Optical Design with Zemax

Lecture 6: Advanced Handling
2012-11-27
Herbert Gross
<table>
<thead>
<tr>
<th>Week</th>
<th>Date</th>
<th>Topic</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16.10</td>
<td>Introduction</td>
<td>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</td>
</tr>
<tr>
<td>2</td>
<td>23.10</td>
<td>Properties of optical systems I</td>
<td>Diameters, stop and pupil, vignetting, Layouts</td>
</tr>
<tr>
<td>3</td>
<td>30.10</td>
<td>Properties of optical systems II</td>
<td>Materials, Glass catalogs, Raytrace, Ray fans and sampling, Footprints, Types of surfaces, Aspheres</td>
</tr>
<tr>
<td>4</td>
<td>06.11</td>
<td>Properties of optical systems III</td>
<td>Gratings and diffractive surfaces, Gradient media, Cardinal elements, Lens properties, Imaging, magnification, paraxial approximation and modelling</td>
</tr>
<tr>
<td>5</td>
<td>13.11</td>
<td>Aberrations I</td>
<td>Representation of geometrical aberrations, Spot diagram, Transverse aberration diagrams, Aberration expansions, Primary aberrations,</td>
</tr>
<tr>
<td>6</td>
<td>20.11</td>
<td>Aberrations II</td>
<td>Wave aberrations, Zernike polynomials, Point spread function, Optical transfer function</td>
</tr>
<tr>
<td>7</td>
<td>27.11</td>
<td>Advanced handling</td>
<td>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</td>
</tr>
<tr>
<td>8</td>
<td>04.12</td>
<td>Optimization I</td>
<td>Principles of nonlinear optimization, Optimization in optical design, Global optimization methods, Solves and pickups, variables, Sensitivity of variables in optical systems</td>
</tr>
<tr>
<td>9</td>
<td>11.12</td>
<td>Optimization II</td>
<td>Systematic methods and optimization process, Starting points, Optimization in Zemax</td>
</tr>
<tr>
<td>10</td>
<td>18.12</td>
<td>Imaging</td>
<td>Fundamentals of Fourier optics, Physical optical image formation, Imaging in Zemax</td>
</tr>
<tr>
<td>11</td>
<td>08.01</td>
<td>Illumination</td>
<td>Introduction in illumination, Simple photometry of optical systems, Non-sequential raytrace, Illumination in Zemax</td>
</tr>
<tr>
<td>12</td>
<td>15.01</td>
<td>Correction I</td>
<td>Symmetry principle, Lens bending, Correcting spherical aberration, Coma, stop position, Astigmatism, Field flattening, Chromatical correction, Retrofocus and telephoto setup, Design method</td>
</tr>
<tr>
<td>13</td>
<td>22.01</td>
<td>Correction II</td>
<td>Field lenses, Stop position influence, Aspheres and higher orders, Principles of glass selection, Sensitivity of a system correction, Microscopic objective lens, Zoom system</td>
</tr>
<tr>
<td>14</td>
<td>29.01</td>
<td>Physical optical modelling I</td>
<td>Gaussian beams, POP propagation, polarization raytrace, polarization transmission, polarization aberrations</td>
</tr>
<tr>
<td>15</td>
<td>05.02</td>
<td>Physical optical modelling II</td>
<td>coatings, representations, transmission and phase effects, ghost imaging, general straylight with BRDF</td>
</tr>
</tbody>
</table>
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

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 expoding/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 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
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
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
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.
7 Advanced handling
Diameters in Zemax

- In the Tools-menu, 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
- Melt data:
  - for small differences of real materials
  - no advantage for new materials

- Menue option:
  'Glass Fitting Tool'
  don't works (data input?)
7 Advanced handling
Material Index Fit

- Menu: Fit Index Data
- Input of data: 2 options:
  1. explicit 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
- 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

<table>
<thead>
<tr>
<th>Surf:Type</th>
<th>Thickness</th>
<th>Glass</th>
<th>Semi-Diameter</th>
<th>2nd Order Term</th>
<th>4th Order Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBJ</td>
<td>Standard</td>
<td>Infinity</td>
<td>Infinity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STO</td>
<td>Standard</td>
<td>5.0000000</td>
<td>2.0000000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2* Even Asph..</td>
<td>10.0000000</td>
<td>BK7</td>
<td>15.0000000 U</td>
<td>0.0000000</td>
<td>-1.507E-005</td>
</tr>
<tr>
<td>3* Even Asph..</td>
<td>52.4612830</td>
<td></td>
<td>15.0000000 U</td>
<td>0.0000000</td>
<td>-1.269E-005</td>
</tr>
<tr>
<td>IMA</td>
<td>Standard</td>
<td>-</td>
<td>4.9563392</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7 Advanced handling
Universal Plot

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

- 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
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: show all configuration in the 3D layout drawing simultaneously
1. shifted, for comparison
2. with same reference, overlayed
7 Advanced handling
Multi Configuration

- Demonstrational example: Twyman-Green interferometer