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Optical Design with Zemax

Lecture 6: Advanced Handling

2012-11-27

Herbert Gross

5 Aberrations II
Time schedule

1	16.10.	Introduction	Introduction, Zemax interface, menues, 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

7 Advancd handling
Contents

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

7 Advanced handling
Telecentricity, Infinity Object and Afocal Image

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1. Telecentric object space
   - Set in menue General / Aperture
   - Means entrance pupil in infinity
   - Chief ray is forced to by 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 menue General / Aperture
   - Aberrations are considered in the angle domain
   - Allows for a plane wave reference
   - Spot automatically scaled in mrad

7 Advanced handling
Miscellaneous

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

2. Scale System
   - In menue Tools / Miscellaneous / Scale
   - Helpful in expoding/imploding all length scales
   - Application: rescale patent systems
   - Alternative option in menue Tools / Miscellaneous / Make focal, desired f realized

3. Add folding mirror
   - Help command in menue Tools / Coordinates / Add fold mirror
   - Automatically inserted coordinate break surface

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

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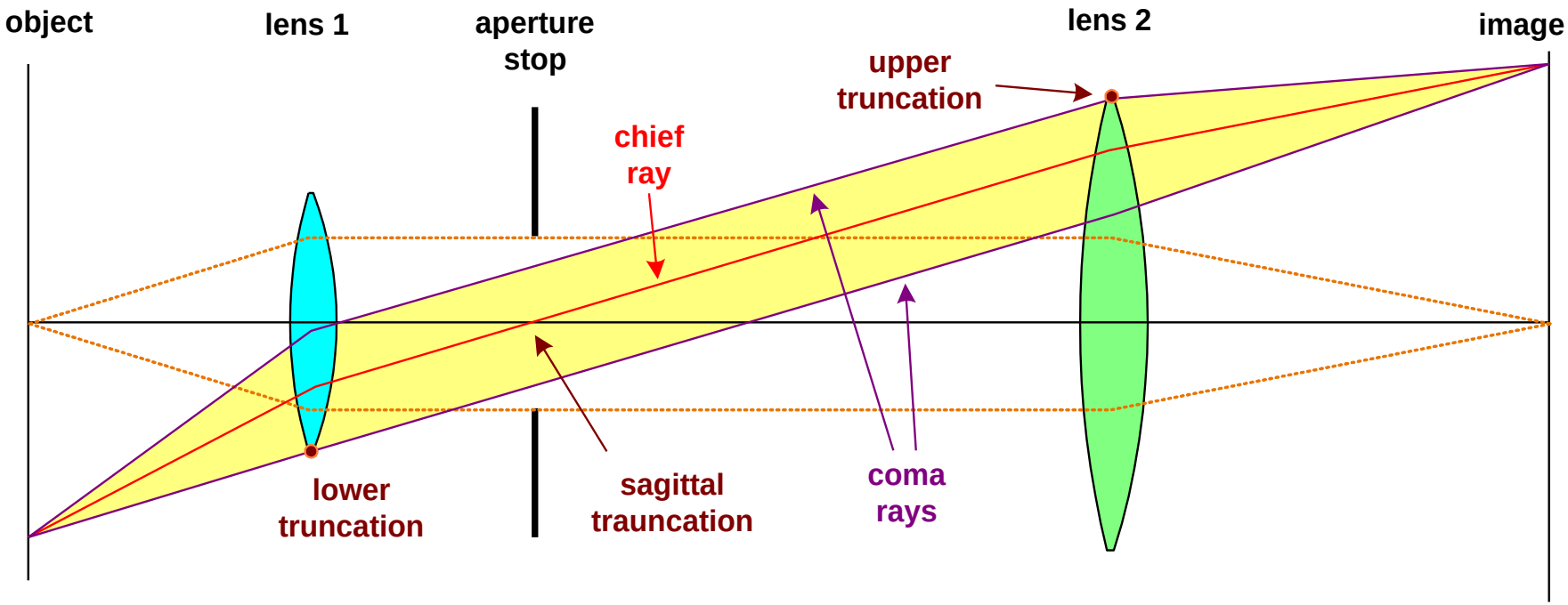
- 3D-effects due to vignetting
- Truncation of the at different surfaces for the upper and the lower part of the cone



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Vignetting

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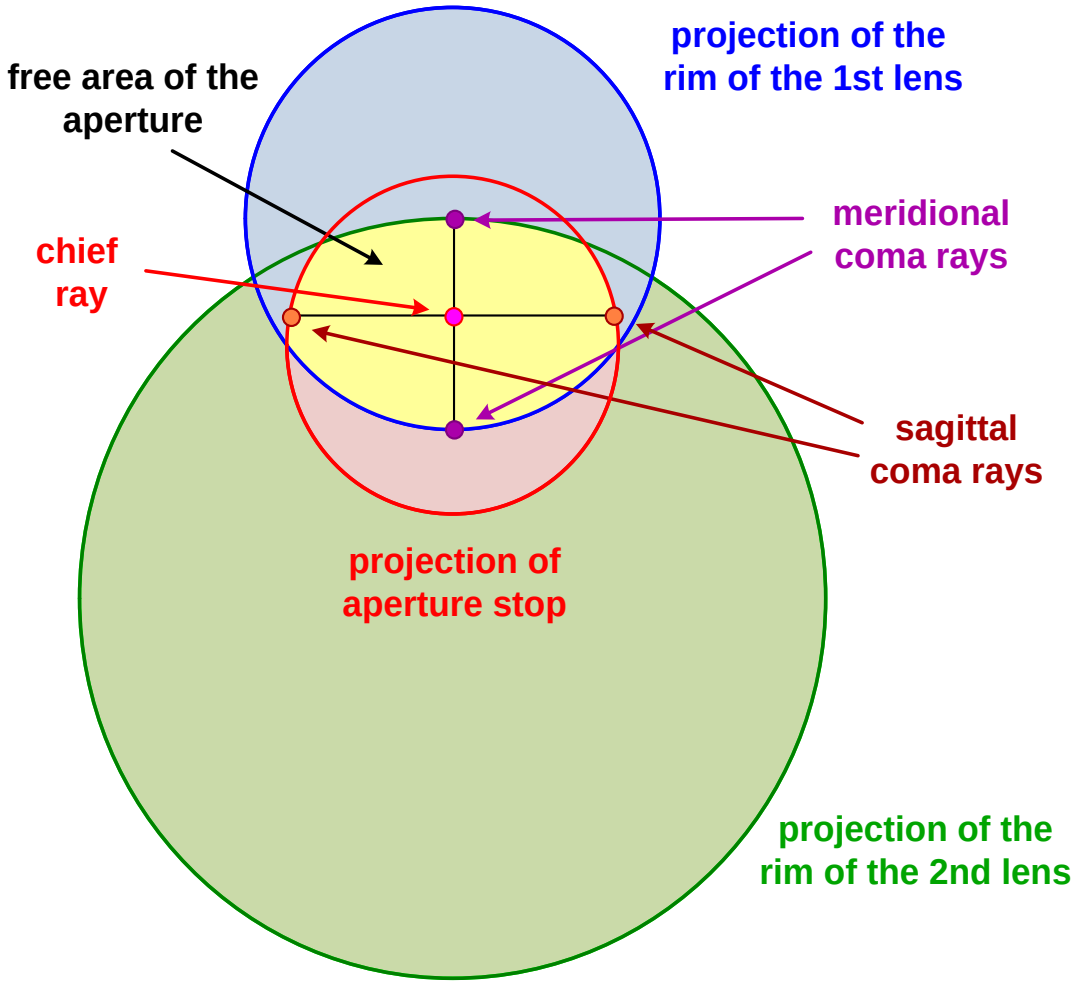
- Truncation of the light cone with asymmetric ray path for off-axis field points
- Intensity decrease towards the edge of the image
- Definition of the chief ray: ray through energetic centroid
- Vignetting can be used to avoid uncorrectable coma aberrations in the outer field
- Effective free area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



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Diameters in Zemax

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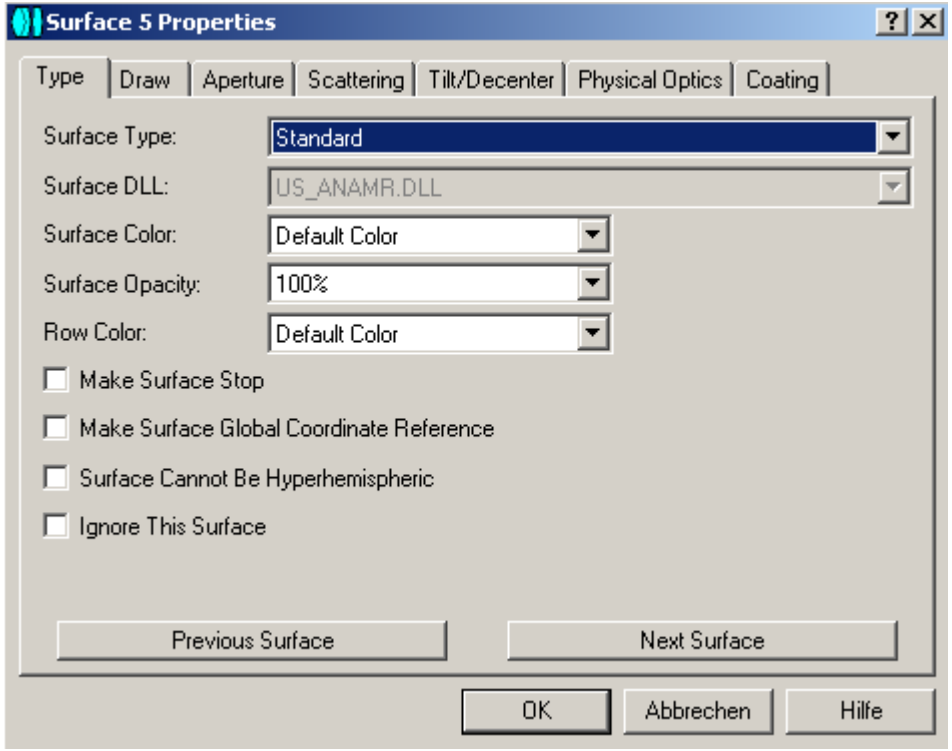
There are several different types of diameters in Zemax:

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

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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 by switched on/off

Lens Data Editor

Edit Solves View Help

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	U
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	

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Diameters in Zemax

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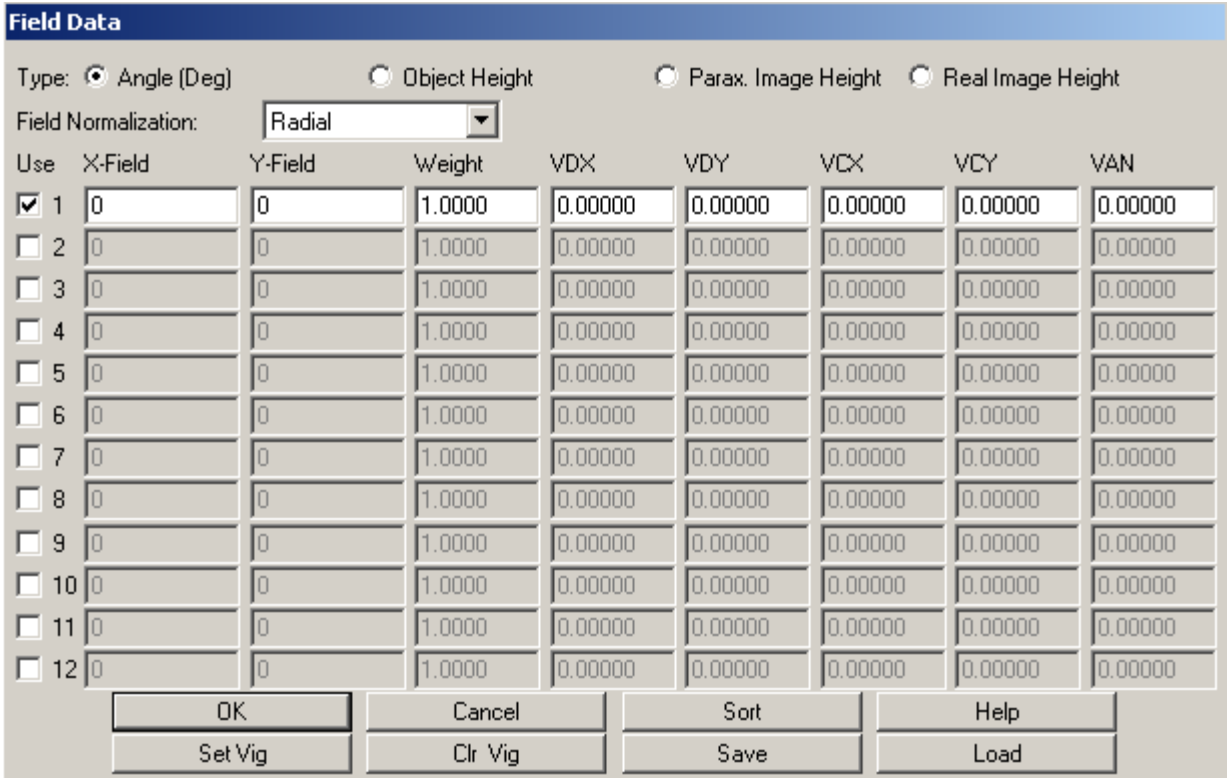
- In the Field data menue, individually vignetting (reduction) factors can be defined for every field point individually
- VDX, VDY: relative decenter of light cone in x, y
- VCX, VCY: compressian factors in x, y
- VAN: azimuthal rotation angle of light cone
- If limiting diameters are set in the system,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



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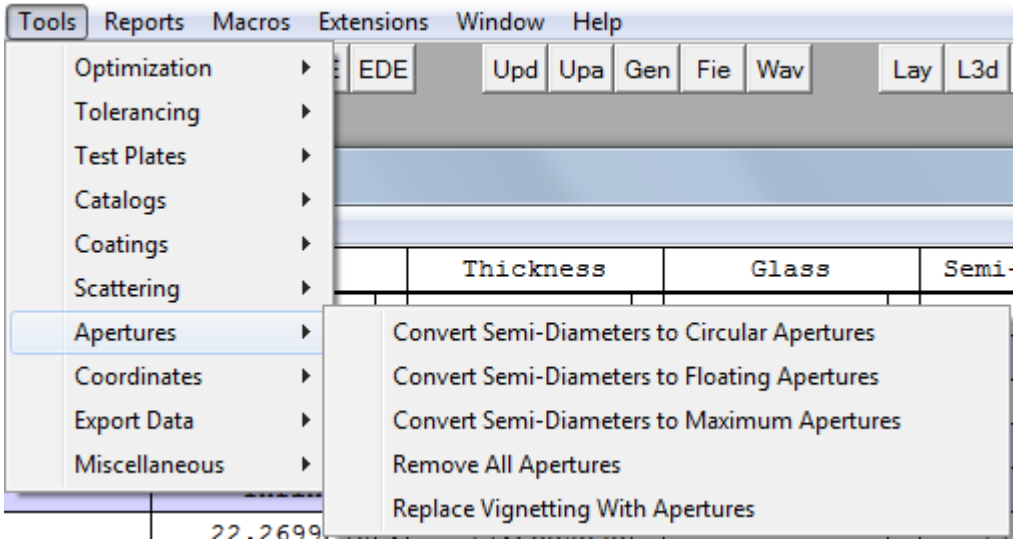
- In the Tools-menue, the diameters and apertures can be converted automatically



7 Advanced handling
Material Index Fit

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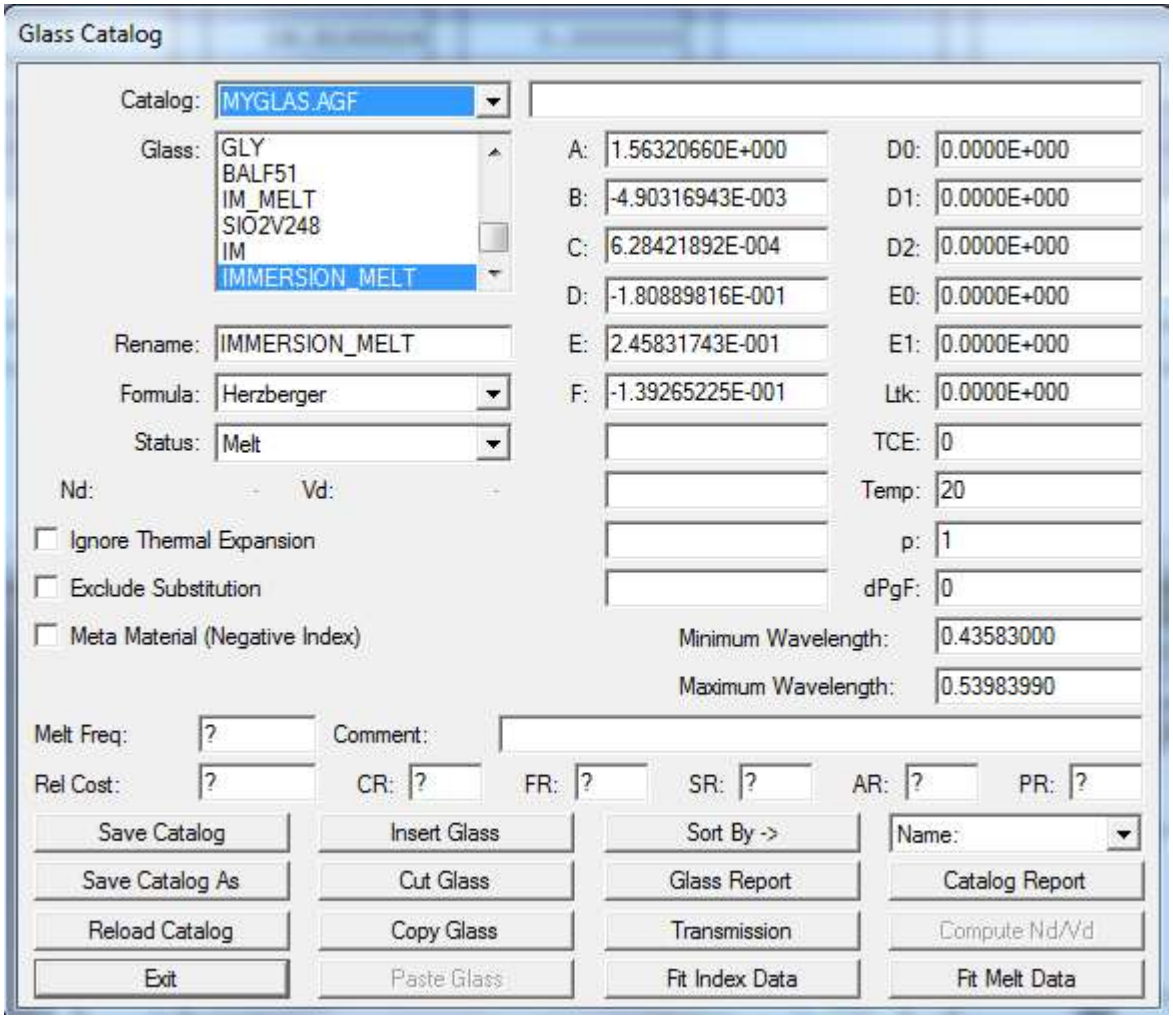
- Establishing a special own material
- Select menue:
  Tools / Catalogs / Glass catalogs
- Options:
  1. Fit index data
  2. Fit melt data
- Input of data for wavelengths and indices
- It is possible to establish own material catalogs with additional glasses as an individual library



7 Advanced handling
Material Index Fit

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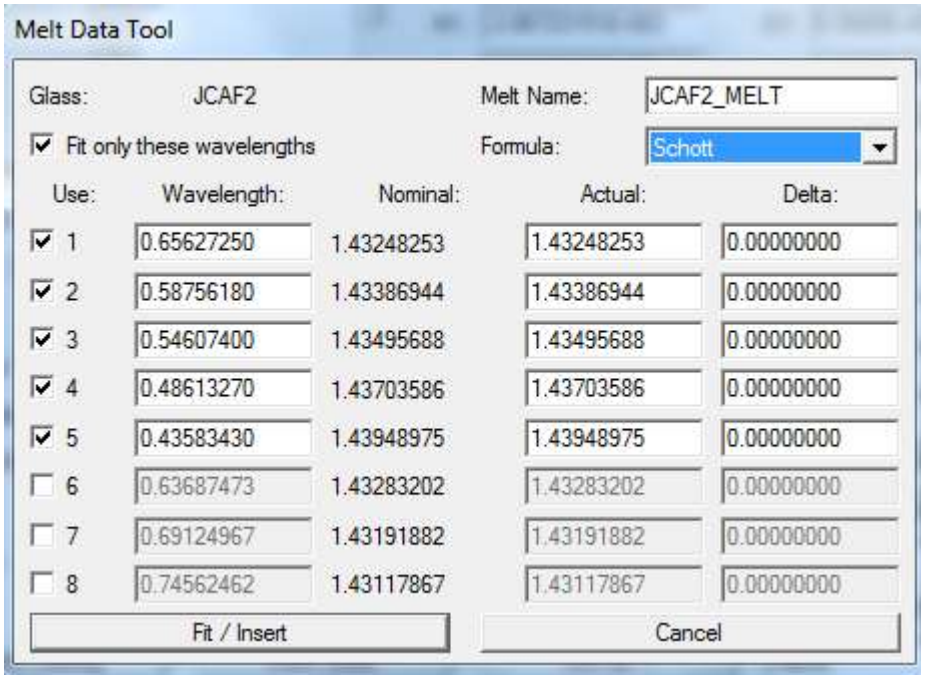
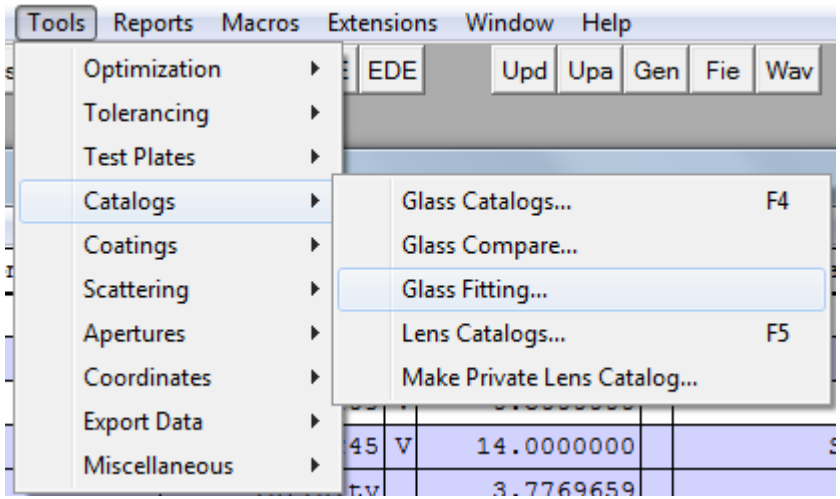
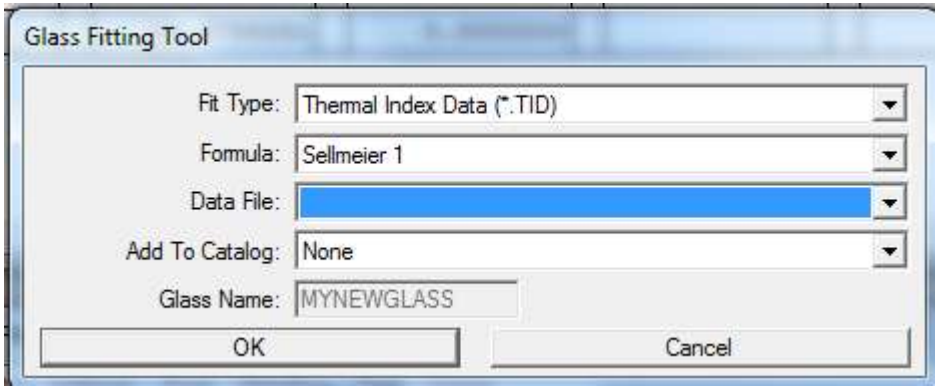
- Melt data:
  - for small differences of real materials
  - no advantage for new materials

- Menue option:
  ‚Glass Fitting Tool‘
  don‘t works (data input?)







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Material Index Fit

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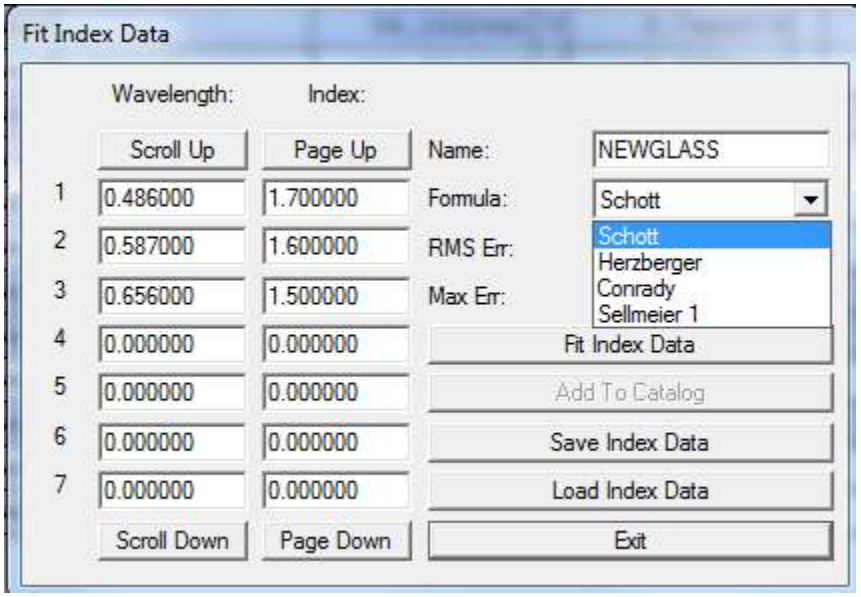
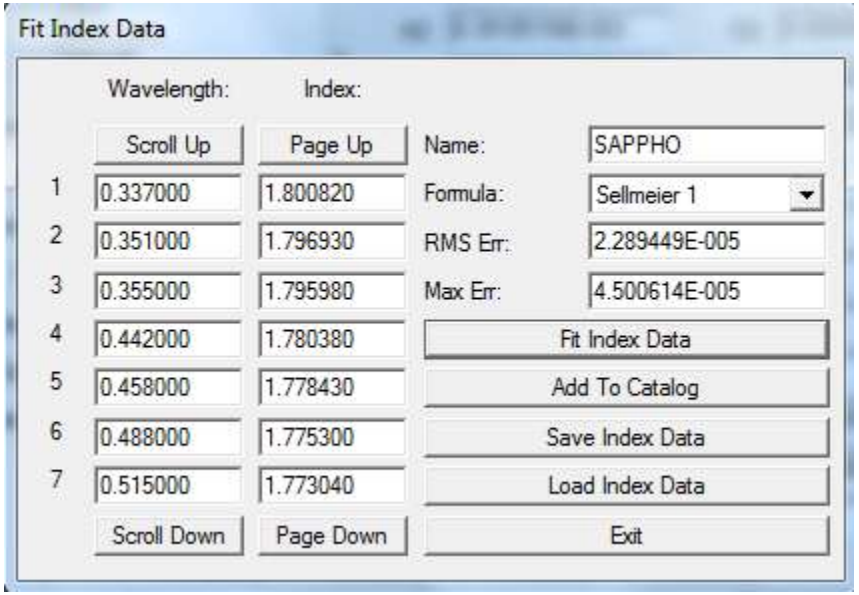
- Menue: Fit Index Data
- Input of data: 2 options:
  1. explicite entering wavelengths and indices
  2. load file xxx.dat with two columns:
     wavelength in μm and index
- Choice of 4 different dispersion formulas
- After fit:
  - pv and rms of approximation visible
  - no individual errors seen
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





7 Advanced handling
Universal Plot

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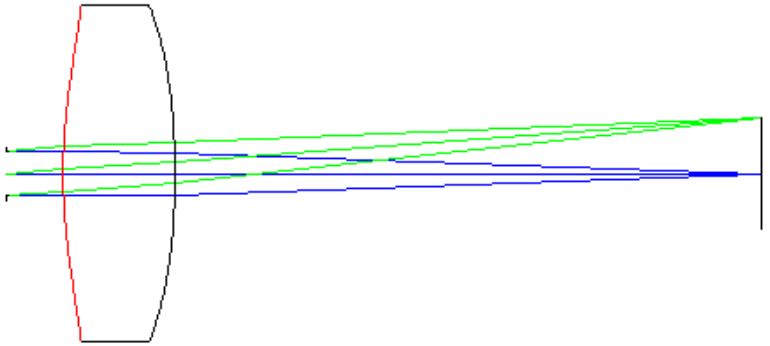
- Possibility to generate individual plots for special properties during changing one or two parameters
- Usually the criteria of the merit function are shown
- Demonstration: aspherical lens, change of Strehl ratio with values of constants
- The sensitivity of the correction can be estimated
- It is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

7 Advanced handling
Universal Plot

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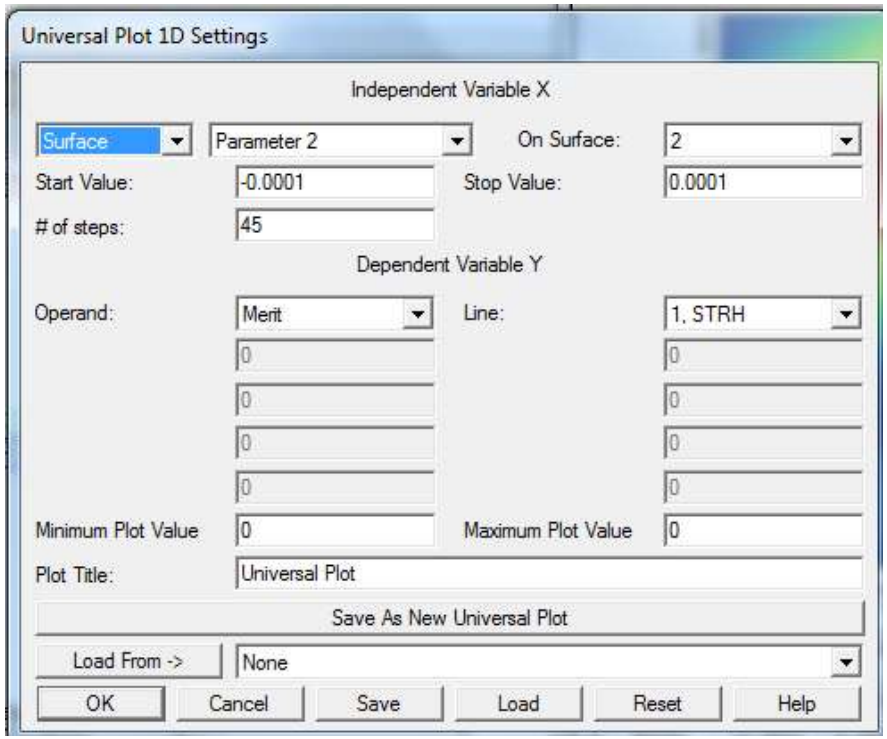
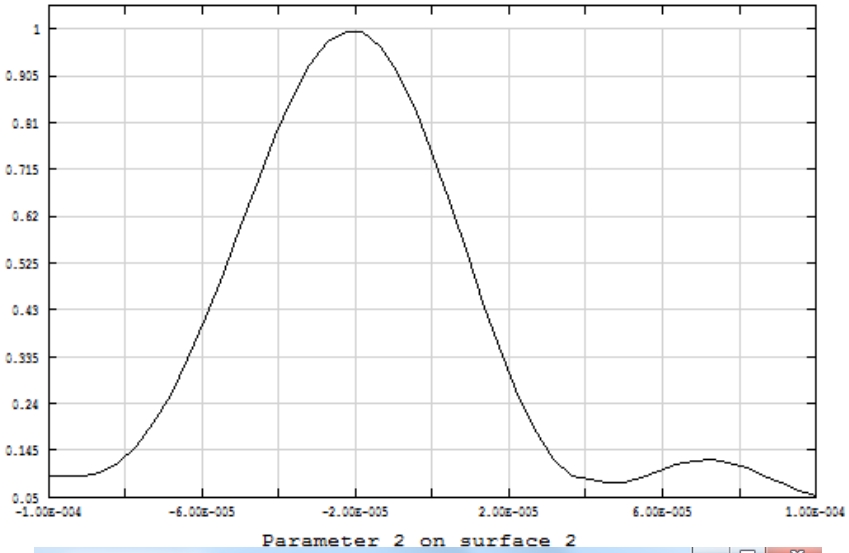
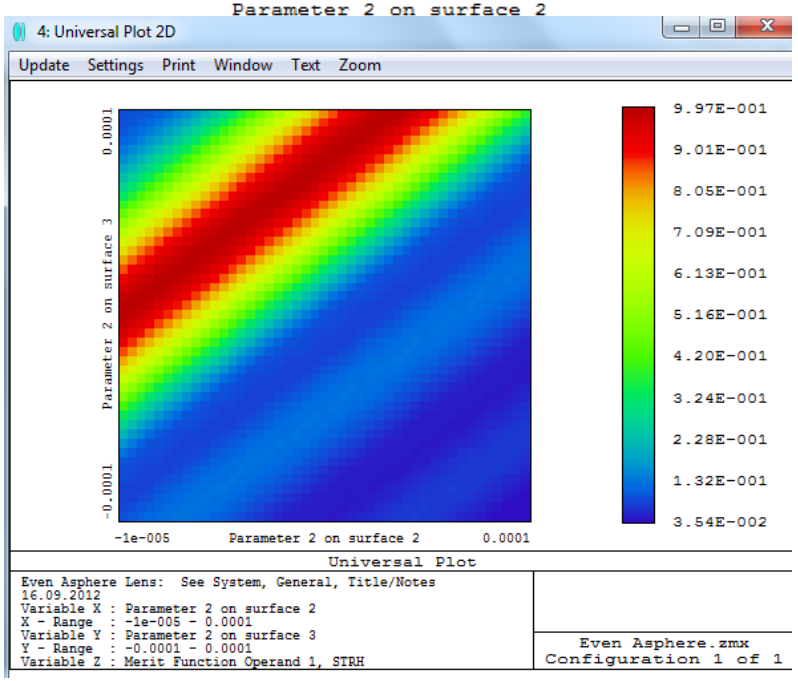
- One-dimensional: change of 4th order coefficient at first surface





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



7 Advanced handling
Slider

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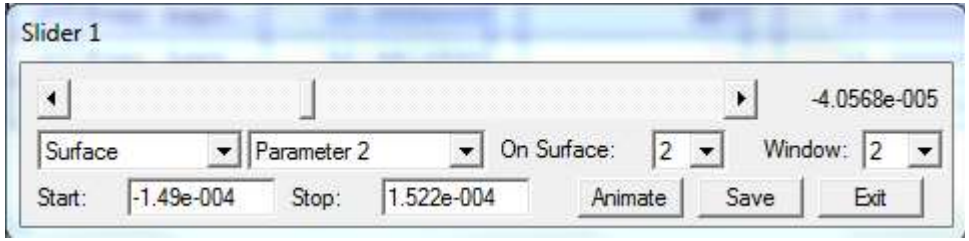
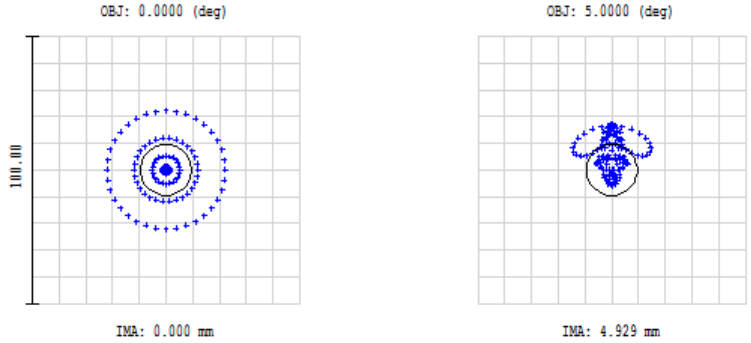
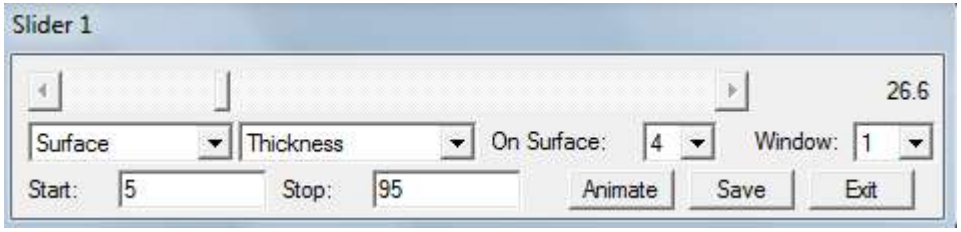
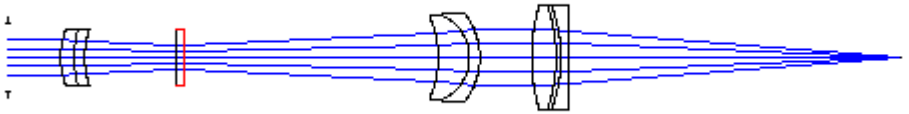
- Slider option in menue: Tools / Miscellaneous / Slider
- Dependence of chosen window output as a function of a varying parameter
- Automatic scan or manual adjustment possible
- Example 1: spot for changing the aspherical constant of 4th order of a lens





- Example 2: Optical compensated zoom system





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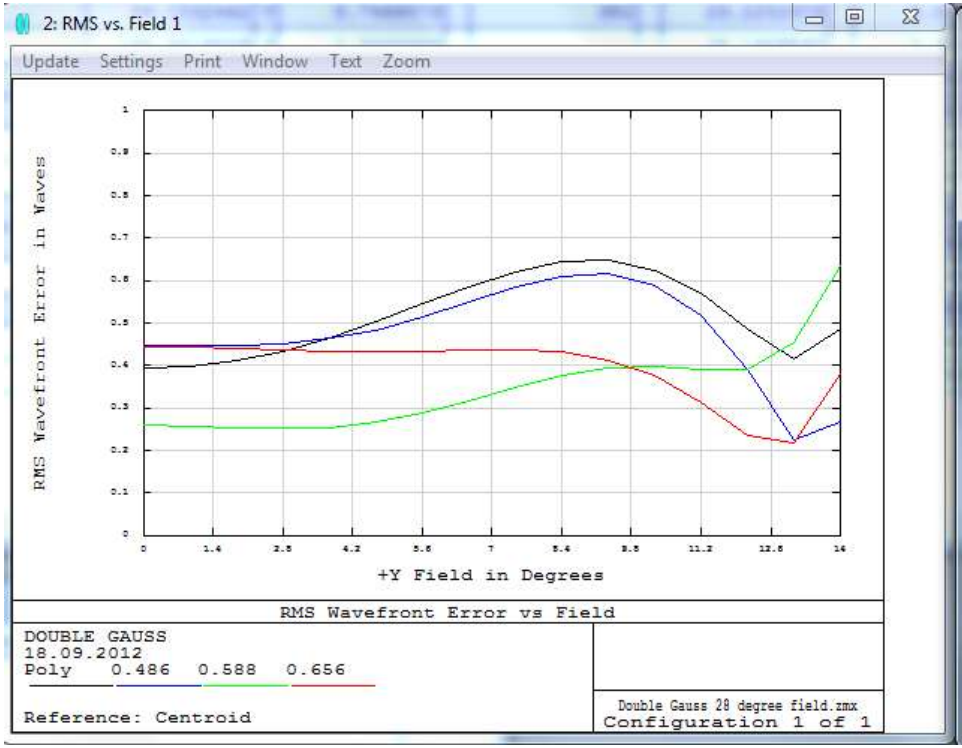
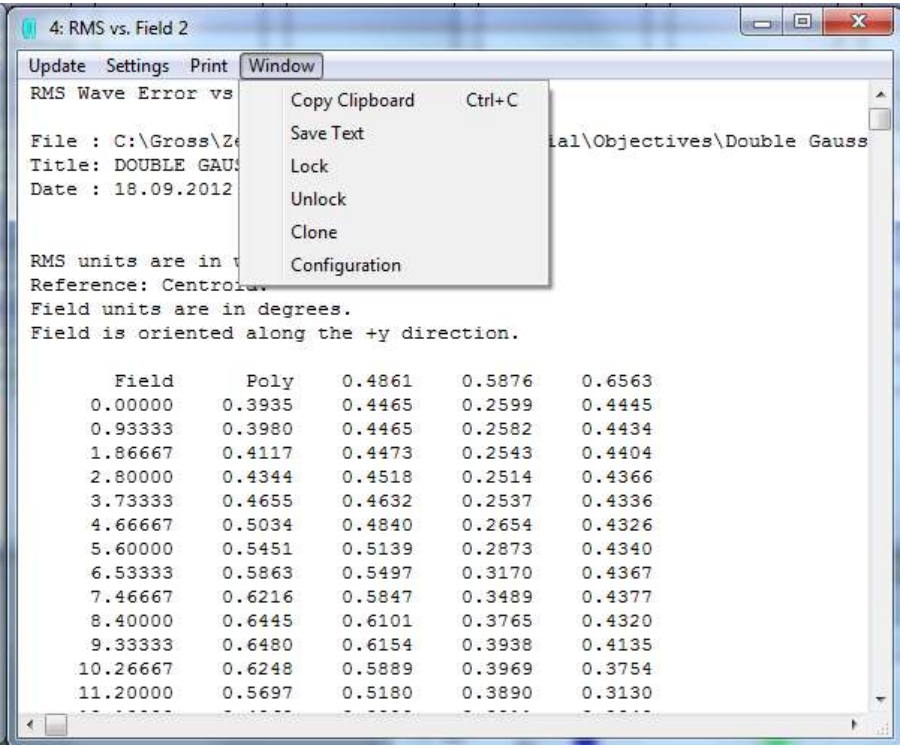
- Output of numerical data of results:
  Text option with save: generation of ASCII file





7 Advanced handling Data IO

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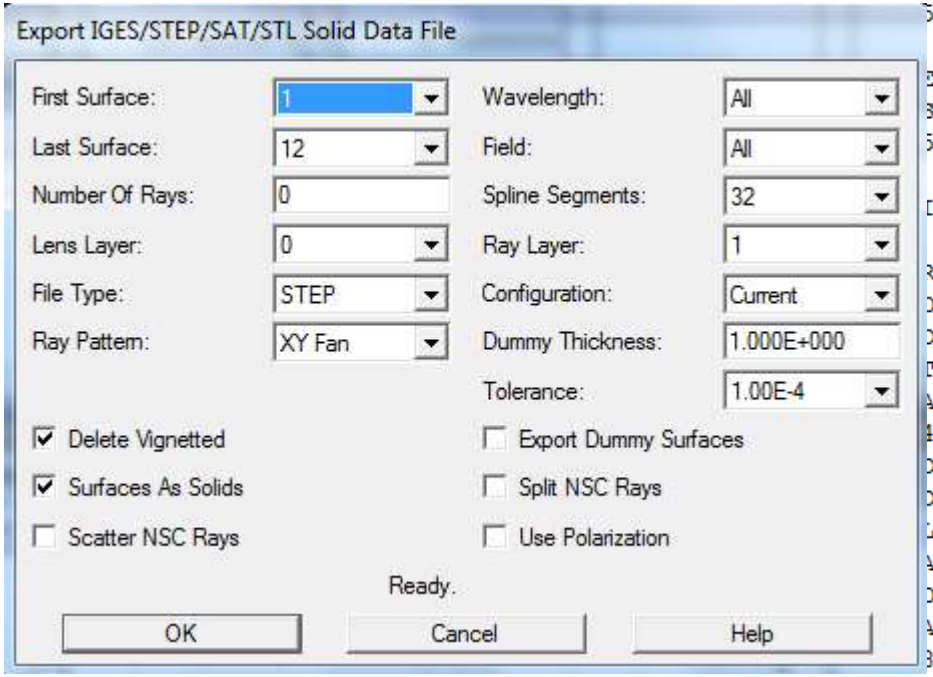
- Export of IGES / STEP files, for CAD data transfer




```
#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,
59), .UNSPECIFIED.)

EPRESENTATION_ITEM ()
SPLINE_CURVE ((1., 0.707106781186548, 1.,
548, 1., 0.707106781186548, 1., 0.707106781186548,

ION_ITEM ('')

RVE ('', #240, #240, #340, .T.);
_EDGE ('', *, *, #350, .T.);
P ('', (#360));
TER_BOUND ('', #370, .T.);
AN_POINT ('', (1.4210854715202E-14, -
4E-14, 161.268578790111));
N ('', (-1., 0., 0.));
N ('', (0., 1., 7.62082612354251E-16));
LACEMENT_3D ('', #390, #400, #410);
AL_SURFACE ('', #420, 152.521920940111);
_FACE ('', (#380), #430, .F.);
AN_POINT ('', (29.225297770111, 0.,
34));
#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,
```

7 Advanced handling
Multi Configuration

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- 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, overlayed

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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

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

- Demonstrational example: Twyman-Green interferometer