Institute of Applied Physics

Friedrich-Schiller-Universität Jena

Lens Design I

Lecture 5: Advanced handling

2024-05-16

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Preliminary Schedule - Lens Design I 2024

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1	04.04.	Basics	Zhang	Introduction, Zemax interface, menues, file handling, preferences, Editors, updates, windows, coordinates, System description, 3D geometry, aperture, field, wavelength
2	18.04.	Properties of optical systems I	Tang	Diameters, stop and pupil, vignetting, layouts, materials, glass catalogs, raytrace, ray fans and sampling, footprints
3	25.04.	Properties of optical systems II	Tang	Types of surfaces, cardinal elements, lens properties, Imaging, magnification, paraxial approximation and modelling, telecentricity, infinity object distance and afocal image, local/global coordinates
4	02.05.	Properties of optical systems III	Tang	Component reversal, system insertion, scaling of systems, aspheres, gratings and diffractive surfaces, gradient media, solves
5	16.05.	Advanced handling I	Tang	Miscellaneous, fold mirror, universal plot, slider, multiconfiguration, lens catalogs
6	23.05.	Aberrations I	Zhang	Representation of geometrical aberrations, spot diagram, transverse aberration diagrams, aberration expansions, primary aberrations
7	30.05.	Aberrations II	Zhang	Wave aberrations, Zernike polynomials, measurement of quality
8	06.06.	Aberrations III	Tang	Point spread function, optical transfer function
9	13.06.	Optimization I	Tang	Principles of nonlinear optimization, optimization in optical design, general process, optimization in Zemax
10	20.06.	Optimization II	Zhang	Initial systems, special issues, sensitivity of variables in optical systems, global optimization methods
11	27.06.	Correction I	Zhang	Symmetry principle, lens bending, correcting spherical aberration, coma, astigmatism, field curvature, chromatical correction
12	04.07.	Correction II	Zhang	Field lenses, stop position influence, retrofocus and telephoto setup, aspheres and higher orders, freeform systems, miscellaneous

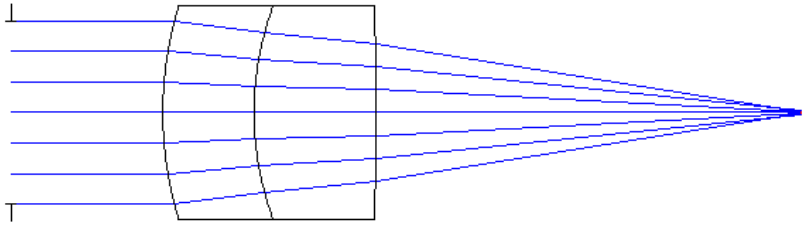
Contents

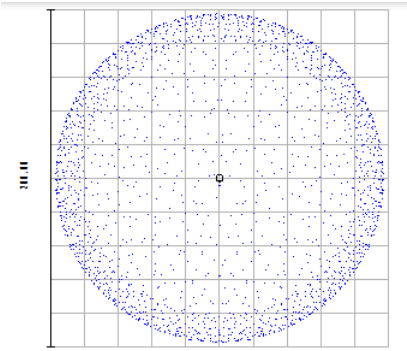
Special Infinity Cases

- Object in infinity
  - **On-axis Field:** incoming marginal ray parallel to axis
  - first distance infinity
  - off-axis field only as angle
  - no initial NA possible
- Image in infinity
  - **On-axis Field:** outgoing marginal ray ideally parallel to axis
  - explicit declaration: ‘afocal image space‘
  - geometrical aberrations as angles
  - wave aberration reference is plane wave
  - definition of Airy diameter in mrad
- Entrance pupil in infinity
  - **All Field:** incoming chief ray parallel to axis
  - explicit declaration: ‘telecentric object space‘
- Exit pupil in infinity
  - **All Field:** outgoing chief ray ideally parallel to axis

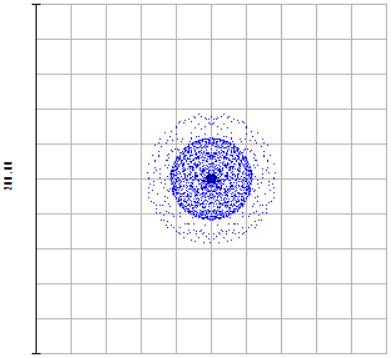
Quick Focus Option

- In the menu OPTIMIZE– QUICK FOCUS we have the opportunity to adjust the image location according to the criteria
  1. Spot diameter
  2. Wavefront rms
  3. Angle radius
- In principle, this option is a simplified optimization
- Example: find the best image plane of a single lens
-





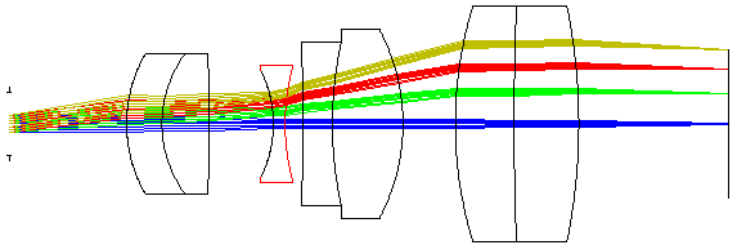
Spot before and after performing the optimal focussing

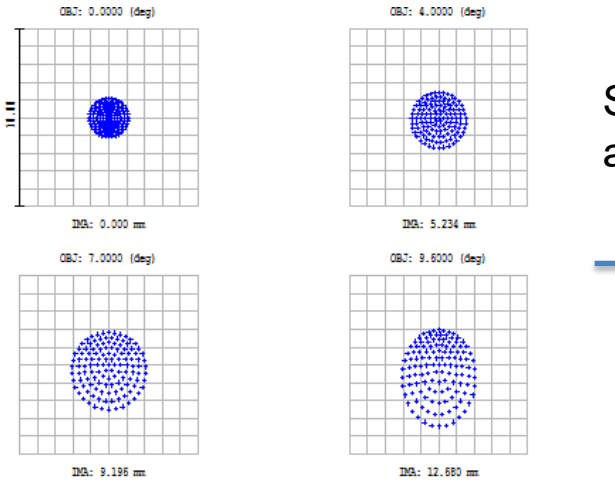


Quick Adjust Option

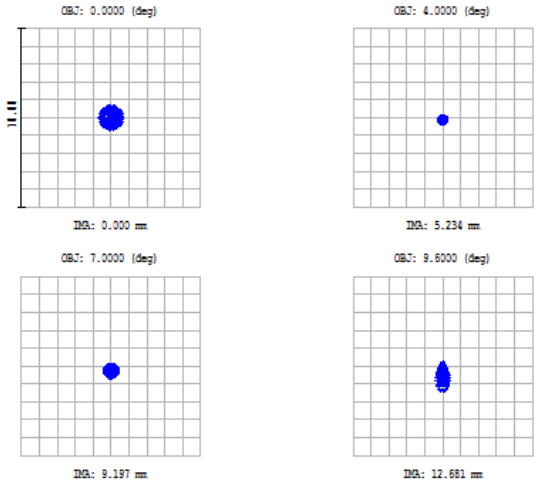
- In the menue OPTIMIZE – QUICK ADJUST we have the opportunity to adjust
  1. one thickness
  2. one radius

  similar to the quick focus function, but not limited for image distance.
  But: the effect is iterative, in case of nonlinearities, some calls are necessary
- As criteria, wavefront, spot diameter or angular radius is possible
- Example: Move a lens in between a system to focus the image



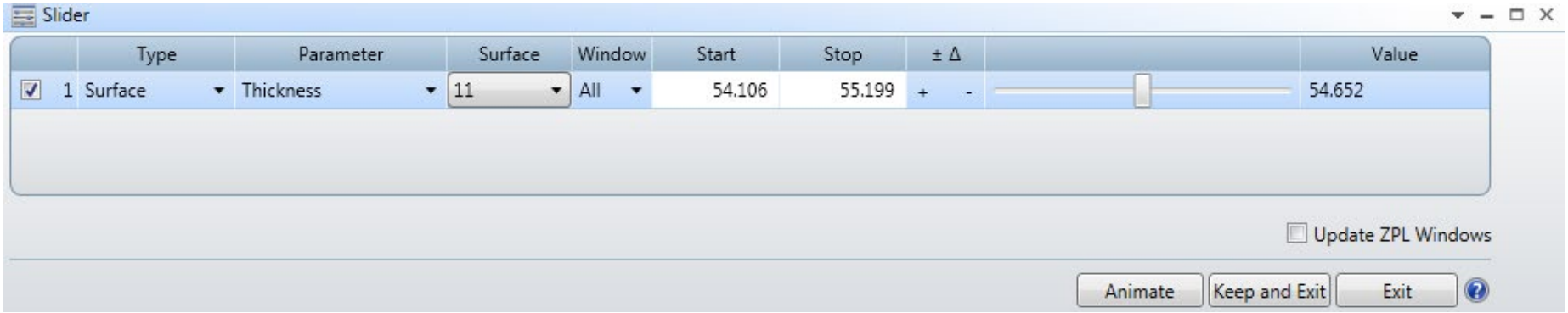


Spots before and after the adjustment



Slider

- Slider option in menu: Optimize - Slider
- Observation of the system depending on a varying parameter
- Automatic scan or manual adjustment possible



Lens Catalogs

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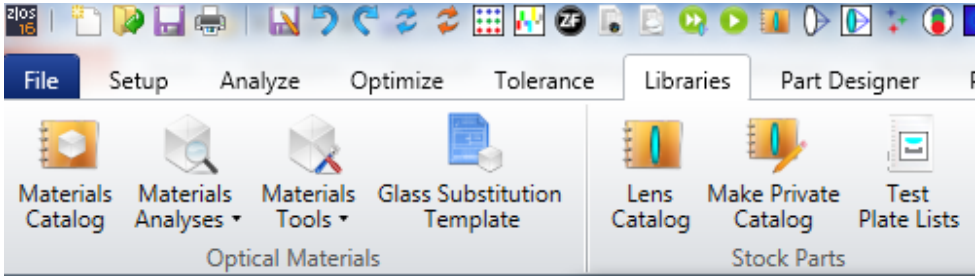
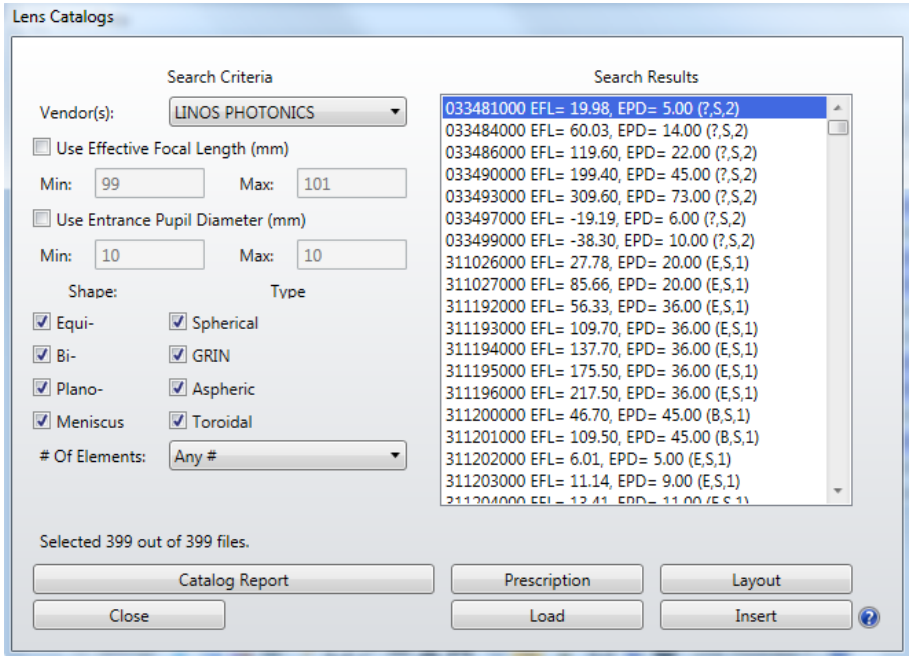
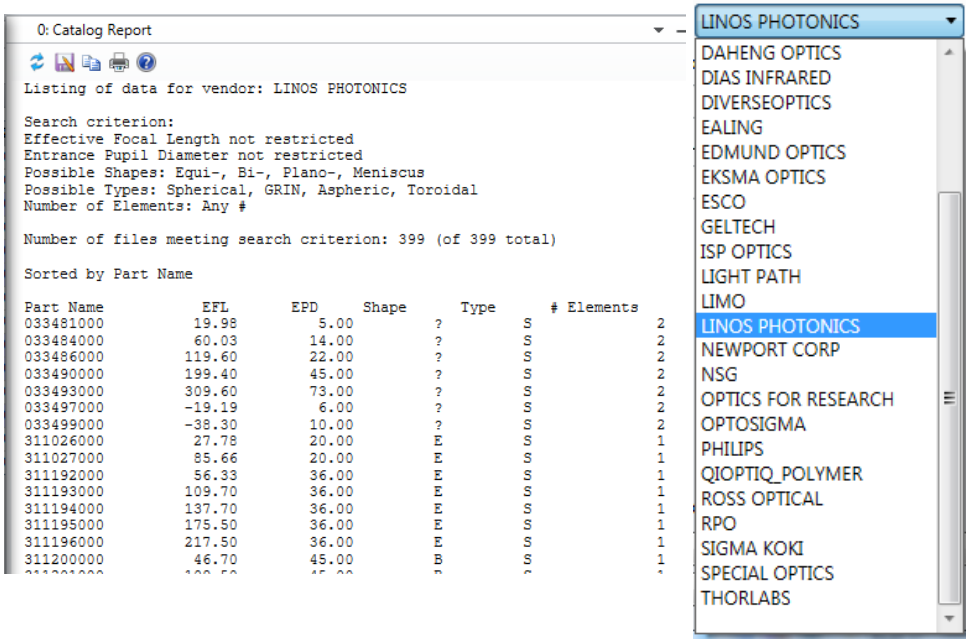
- Lens catalogs:
  Data of commercial lens vendors
- Searching machine for one vendor
- Componenets can be loaded or inserted
- Preview and data prescription possible
- Special code of components in brackets according to search criteria

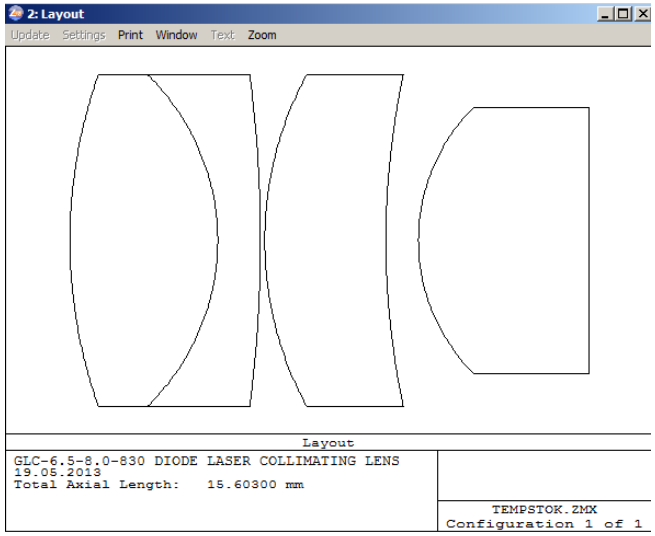






Lens Catalogs

- Some system with more than one lens available
- Sometimes:
  - aspherical constants wrong
  - hidden data with diameters, wavelengths,...
  - problems with old glasses
- Data stored in binary .ZMF format
- Search over all catalogs not possible
- Catalogs changes dynamically with every release
- Private catalog can be generated



6: Prescription Data 3

Settings 3 x 4 Thin

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System/Prescription Data

File : C:\Gross\Zemax\Data collections\Samples Zemax\Sequential\Objectives\TEM
Title: 033481000 Laser-Monochromat  f = 20 / 4.5 mm
Date : 14.03.2017


GENERAL LENS DATA:

Surfaces               :                5
Stop                   :                1
System Aperture        :   Entrance Pupil Diameter =   5
Fast Semi-Diameters    :   On
Field Unpolarized      :   On
Convert thin film phase to ray equivalent : On
J/E Conversion Method  :   X Axis Reference
Glass Catalogs         :   SCHOTT OHARA MISC
Ray Aiming             :   Off
Apodization            :   Uniform, factor =      0.00000E+00
Reference OPD          :   Exit Pupil
Paraxial Rays Setting  :   Ignore Coordinate Breaks
Method to Compute F/#  :   Tracing Rays
Method to Compute Huygens Integral   : Force Spherical
Print Coordinate Breaks :  On
Multi-Threading        :   On
OPD Modulo 2 Pi        :   Off
Temperature (C)        :       2.00000E+01
Pressure (ATM)         :       1.00000E+00
Adjust Index Data To Environment  : Off
Effective Focal Length :          19.98426    (in air at system temperature
Effective Focal Length :          19.98426    (in image space)
```

Universal Plot

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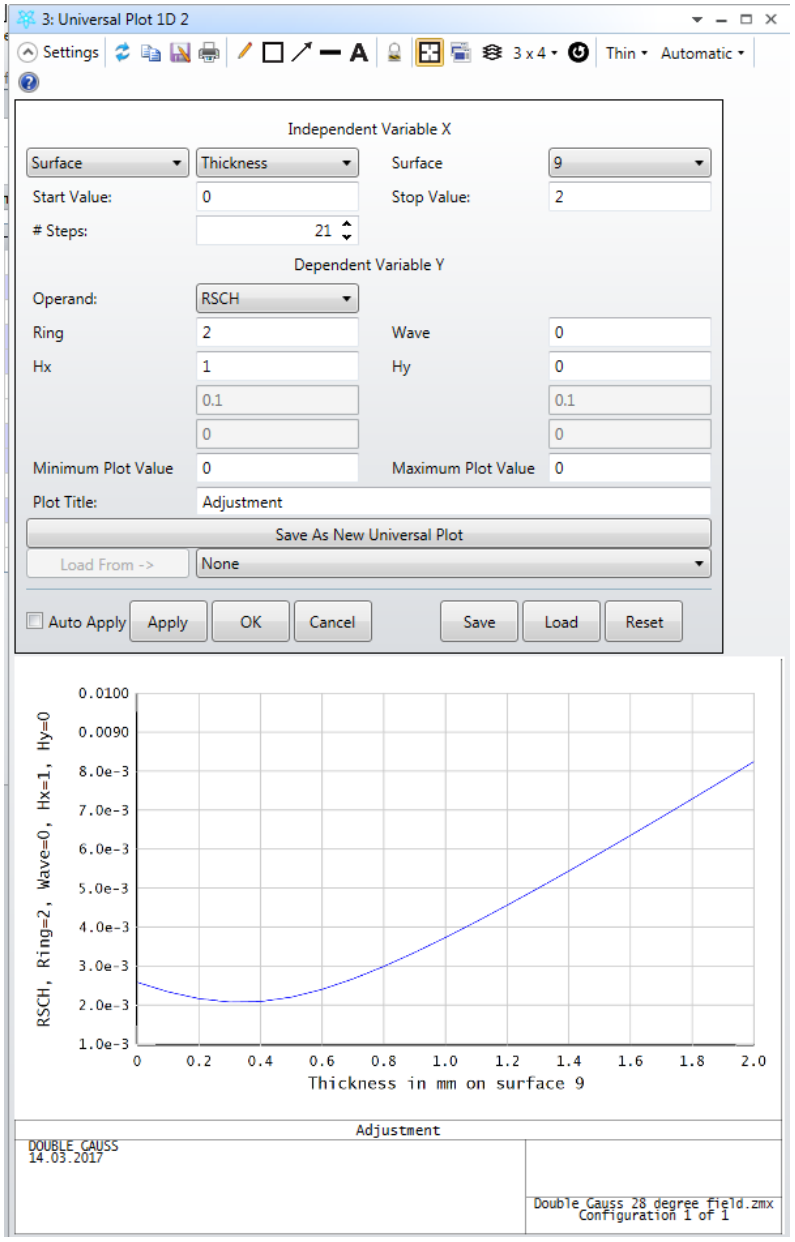
- Possibility to generate individual plots for special properties during changing one or two parameters
- The sensitivity of the correction can be estimated
- One-dimensional:
  spot size by changes of an air thickness
- Universal plot configurations can be saved and called later
- Useful example: spot diameter as a function of a variable: operator RSCH



Universal Plot

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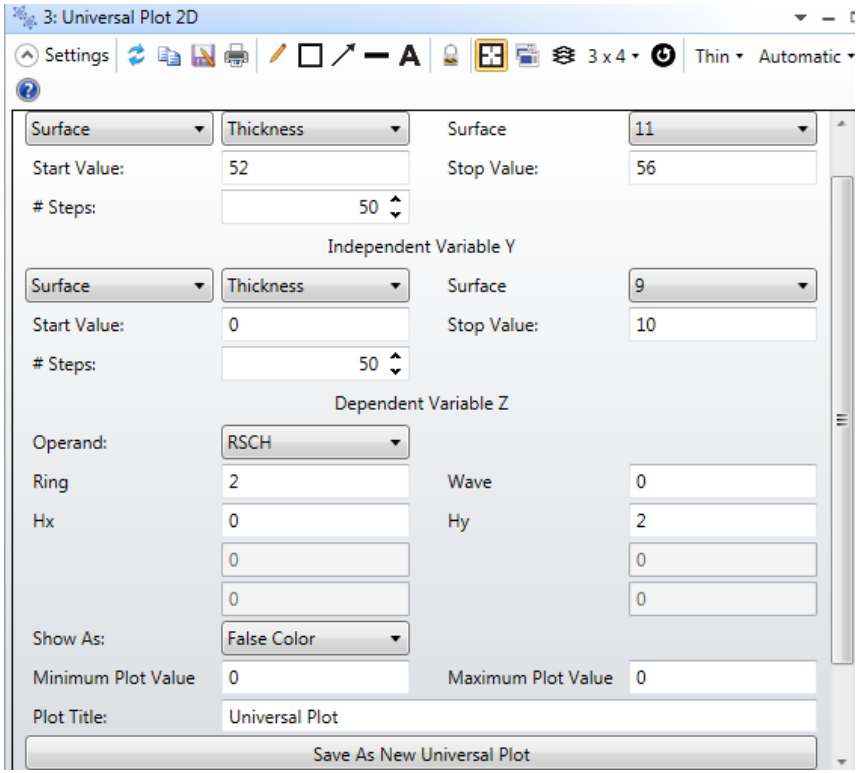
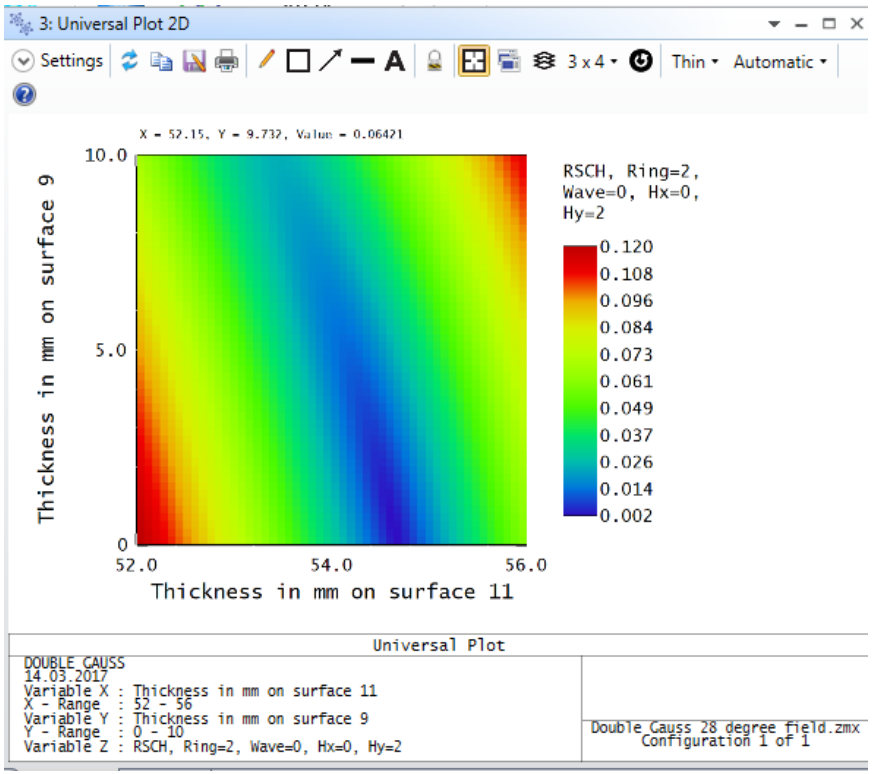
- Two-dimensional case:
  change of one air gap, readjustment of image distance





Exercise 1: Universal plot for 4f-System Telecentricity

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Establish a generalized 4-f-optical system with the achromatic lens LAL 50.0 -20.0 from the catalog of CVI Melles and Griot with focal length f_1 =50 mm as front lens and LAO 200.0 - 50.0 with f_2 = 200 mm as a rear group. The wavelength should be 632 nm and the initial numerical aperture NA = 0.1.

a) What is the numerical aperture in the image space ?

b) If the stop is located in the intermediate focal point, the system is both sided telecentric. If the object sided telecentricity is forced explicitly in Zemax, determine the residual telecentricity error in the image space as a function of the object field height between y = 0 and 4 mm as a universal plot.

c) Generate a two-dimensional universal plot, which shows the spot rms-diameter in the image on axis as a function of the object distance and the image distance. The distances should be varied in a range of 10 mm in the object space and 20 mm in the image space.

d) If the lens groups are turned around, the performance of the image is worse. Compare the two spot diameters of both configurations. What happens to the telecentricity criterion of b) ?

Multi Configuration

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- Multi configuration editor
- Establishment of different system paths or configurations
- 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: show all configuration in the 3D layout drawing simultaneously
  1. shifted, for comparison
  2. with same reference, overlayed

Multi Configuration

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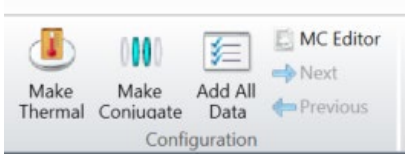
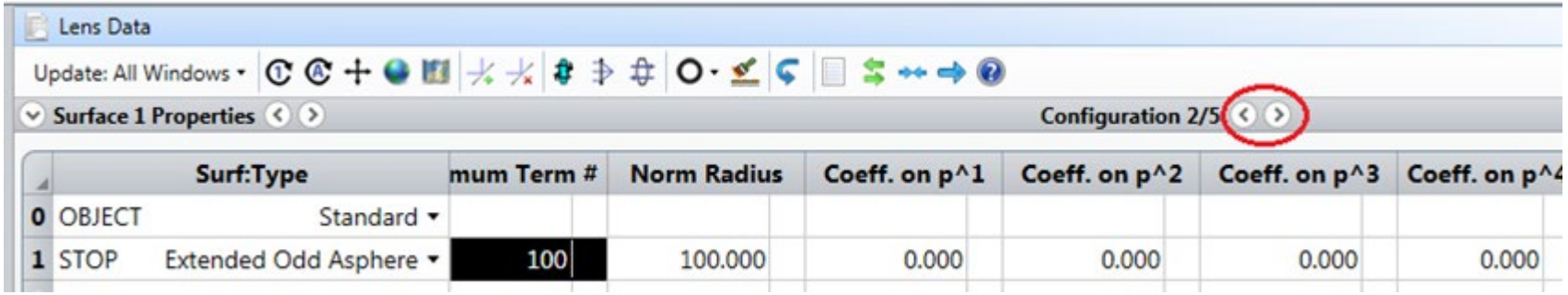
- Multi configuration editor: Setup menu



- Change of configuration

Shortcut: Ctrl+A



Exercise 2: Twyman-Green-Interferometer

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A Twyman-Green interferometer is classically used in the optical shop for measuring optical surfaces. The setup corresponds to a Michelson interferometer and can easily be established as a multiconfiguration.

a) Establish first the test arm of the interferometer above. The beam splitter is made of BK 7 with a length of 20 mm. The auxiliary lens is biconvex with radii of 100 mm made of SF6 with a thickness of 5 mm, the test surface is convex with a radius of 35.88843 mm. The objective lens is made of SF6 with thickness 12 mm and the radii 95.1413 mm and -858.5581 mm. The wavelength is 632.8 nm and the incoming beam diameter 16 mm.

b) Now insert the test arm with the corresponding data before the objective lens. Define a multiconfiguration and mark the corresponding not used surfaces by IGNR (ignore).

c) Establish an interferogram. See the change of the fringes, if the test surface is moved along the axis.