Optical Design with Zemax

Lecture 6: Advanced Handling
2012-09-25
Herbert Gross

Summer term 2012
<table>
<thead>
<tr>
<th>Week</th>
<th>Date</th>
<th>Topic</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>1</td>
<td>17.07</td>
<td>Introduction</td>
<td>Zemax interface, menus, file handling, system description, editors,</td>
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<td>preferences, updates, system reports, coordinate systems, aperture,</td>
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<td>field, wavelength, glass catalogs, layouts, raytrace, diameters, stop</td>
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<td>and pupil, pick ups, solves, variables, ray fans, quick focus, 3D</td>
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<td>geometry, ideal lenses, vignetting, footprints, system insertion,</td>
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<td>scaling, component reversal</td>
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<td>Properties of optical systems</td>
<td>aspheres, gradient media, gratings and diffractive surfaces, special</td>
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<td>types of surfaces, telecentricity, ray aiming, afocal systems, Delano</td>
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<td>diagram, lens catalogs</td>
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<td>Aberrations</td>
<td>representations, spot, Seidel, transverse aberration curves, Zernike</td>
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<td>4</td>
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<td>Optimization</td>
<td>algorithms, merit function, methodology, correction process, first</td>
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<td>Imaging and illumination</td>
<td>Fourier imaging, geometrical images, non-sequential option</td>
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<td>Advanced handling</td>
<td>slider, universal plot, I/O of data, material index fit, multi</td>
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<td>configuration, macro language, link of DLLs, MDD Matlab coupling</td>
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<td>Correction I</td>
<td>simple systems</td>
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<td>systems with medium complexity</td>
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<td>Correction II</td>
<td>layout and correction of a microscopic objective lens, design and</td>
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<td>correction of a zoom system</td>
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<td>Physical optical modelling I</td>
<td>Gaussian beams, POP propagation</td>
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<td>polarization raytrace, transmission, aberrations</td>
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<td>10</td>
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<td>Physical optical modelling II</td>
<td>coatings, representations, transmission and phase effects</td>
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<td>Ghost imaging, general straylight with BRDF</td>
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</table>
6 Advanced handling

Contents

1. Telecentricity, infinity object distance and afocal image
2. Local/global coordinates
3. Add fold mirror
4. Scale system
5. Make double pass
6. Vignetting
7. Diameter types
8. Material index fit
9. Report graphics
10. Universal plot
11. Slider
12. Visual optimization
13. IO of data
14. Multiconfiguration
15. Fiber coupling
16. Macro language
17. DLL link
18. MDD coupling with Matlab
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
6 Advanced handling
Vignetting

- 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
6 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
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.

### Field Data Table

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<th>Y-Field</th>
<th>Weight</th>
<th>VDX</th>
<th>VDY</th>
<th>VCX</th>
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**Set Vig**
In the Tools-menu, the diameters and apertures can be converted automatically.
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

Menu option:
'Glass Fitting Tool' doesn't work (data input?)
6 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 $\mu$m 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
Compact window with 4 or 6 output options can be summarized and defined individually.
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
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Universal Plot

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

- Two-dimensional case: dependence on the coefficients on both sides
6 Advanced handling
Slider

- 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
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Visual optimization

- Menu Tools / Design / Visual optimization
- Change of variable quantities by slider and instantaneous change of all windows
- 'Optimization' under visual control of the consequences
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Data IO

- Output of numerical data of results:
  Text option with save: generation of ASCII file
6 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: showallconfiguration in the 3D layout drawing simultaneously
1. shifted, for comparison
2. with same reference, overlayed
6 Advanced handling
Multi Configuration

- Demonstrational example: Twyman-Green interferometer
1. Geometrical with raytrace:
   image of circular object
   only geometrical truncation on the diameter is considered

2. Geometrical with raytrace:
   footprint
   only geometrical truncation on the diameter is considered

3. Monomode fiber:
   special menue entry:
   Calculations / Fiber Coupling Efficiency
   Transmission, apodization, vignetting
   are taken into account
   Angle and spatial acceptance is
   considered simultaneously
   Huygens integral PSF is calculated

4. With physical optical propagation code
   Most general tool
6 Advanced handling
Fiber Coupling

- Monomode fiber coupling example
Fiber coupling with POP example
There is a macro language for Zemax to allow for individual problem solving

Some provided example files are distributed

Editing and running can be done from Zemax interface

Necessary: xxx.ZMX-file

Debugging of macro-language errors is cumbersome

Not all of the output data is provided by the commands

Coding of parameters is in many cases a bit tricky

Graphical options rather limited

Possibilities:
1. special and individual analysis
2. change of system data and case studies
3. optimization
4. print export of data
6 Advanced handling
Macro Language

- Code Example:
  Incidence angles at all surfaces for 3 field positions

- Online output
User defined surfaces are possible
A routine written in C or C++ must be provided as DLL
By linking the DLL, the raytrace can be performed through user defined surfaces
Debugging of wrong DLL’s is cumbersome, there is limited support from the hotline
Runtime is quite fast
Best way to establish a DLL due to the specific interface: modify a provided C-source-routine
6 Advanced handling
Matlab Coupling with MZDDE

- Calling Zemax as Raytrace-engine from Matlab
- Freeware MZDDE (Mathworks File Exchange) allows coupling of Matlab with Zemax
- Zemax DDE server toolbox
- Zemax must be opened
- Debugging is complicated
- Problems with timeout, refreshing and updating of data, especially under 64 bit windows

```matlab
% Direct called subroutines:

(ierr = 0 ; vig = ones(npy, npx, 1); cz = zeros(nzern, 1);
focL = 0; NA = 0; distP = zeros(21,1);
auto = 0;

% Initializing Zemax system data
chan = zDDEInit;
Status = zLoadFile(fname);
Timeout = 5; UpdateFlag = 1;
Status = zPushLens(Timeout, UpdateFlag);

% set desired wavelength for wavenumber 1
WaveNumber = 1; % check old wavelength
WaveData = zGetWave(WaveNumber); wvlold = WaveData;
WaveData = zSetWave(WaveNumber, w1*1000, 1);
Status = zPushLens(Timeout, UpdateFlag);

% set of desired chief ray coordinates
FieldInfo = zGetField(0);
FieldData = zSetField(1, xi, yi, 1, 0, 0, 0, 0, 0);
Status = zPushLens(Timeout, UpdateFlag);
pause(0.2);
zGetRefresh;

% number of surfaces
SystemData = zGetSystem;
nsurf = SystemData(1);
```
Collection of Matlab-routines zset, zget,...
Well documented library of routines

- Close DDE communications channel to ZENAX.
- Open communications channel to ZENAX DDE server.
- Attempts ADDENit. If no ZENAX running, attempt to s:
- Delete a lens surface.
- Export lens CAD data (IGES, STEP, SAT) to a file.
- Check if lens CAD export has completed.
- Find integer label attached to a lens surface using
- Set lens surface data to 'fixed' mode.
- Set all lens surface data to 'fixed' mode.
- Get address line in Preferences/Address.
- Get the aspect ratio of ZENAX graphics or print window.
- Get DDE client specific data from a ZENAX window.
- Get a list of available coatings from the ZENAX COx
- Get current lens configuration, number of configurations
- Get current date from ZENAX DDE server.
- Get single extra data value from ZENAX DDE server.
- Get data on lens field points.
- Get the filename of the currently loaded lens.
- Get first order data about the lens.
- Get data on a glass at a particular lens surface.
- Get a list of available text glass catalogues from
- Get transformation matrix from local surface coordinates
- Get index of refraction data at a lens surface.
- Retrieve integer label associated with a surface.
- Create Windows Metafile of a ZENAX graphic analysis
- As for zGetMetaFile, but with Save As dialog box.
- Get data from the ZENAX multi-configuration editor.
- Get MTF computation from ZENAX for current lens. Re
- Get the name of the lens in ZENAX.
- Get number of NSC objects.
- Get data describing NSC objects in ZENAX.
- Get position data for an NSC object in ZENAX.
- Get numeric parameters associated with an NSC object
- Get ZENAX settings affecting raytracing in non-sequench...