 14.0000000	SK16	24.2958124
4	Standard		Infinity	3.7769659	F5	21.2971909
5	Standard		22.2699246	V 14.2530593		14.9193526
STO	Standard		Infinity	12.4281291		10.2200000
7	Standard		-25.6850330	V 3.7769659	F5	13.1877585
8	Standard		Infinity	10.8339285	SK16	16.4681224
9	Standard		-36.9802207	V 0.5000000		18.9295675
10	Standard		196.4173341	V 6.8581749	SK16	21.3107647
11	Standard		-67.1475500	V 57.3145379	V	21.6462584
IMA	Standard		Infinity	-		24.5705331



Surface 7 Properties

Type | Draw | Aperture | Scattering | Tilt/Decenter | Physical Optics | Coating

Pickup From: None

Aperture Type: Circular Aperture

Aperture File:

Edit Aperture File

UDA Scale: 1

Minimum Radius: 0

Maximum Radius: 13.1877584856

Aperture X-Decenter: 0

Aperture Y-Decenter: 0

Previous Surface | Next Surface

OK | Abbrechen | Hilfe

7 Advanced handling Diameters in Zemax

- In the Field data menu, individually vignetting (reduction) factors can be defined for every field point individually
- VDX, VDY: relative decenter of light cone in x, y
- VCX, VCY: compression factors in x, y
- VAN: azimuthal rotation angle of light cone
- If limiting diameters are set in the system, the corresponding factors can be calculated by the **Set Vig** command

Field Data

Type: Angle (Deg) Object Height Parax. Image Height Real Image Height

Field Normalization:

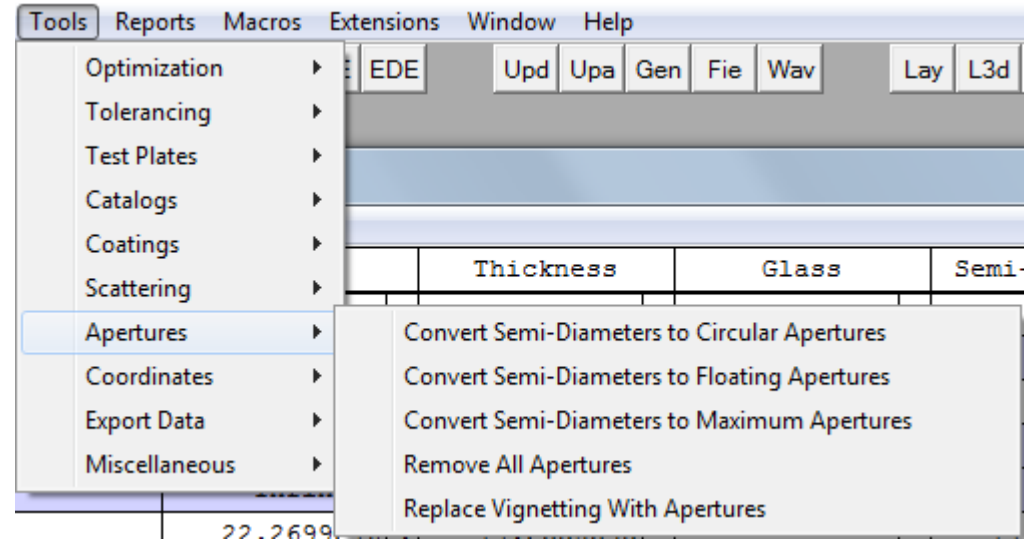
Use	X-Field	Y-Field	Weight	VDX	VDY	VCX	VCY	VAN
<input checked="" type="checkbox"/>	1	0	0	1.0000	0.00000	0.00000	0.00000	0.00000
<input type="checkbox"/>	2	0	0	1.0000	0.00000	0.00000	0.00000	0.00000
<input type="checkbox"/>	3	0	0	1.0000	0.00000	0.00000	0.00000	0.00000
<input type="checkbox"/>	4	0	0	1.0000	0.00000	0.00000	0.00000	0.00000
<input type="checkbox"/>	5	0	0	1.0000	0.00000	0.00000	0.00000	0.00000
<input type="checkbox"/>	6	0	0	1.0000	0.00000	0.00000	0.00000	0.00000
<input type="checkbox"/>	7	0	0	1.0000	0.00000	0.00000	0.00000	0.00000
<input type="checkbox"/>	8	0	0	1.0000	0.00000	0.00000	0.00000	0.00000
<input type="checkbox"/>	9	0	0	1.0000	0.00000	0.00000	0.00000	0.00000
<input type="checkbox"/>	10	0	0	1.0000	0.00000	0.00000	0.00000	0.00000
<input type="checkbox"/>	11	0	0	1.0000	0.00000	0.00000	0.00000	0.00000
<input type="checkbox"/>	12	0	0	1.0000	0.00000	0.00000	0.00000	0.00000

OK Cancel Sort Help

Set Vig Clr Vig Save Load

7 Advanced handling Diameters in Zemax

- In the Tools-menue, the diameters and apertures can be converted automatically



7 Advanced handling Material Index Fit

- Establishing a special own material
- Select menu:
Tools / Catalogs / Glass catalogs
- Options:
 1. Fit index data
 2. Fit melt data
- Input of data for wavelengths and indices
- It is possible to establish own material catalogs with additional glasses as an individual library

Glass Catalog

Catalog: MYGLAS.AGF

Glass: GLY
BALF51
IM_MELT
SIO2V248
IM
IMMERSION_MELT

Rename: IMMERSION_MELT

Formula: Herzberger

Status: Melt

Nd: Vd:

Ignore Thermal Expansion

Exclude Substitution

Meta Material (Negative Index)

A: 1.56320660E+000 D0: 0.0000E+000

B: -4.90316943E-003 D1: 0.0000E+000

C: 6.28421892E-004 D2: 0.0000E+000

D: -1.80889816E-001 E0: 0.0000E+000

E: 2.45831743E-001 E1: 0.0000E+000

F: -1.39265225E-001 Ltk: 0.0000E+000

TCE: 0

Temp: 20

p: 1

dPgF: 0

Minimum Wavelength: 0.43583000

Maximum Wavelength: 0.53983990

Melt Freq: ? Comment:

Rel Cost: ? CR: ? FR: ? SR: ? AR: ? PR: ?

Save Catalog Insert Glass Sort By -> Name:

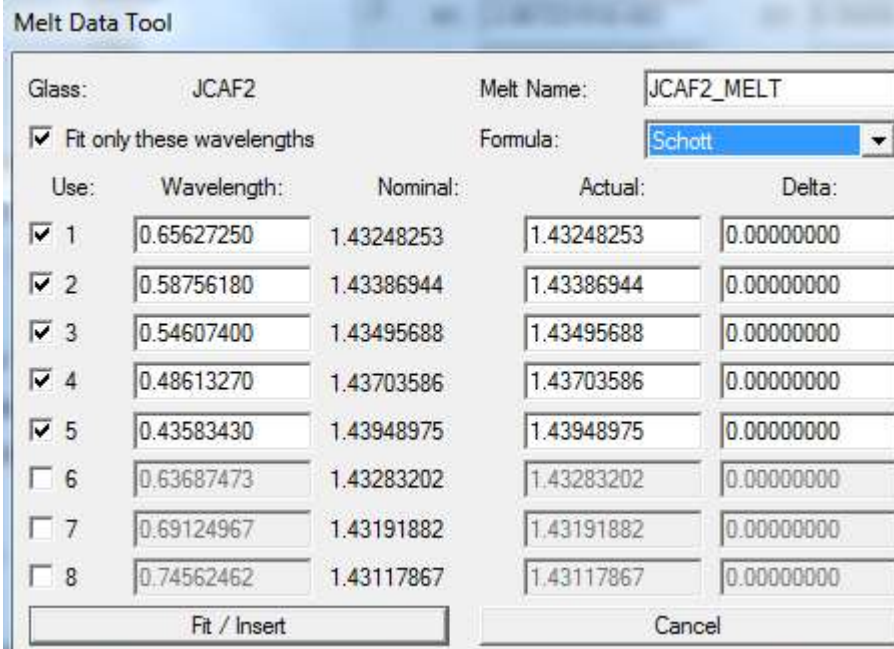
Save Catalog As Cut Glass Glass Report Catalog Report

Reload Catalog Copy Glass Transmission Compute Nd/Vd

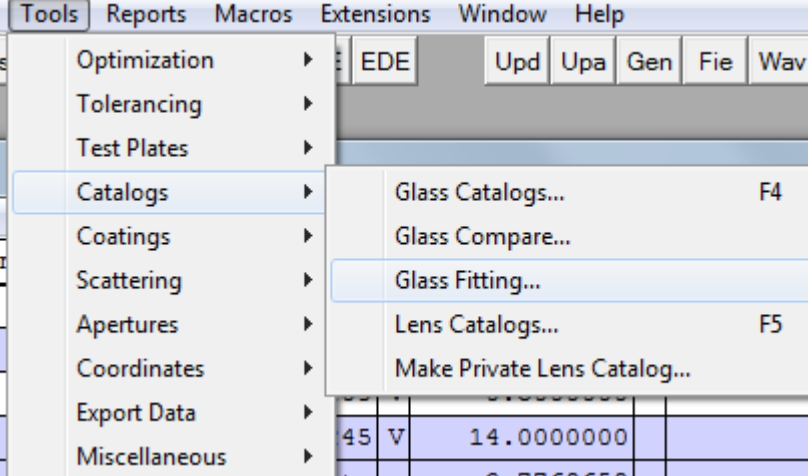
Exit Paste Glass Fit Index Data Fit Melt Data

7 Advanced handling Material Index Fit

- Melt data:
 - for small differences of real materials
 - no advantage for new materials
- Menu option:
,Glass Fitting Tool'
don't works (data input?)

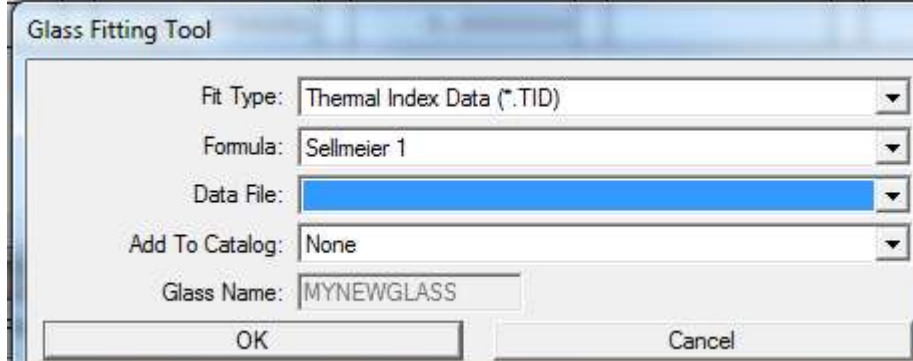


Use:	Wavelength:	Nominal:	Actual:	Delta:
<input checked="" type="checkbox"/>	0.65627250	1.43248253	1.43248253	0.00000000
<input checked="" type="checkbox"/>	0.58756180	1.43386944	1.43386944	0.00000000
<input checked="" type="checkbox"/>	0.54607400	1.43495688	1.43495688	0.00000000
<input checked="" type="checkbox"/>	0.48613270	1.43703586	1.43703586	0.00000000
<input checked="" type="checkbox"/>	0.43583430	1.43948975	1.43948975	0.00000000
<input type="checkbox"/>	0.63687473	1.43283202	1.43283202	0.00000000
<input type="checkbox"/>	0.69124967	1.43191882	1.43191882	0.00000000
<input type="checkbox"/>	0.74562462	1.43117867	1.43117867	0.00000000



Tools Reports Macros Extensions Window Help

- Optimization
- Tolerancing
- Test Plates
- Catalogs**
 - Glass Catalogs... F4
 - Glass Compare...
 - Glass Fitting...**
 - Lens Catalogs... F5
 - Make Private Lens Catalog...
- Coatings
- Scattering
- Apertures
- Coordinates
- Export Data
- Miscellaneous



Glass Fitting Tool

Fit Type: Thermal Index Data (*.TID)

Formula: Sellmeier 1

Data File:

Add To Catalog: None

Glass Name: MYNEWGLASS

7 Advanced handling Material Index Fit

- Menue: Fit Index Data
- Input of data: 2 options:
 1. explicite entering wavelengths and indices
 2. load file xxx.dat with two columns:
wavelength in μm and index
- Choice of 4 different dispersion formulas
- After fit:
 - pv and rms of approximation visible
 - no individual errors seen
 - new material can be added to catalog
 - data input can be saved to file

Fit Index Data

	Wavelength:	Index:	Name:	Formula:	RMS Err:	Max Err:
1	0.486000	1.700000	NEWGLASS	Schott		
2	0.587000	1.600000		Schott		
3	0.656000	1.500000		Herzberger		
4	0.000000	0.000000		Conrady		
5	0.000000	0.000000		Sellmeier 1		
6	0.000000	0.000000				
7	0.000000	0.000000				

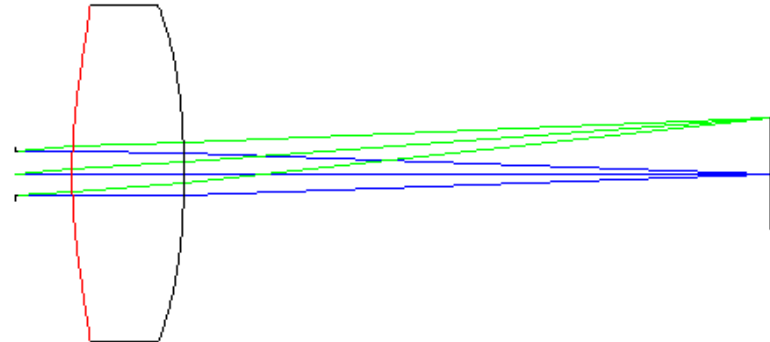
Buttons: Scroll Up, Page Up, Scroll Down, Page Down, Add To Catalog, Save Index Data, Load Index Data, Exit

Fit Index Data

	Wavelength:	Index:	Name:	Formula:	RMS Err:	Max Err:
1	0.337000	1.800820	SAPPHO	Sellmeier 1	2.289449E-005	4.500614E-005
2	0.351000	1.796930				
3	0.355000	1.795980				
4	0.442000	1.780380				
5	0.458000	1.778430				
6	0.488000	1.775300				
7	0.515000	1.773040				

Buttons: Scroll Up, Page Up, Scroll Down, Page Down, Add To Catalog, Save Index Data, Load Index Data, Exit

- Possibility to generate individual plots for special properties during changing one or two parameters
- Usually the criteria of the merit function are shown
- Demonstration: aspherical lens, change of Strehl ratio with values of constants
- The sensitivity of the correction can be estimated
- It is seen, that the aspherical constants on one side are enough to correct the system



Lens Data Editor							
Edit Solves View Help							
Surf	Type	Thickness	Glass	Semi-Diameter		2nd Order Term	4th Order Term
OBJ	Standard	Infinity		Infinity			
STO	Standard	5.0000000		2.0000000			
2*	Even Asph..	10.0000000	BK7	15.0000000	U	0.0000000	-1.507E-005
3*	Even Asph..	52.4612830		15.0000000	U	0.0000000	-1.269E-005
IMA	Standard	-		4.9563392			

- One-dimensional: change of 4th order coefficient at first surface

Universal Plot 1D Settings

Independent Variable X

Surface Parameter 2 On Surface: 2

Start Value: -0.0001 Stop Value: 0.0001

of steps: 45

Dependent Variable Y

Operand: Merit Line: 1, STRH

0 0

0 0

0 0

0 0

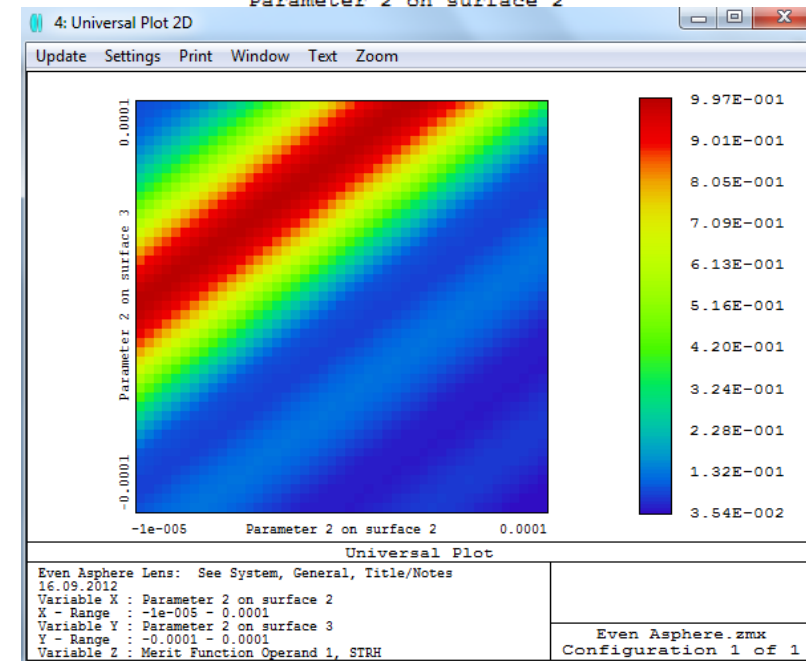
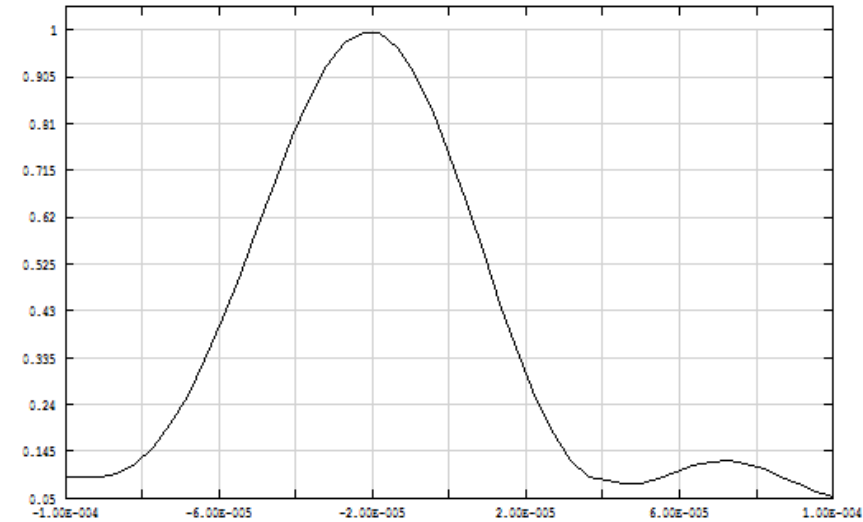
Minimum Plot Value 0 Maximum Plot Value 0

Plot Title: Universal Plot

Save As New Universal Plot

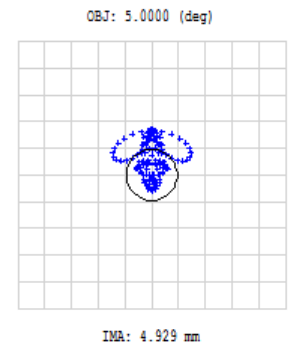
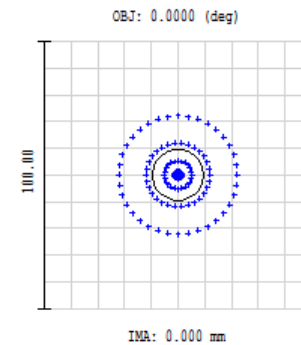
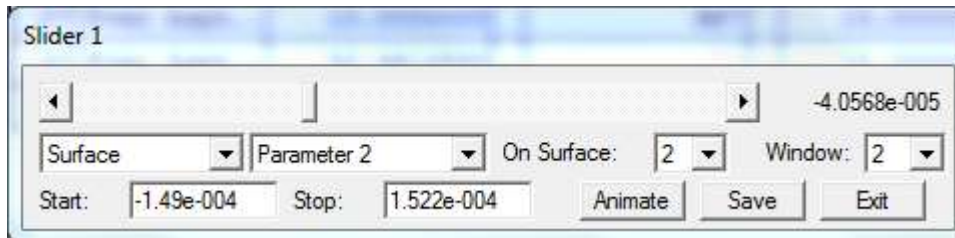
Load From -> None

OK Cancel Save Load Reset Help

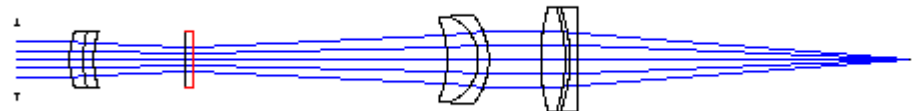
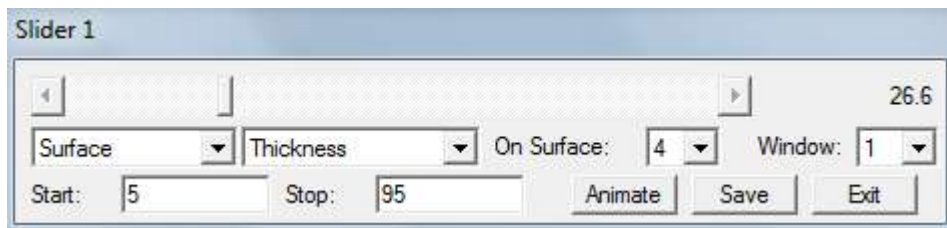


- Two-dimensional case: dependence on the coefficients on both sides

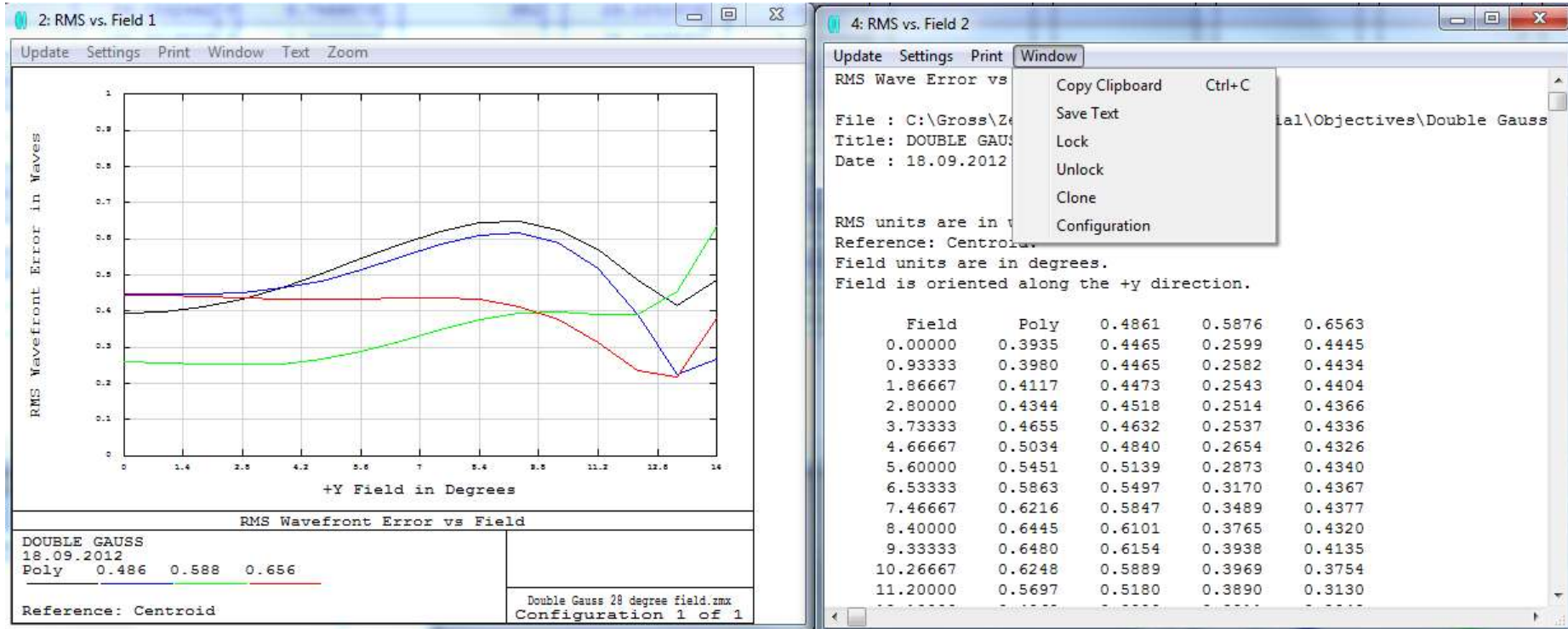
- Slider option in menu: Tools / Miscellaneous / Slider
- Dependence of chosen window output as a function of a varying parameter
- Automatic scan or manual adjustment possible
- Example 1: spot for changing the aspherical constant of 4th order of a lens



- Example 2: Optical compensated zoom system



- Output of numerical data of results:
Text option with save: generation of ASCII file



7 Advanced handling Data IO



- Export of IGES / STEP files, for CAD data transfer

Export IGES/STEP/SAT/STL Solid Data File

First Surface:	1	Wavelength:	All
Last Surface:	12	Field:	All
Number Of Rays:	0	Spline Segments:	32
Lens Layer:	0	Ray Layer:	1
File Type:	STEP	Configuration:	Current
Ray Pattern:	XY Fan	Dummy Thickness:	1.000E+000
		Tolerance:	1.00E-4

Delete Vignetted
 Surfaces As Solids
 Scatter NSC Rays
 Export Dummy Surfaces
 Split NSC Rays
 Use Polarization

Ready.

OK Cancel Help

```
#340 = (  
  BOUNDED_CURVE (  
    B_SPLINE_CURVE (2, (#250, #260, #270, #280, #290, #300, #310,  
#320, #330), .UNSPECIFIED., .T., .U.)  
    B_SPLINE_CURVE_WITH_KNOTS ((3, 2, 2, 2, 3), (0.,  
1.5707963267949, 3.14159265358979, 4.71238898038469,  
5.26179144370819), .UNSPECIFIED.)  
  )  
  REPRESENTATION_ITEM (  
    B_SPLINE_CURVE ((1., 0.707106781186548, 1.,  
0.707106781186548, 1., 0.707106781186548, 1., 0.707106781186548,  
1., 0.707106781186548),  
    1, .T., .U.  
  )  
  CON_ITEM ('')  
  )  
  SURFACE ('', #240, #240, #340, .T.);  
  )_EDGE ('', *, *, #350, .T.);  
  )_OP ('', (#360));  
  )_PER_BOUND ('', #370, .T.);  
  )_AN_POINT ('', (1.4210854715202E-14, -  
1.4210854715202E-14, 161.268578790111));  
  )_ON ('', (-1., 0., 0.));  
  )_ON ('', (0., 1., 7.62082612354251E-16));  
  )_PLACEMENT_3D ('', #390, #400, #410);  
  )_AL_SURFACE ('', #420, 152.521920940111);  
  )_O_FACE ('', (#380), #430, .F.);  
  )_AN_POINT ('', (29.225297770111, 0.,  
0.707106781186548));  
#460 = VERTEX_POINT ('', #450);  
#470 = CARTESIAN_POINT ('', (29.225297770111, 0.,  
11.3651996637384));  
#480 = CARTESIAN_POINT ('', (29.225297770111, 29.225297770111,  
11.3651996637384));  
#490 = CARTESIAN_POINT ('', (1.78953336841473E-15,  
29.225297770111, 11.3651996637384));  
#500 = CARTESIAN_POINT ('', (-29.225297770111, 29.225297770111,  
11.3651996637384));  
#510 = CARTESIAN_POINT ('', (-29.225297770111,  
29.225297770111, 11.3651996637384));
```

- Multi configuration editor
- Establishment of different system paths or configurations
- Toggle between configurations with CNTR A
- Examples:
 1. Zoom systems, lenses moved
 2. Scan systems, mirror rotated
 3. Switchable optics, components considered / not taken into account
 4. Interferometer, test and reference arm
 5. Camera with different object distances
 6. Microscope tube system for several objective lenses
 7. ...
- In the multi configuration editor, the parameters / differences must be defined
- Many output options and the optimization can take all configurations into account
- Special option: showallconfiguration in the 3D layout drawing simultaneously
 1. shifted, for comparison
 2. with same reference, overlaid

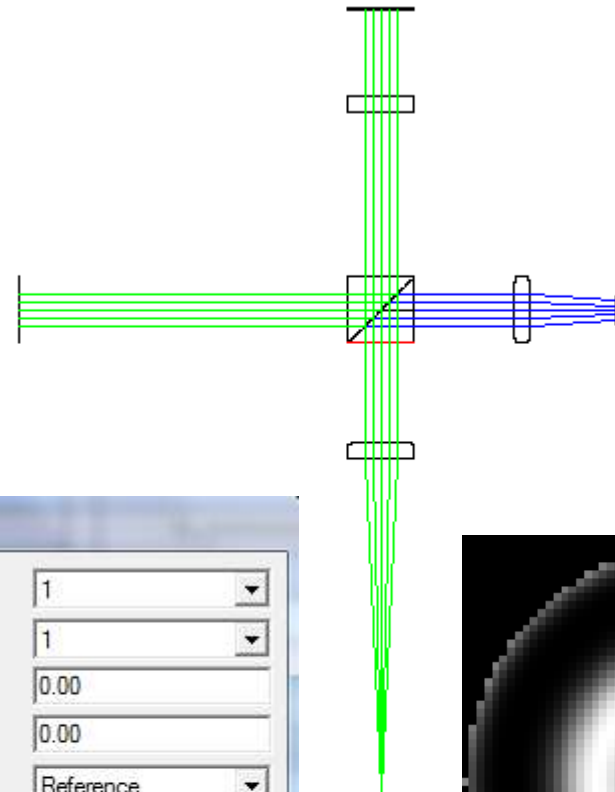
7 Advanced handling Multi Configuration

Multi-Configuration Editor

Edit Solves Tools View Help

Active : 1/2		Config 1*	Config 2
1: GLSS	4	BK7	MIRROR
2: THIC	6	10.0000000	-10.0000000
3: THIC	7	30.0000000	-50.0000000
4: THIC	8	5.0000000	-5.0000000
5: THIC	9	26.0000000	-26.0000000
6: CRVT	8	1.0000E-002	0.0000000
7: CRVT	9	-1.000E-002	0.0000000
8: CRVT	10	0.0278641	0.0000000
9: PRAM	5/3	-45.0000000	45.0000000
10: PR*	14/3	45.0000000	-45.0000000
11: GL*	15	MIRROR	BK7

- Demonstrational example:
Twyman-Green interferometer



Interferogram Settings

Sampling:	64 x 64	Wavelength:	1
Surface:	Image	Field:	1
Scale Factor:	1.00	X - Tilt:	0.00
Show As:	Grey Scale	Y - Tilt:	0.00
Beam 1:	Configuration 1	Beam 2:	Reference

Ref Beam 1 To Vertex Ref Beam 2 To Vertex
 Use Exit Pupil Shape Consider Path Length Difference

Contour Format: 1

Subaperture Data -> Sx: 0 Sy: 0 Sr: 1

OK Cancel Save Load Reset Help

