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Release Notes of VirtualLab 4 and 5

Technical Note No. 003 (TN.003)

1 Version 5.1.2

General Information:

- Release Date: January 2012.
- Update Service: 4th quarter 2011 is required.
- Installation: VirtualLab 5.0 (basic installation) or 5.0.3, 5.1, 5.1.1 (update) required.

VirtualLab 5.1.2 resolves some GUI problems for detectors and interfaces.

2 Version 5.1.1

General Information:

- Release Date: January 2012.
- Update Service: 4th quarter 2011 is required.
- Installation: VirtualLab 5.0 (basic installation) or 5.0.3, 5.1 (update) required.

VirtualLab 5.1.1 resolves some GUI problems which occured on Windows XP and Japanese systems. Further version 5.1.1 provides the following new features and enhancements.

- Simulation of Gratings
  - The Geometrical Optics Propagation is now available also for 3D gratings.
  - Similar to other sources, the Ideal Plane Wave has a the new parameter Weight now.
- Detectors, Views and Data Arrays
  - Both detectors, for the Magnetic Field and for the Poynting Vector use now Data Arrays and their views with extended options.
- New and Updated Tutorials and Application Scenarios
  - Tutorial G.001a: Near Field and Efficiency Analysis of a Sinusoidal Grating (update). This tutorial demonstrates the basic investigation of the near field and the diffraction efficiencies of the orders created by a sinusoidal grating.
  - Module MOD.015: Periodic Replicate of Data Arrays (new). This module replicates a one- or two-dimensional, equidistantly sampled data array periodically. Therefor the user has to specify an integer replication factor for both x- and y-direction.

  - Snippet SN.019 Hexagonal Lens Array (new). This snippet defines a lens array on a hexagonal grid. Each lens is a conical interface.

3 Version 5.1

General Information:

- Release Date: December 2011.
- Update Service: 4th quarter 2011 is required.
- Installation: VirtualLab 5.0 (basic installation) or 5.0.3 (update) required.

VirtualLab 5.1 provides the following new features and enhancements. New and updated tutorials and application scenarios are listed in the last section.

- Simulation and Optimization of Gratings
  - New modes for defining rotation of grating components have been added: Spherical Angles, Direction Angles, Cartesian Angles, Euler Angles and Sequence of Axis Rotation are supported.
  - The handling of TE and TM in the Grating Toolbox has been improved. It is now possible to show the Rayleigh coefficients in TE- and TM-direction via the Grating Efficiency Analyzer.
  - The Grating Efficiency Analyzer 3D is now available for parametric optimization. Further, it filters evanescent waves and inserts the resulting data arrays to the parameter run (as the grating efficiency analyzer 2D).
  - Both the General Grating 2D and the General Grating 3D have now two tools (Swap Stacks, Use First Stack Only) which simplify the configuration of the stacks.
  - More information is shown about the transition point decomposition of grating components.
  - The Grating Session Editors have been replaced by menu items that result directly in a light path diagram with the corresponding stack in the grating component. Further the old specific grating components have been removed.
  - Analyzers can be added at any time to light path diagrams for the analysis of gratings.
  - The default number of evanescent orders for the FMM has been increased to 50. Thus, new grating light path diagrams do their simulations a little bit slower but more accurate.
  - The Field Inside Grating Analyzer as well as the combined output for 1D fields in the parameter run now use data arrays as output format and thus show all vectorial components in a single document.

- Ray Tracing
  - The Ray Tracing mode has been introduced for light path diagrams in the Starter Toolbox. This mode gives a first insight about the behavior of systems. The mode is available for systems with one detector only. Further, the impact of ideal components on the rays is restricted to their aperture. Further effects are ignored.
  - In the light path diagram, the sources allow to define rays (tabpage Ray Selection) for the ray tracing mode.
  - The result of ray tracing can be viewed in a new 3D view. Also dot diagrams are available at all interfaces that are present in the system.
- Catalogs and Components
  - Light Sources Catalogs and Components Catalogs have been introduced and can be used now for storing such light path elements.
  - The dialog for the definition of the Propagation of components has been changed. For all components a matrix-like definition is used now. The propagation of two interfaces of the Double Interface Component can be defined individually now (in version 5.0 the two propagation steps were synchronized always). For a simpler usage, the tool Synchronize Interface Propagation Parameters has been introduced.
- Parameter Run
  - The result table in the Parameter Run can now display physical values without units. This simplifies the export (e.g. via copy to clipboard) of the extire result table of indivdual values for external analysis.
  - The performance for large result tables has been improved.
- Optical Interfaces and Media
  - The definition of media is supported now by Periodization and Scaling (similar to optical interfaces).
  - The Transition Point List interface now offers a tool which simplifies its periodization.
  - The Rectangular Grating interface now supports to define either the slit width or the relative slit width.
  - The edit dialog of interfaces (especially for sampled interface) can be opened much faster now. Further the reliability has been improved.
- Views and Data Arrays
  - A new 3D View of entire systems is available for light path diagrams now. The 3D view support different display modes now.

  - The 2D view of the Ray Tracing Analyzer has been improved: axis of the coordinate system are displayed now.
  - A new diagram view has been introduced in the media view, the transition point view, for the parameter run 1D combined output and for the field inside grating analyzer output. The view is based on using data arrays and supports more options.
  - Linkages which are "Off" are now viewed with dashed line within the Light Path View.
  - New view for the Chromatic Fields Set in 1D mode. The view is integrated within the source catalog.
  - The Export for Data Arrays is available now.

- Handling

  - VirtualLab initializes all components once at startup time. This impoves the handling of dialogs during later usage.
  - Several parameters have been added to the Global Options in order to set default values:
    * Default Color Lookup Table for the view of data arrays.
    * Default Free Space Propagation Method for Linkages to be used in new light path diagrams. The Automatic Propagation Operator is used as default value after installation.
    * The Global Font to be used by VirtualLab can be selected (size and type). The default font is selected automatically and is adapted to Windows settings.So, VirtualLab adapts better to different dpi scaling of Windows now.
  - The availability of the Tools, view and save buttons has been unified in VirtualLab. Examples are the dialogs of the light path diagram, of components and of interfaces.
  - Now VL detects equidistantly sampled data that were read from file automatically.
  - The tooltips in the session editors of the Diffractive Optics Toolbox have been replaced by entries in the VirtualLab online help which makes them easier readable.
  - The default materials in the Fresnel Effects Calculator have been changed. Now both the Fresnel Effects Calculator and the Diffraction Angle Calculator use Fused Silica as substrate and Standard Air as superstrate. Further default values for the Diffraction Angle Calculator have been changed.
  - The Programming Reference contains the documentation of data arrays now.
  - The Trial Version can now be used 50 times (instead of 30 before).

- New and Updated Tutorials and Application Scenarios

- Tutorial 337.01: Introduction to the Data Array Import Wizard (new). This tutorial gives an introduction to the import wizard for data arrays. An overview about the possibilities of the import wizard is given.
- Module MOD.012: Power Evaluation on Grid Cells (new). The module is applied to a 2D harmonic field. The harmonic field is covered by an array of cells with a user-defined size. The power of the harmonic field is computed for all cells and the values are shown as data array.
- Module MOD.010: Convert Spectral Harmonic Field to DataArray in Cartesian Angles (new). This module converts a harmonic field given in spectral domain to a Data Array in Cartesian angles.
- Module MOD.009: Calculate Far Field from Angular Radiant Intensity (new). It is convenient to set the modulation of the angular distribution in the far field source by data that have been calculated from radiant intensity measurements. The "Databased Input" for this source is calculated by this module.
- Module MOD.013: Convert GCA to Transmission (new). The module can be used to extract the information of a grating cells array (GCA) and convert it to a transmission function. This transmission function can be used for further investigations and additional export formats of the GCA.

4 Version 5.0.3

General Information:

- Release Date: September 2011.
- Update Service: 2nd quarter 2011 is required.
- Installation: VirtualLab 5.0.0 (basic installation) required.

  VirtualLab 5.0.3 is a service release without additional features.

5 Version 5.0.0

General Information:

- Release Date: June 2011.
- Update Service: 2nd quarter 2011 is required.
- Installation: VirtualLab 5.0 is a complete installation. It is not necessary to uninstall version 4.x.

VirtualLab 5.0 provides the following new features and enhancements. New and updated tutorials and application scenarios are listed in the last section.

- Lighting Toolbox: Shaping and homogenization of LED light.
  - The Lighting Toolbox provides field tracing for the analysis and design of illumination systems. Field tracing enables the usage of new concepts with emphasis on the integration of microstructures and diffractive optics. That gives more flexibility for the design of compact illumination systems for the homogenization and shaping of LED light as well as light of other sources with highly divergent radiation.
  - The light shaping concept is based on a Grating Cells Array. The array is defined by means of a boundary operator. Each cell of the array deflects the light into predefined directions and results in a light spot in the target plane. The light spots of all array cells together form the desired light pattern.
  - A design algorithm is provided for the design of Grating Cells Arrays. Period and rotation angle of all grating cells are determined so that the first order of the grating cell diffracts the incoming light into the outgoing direction such that a desired light pattern is generated.
  - The data of Grating Cells Arrays can be exported in csv-format and as GDSII-format describing fabrication data in case of discrete height levels.
  - The Local Linear Grating Approximation (LLGA) analyzer extracts all grating parameters present in the Grating Cells Array of a Lighting Toolbox Light Path Diagram and formats them so that they can be used as input for the LLGA Results Generator (see below).
  - A Ray Tracing simulation is provided for Light Path Diagrams of the Lighting Toolbox.
  - In the Lighting Toolbox, the Camera detector is introduced for visualizing field intensities as Chromatic Fields Sets.
- Light Sources
  - The Far Field Source has been introduced as a new light source. The far field source allows to define a spatially partially coherent light source by its far field including local polarization.
  - Partially coherent source models are defined by mode-based models. Now, the positions of modes and their weights can be defined as data based (import data) or programmable for most of these source models.
- Beam Shaper Design

  - The geometrical optics based design of a transmission that converts a Gaussian profile to a top hat is now supported by an easy to use dialog.
  - A new session editor for the refractive beam shaping has been introduced. Several setups are available including the shaping of a Gaussian beam into circular or rectangular top hats or lines.

- Simulation and Optimization of Gratings
  - The LLGA (Local Linear Grating Approximation) Result Generator can calculate rigorous results (Rayleigh coefficients per order for both E_x- and E_y-polarization) by means of the Fourier Modal Method (FMM) for a set of simple gratings. Such gratings are defined by a data series containing period, rotation angle, and incident angle of the incoming light. The data series can be imported from a matching xml-file or can be obtained from the Local Linear Grating Analyzer.
  - The Polarization Analyzer for the analysis of gratings has been added. For a given range of wavelengths, the Polarization Analyzer is used to compute minimum and maximum values related to polarization. Those min/max values can be computed for the overall reflection or transmission for both E_x and E_y-polarization. Further advanced merit functions like the polarization contrast can be computed.
  - The results of the Efficiency Analyzer and the Polarization Analyzer are available in the Parametric Optimization. Hence, parametric optimization can be applied for the design of sub-wavelength gratings which can be used e.g. as antireflection structures or in order to modify the polarization of incident light.

- Parametric Optimization
  - The parametric optimization has been extended by Simulated Annealing - a global optimization algorithm. This new algorithm enables the global search for the minimum of the target function.

- Parameter Run
  - New modes have been added for the control of the parameter run. The Scanning mode allows to fully scan the parameter space in equidistant steps. In the Random mode, uniformly distributed random combinations of parameters are used which is especially useful for Monte Carlo simulations and tolerance analysis.

- Optical interfaces
  - All optical interfaces allow to introduce Fresnel zones. This option results in wrapped interface profiles with height values resulting in a predefined total profile height.

  - For the Sampled Interface, VirtualLab allows to fit a polynomial to the sampled height profile resulting in either a Cylindrical Interface, an Aspherical Interface or a Polynomial Interface.

- Data Arrays
  - The concept of Data Arrays has been introduced. Data Arrays are designed as containers for any data that represent mappings from any N-dimensional real space to any M-dimensional complex space. An appropriate view with a variety of view-options is available.
  - VirtualLab allows to import one or more bitmap and text files into one data array supported by an import wizard. Beside the import of .txt and .csv containing an one- or two-dimensional array of real numbers, .bmp, .jpeg, .png, .pcx, .gif. formats are supported.

- Removed Items
  - Spread Sheets (formerly available via System -> New Spread Sheet) are no longer supported. The menu item has been removed. Currently, Spread Sheet documents can be opened. In a forthcoming version, those Spread Sheets will be converted to a Light Path Diagram automatically.

- New and Updated Tutorials and Application Scenarios
  - Tutorial 96.01: Lighting Toolbox (new). This tutorial gives an introduction to the concepts and the usage of the Lighting Toolbox. Analysis and Design of Grating Cells Arrays are demonstrated.
  - Tutorial 101.01: Introduction to Parametric Optimization (update). This tutorial gives an introduction to the usage of the parametric optimization in VirtualLab^{TM}. As an example, we consider the search of the focus of a spherical lens.
  - Scenario 246.01: Rigorous Simulation of Light Diffraction at Coated Sinusoidal Grating (update). This example demonstrates the rigorous simulation of a coated sinusoidal grating and it illustrates the effect of the coating on on the summed efficiency of all reflected orders.
  - Scenario 315.01: Parametric Optimization of a Grating Polarizer (new). This application scenario demonstrates the parametric optimization of a sub-wavelength rectangular chromium grating used to polarize incident VIS light. For this purpose the modulation depth and the slit width of the grating are varied to find an optimal combination of maximal TE polarization and high polarization contrast (>50) of transmitted light for wavelengths from 450nm to 800nm.
  - Scenario 307.01: Parametric optimization of refractive beam shaping element for shaping of circular Top Hat (new). This example

demonstrates the setup of a beam shaper system by the refractive beam shaper session editor. The optical performance of the resulting system can be improved by the parametric optimization of VirtualLab.

– Scenario 317.01: Design and analysis of grating array for reshaping of LED light into a cross pattern (new). This application scenario demonstrates the design and analysis of an illumination system for the shaping of LED light into a cross light pattern. The shaping is done by a grating cells array.
– Technical Note 010: Programming Reference (update). This technical note describes how VirtualLab can be customized with modules and snippets and describes the used syntax. It includes the VirtualLab Programming Reference.
– Technical Note 021: Parametric Optimization in VirtualLab (update). This technical note gives an introduction to the usage of the parametric optimization in VirtualLab™. It describes the algorithmic background, especially how the target function is defined and how constraints are being handled.

6 Version 4.10.2

General Information:

- Release Date: March 2011.
- Update Service: 4th quarter 2010 is required.
- Installation: VirtualLab 4.8 (basic installation), 4.9.x or 4.10.x (update) required.

VirtualLab 4.10.2 is a service release with this additional enhancement:

- In VirtualLab Advanced, grating simulations make extended use of multiple cores resulting in a better performance. Further it is possible to switch off the parallelization of the loop of the parameter run separately, which might improve the performance in case of grating simulations.

7 Version 4.10.1

General Information:

- Release Date: January 2011.
- Update Service: 4th quarter 2010 is required.

- Installation: VirtualLab 4.8 (basic installation), 4.9.x or 4.10.0 (update) required.

  VirtualLab 4.10.1 is a service release with a few minor enhancements:

- In parametric optimization, the general constraint "'Minimal local radius"' is available for rotated cylindrical interfaces.
- Both, the period and the rotation angle of grating interfaces in a stack can now be varied in the parameter run.
- Some more parameters, especially of light sources and both, the period and the rotation angle of grating interfaces in a stack can now be varied in the parameter run.
- The beam parameter detector uses a new analytical formula to compute results more accurate without a resampling of the spherical phase.

8 Version 4.10

General Information:

- Release Date: December 2010.
- Update Service: 4th quarter 2010 is required.
- Installation: VirtualLab 4.8 (basic installation) or 4.9.x (update) required.

  VirtualLab 4.10 provides the following enhancements:

- Parametric Optimization
  - VirtualLab Advanced provides parametric optimization for optical systems, e.g. laser systems, represented by a light path diagram (Starter Toolbox). Most of the structural parameters of the system can be used as free parameters in the optimization. Target functions can be defined from weighted sums of detector values. Structure constraints are handled by penalty terms of the target function.
- Import of coating data from Essential Mcleod
  - VirtualLab supports the import of coating data generated by Essential Mcleod (see http://www.thinfilmcenter.com/).
- Access to FFT algorithm provided by the Intel Math Kernel Library
  - VirtualLab Advanced allows now to switch between two different FFT algorithms, namely a native LightTrans implementation and the implementation provided by Intel via the Math Kernel Library. Typically the Intel MKL version shows a better performance depending on the used precision (float or double) and the actual number of sampling points.

- Diffractive Optics Design
  - For a given IFTA document, VirtualLab provides the option to run the design multiple times with random initial transmissions. This feature is available via "'IFTA Optimization - Multiple Runs"'.
  - A simple session editor for diffractive beam shapers has been introduced to support the setup of the corresponding IFTA design document.
- Optical Interfaces
  - More options have been added to define the position of outer planes. Beside the manual definition, these planes can be adjusted automatically to minimum and maximum height values of the interface.
  - Now the user can see the validity of (inner) definition area, period and outer definition area in a dynamic sketch, accessible from the interface's edit dialog.
  - The data based "'Transition Point List"' interface has been added. It allows to specify a height profile by non-equdistant data points.
- Parameter Run
  - The tables in the parameter run are now sorted by the number of the light path element.
  - New parameters are now available in the parameter run, e.g. the distance between interfaces of an OIS can be modified.
- Catalogs
  - Several samples have been added to the LightTrans defined catalogs of interfaces and media.
- Handling
  - "Maximum Noise Intensity" has been renamed to "Maximum Relative Intensity of Stray Light"

9 Version 4.9.3

General Information:

- Release Date: November 2010.
- Update Service: 3rd quarter 2010 is required.
- Installation: VirtualLab 4.8 (basic installation) or 4.8.1, 4.9 or 4.9.2 (updates) are required.

VirtualLab 4.9.3 is a service release without additional features. A bug in the export functions for interfaces has been resolved.

10 Version 4.9.2

General Information:

- Release Date: October 2010.
- Update Service: 3rd quarter 2010 is required.
- Installation: VirtualLab 4.8 (basic installation) or 4.8.1 (update) or 4.9 (update) are required.

VirtualLab 4.9.2 is a service release without additional features. Some computational issues have been resolved and the behavior of dialogs of optical interfaces has been improved.

11 Version 4.9

General Information:

- Release Date: September 2010.
- Update Service: 3rd quarter 2010 is required.
- Installation: VirtualLab 4.8 (basic installation) or 4.8.1 (update) required.

VirtualLab 4.9 provides the following enhancements:

- Grating Simulations
  - General 3-D gratings allow to define stacks with x-y-modulated optical interfaces and x-y-z index modulated media in between. Stacks can be added at both sides of a base block, a common (x-y) period is assumed to compute near- and far field and grating efficiencies using the Fourier Modal method.
  - For general 2-D grating the definition of stacks has been revised. The stacks can now be defined as a sequence of optical interfaces with a relative geometrical distance to each other. That allows to consider overlapping (but non-intersecting) interfaces now.
  - Stack tools allow to import coatings from the catalog and to analyze coatings using the FMM.
  - Stacks can be visualized in 2D and 3D views.
  - A zoom function has been added to the 2-D view of the transition points and layers.
- Structure Design of DOEs and Export of Interfaces
  - The structure design has been revised. In particular it has been seperated into 2 steps: (1) an optical interface (sampled interface) is computed from a transmission function (DOE), (2) an export function has been added to all optical interfaces.

  - All optical interfaces allow to export the height profile as GDSII, bitmap and plain text now. Discrete height levels can be introduced easily.

- Spectra and Pulse Modeling
  - The generators for spectra (formerly power spectra) have been extended. Databased spectra and programmable spectra have been added.
  - Database pulse spectra and programmable pulse spectra have been added.

- Modeling of Optical Components
  - The option "Periodization" has been added to all optical interfaces. This allows to model periodic structures easily.
  - "Field passes plane interface" and "Field is Absorbed" have been added to all interfaces as effects on fields outside the definition area.
  - The combined interface allows to load interfaces from the catalog now.
  - Special grating components have been removed from the light path tree. The double interface component with appropriate interfaces is to be used instead.

- Phase Detectors
  - The Zernike detector has been revised and re-designed.
  - The polynomial phase detector has been added.

- Geometrical Optics Propagation
  - The mode "Polynomial" has been added to the options for the fit of the phase within the geometrical optics propagation.

- Parameter Run
  - The sorting of the parameter run results has been improved for detectors that are applied to a harmonic fields set.

- Handling
  - Two-dimensional diagrams can be transposed now.
  - An accuracy factor can be set for the 3-D view of optical interfaces.
  - The total time for the simulation of light path diagrams is logged into the message window.

12 Version 4.8.1

General Information:

- Update Service: The release date is July 2010. Update service including the 2nd quarter 2010 is required.
- Installation: VirtualLab 4.8.1 is an update. VirtualLab 4.8.1 requires the installation of VirtualLab 4.8.

VirtualLab 4.8.1 is a service release without additional features. Some computational issues with respect to the Grating Toolbox have been resolved.

13 Version 4.8

General Information:

- Update Service: The release date is June 2010. Update service including the 2nd quarter 2010 is required.
- Installation: VirtualLab 4.8 is a complete installation. Uninstall any previous version of VirtualLab 4 first. After that, install VirtualLab 4.8.

VirtualLab 4.8 provides the following enhancements:

- Grating Simulations
  - General 2-D gratings can be defined now. Using so called stacks, the period of the structure can be defined by a sequences of optical interfaces, including grating, conical, aspherical, sampled and programmable interfaces. Stacks can be added at both sides of a base block. Hereby a great flexibility for the definition of gratings is available. Until now, these interfaces must by separated in z-direction.
  - In VirtualLab Advanced multi-core computing is now supported. The core of the FMM now works in parallel and single simulation can be accelerated.
  - In VirtualLab Advanced larger periods (about 1900*wavelength in 2D or $(37*\text{wavelength})^2$ in 3D) and more orders (about 5800 in 2D and (75*75) in 3D) can now be simulated.
  - Field Inside Grating Analyzer now works for non-perpendicular incidence.
  - Near field propagation now considers absorption coefficients.
  - The reflection channel of gratings accepts distances greater than zero.

  - Active/deactivate of light path linkages is now available in the Grating Toolbox.

- Modeling of Optical Components
  - Pixelation and quantization can be applied to any optical interface. This allows to simulate the interfaces as they appear after certain production processes. For quantized interfaces parabasal geometrical optics propagation or mode (AI)/(AII) of geometrical optics propagation should be used.
  - Several scaling factors for optical interfaces have been introduced. This allows in particular to perform tolerance analysis with respect to pixelation errors and quantization errors caused. e.g. by non-exact etching.

- Parameter Run
  - In VirtualLabAdvanced the parameter run can be accelerated by using multiple cores.
  - Many more structure parameters are available for parameter run now. This applies especially to parameters of optical interfaces in the optical interface sequence and the double interface component.
  - The weight for monochromatic light sources is available in the parameter run.

- Programming
  - The editor for snippets and modules has been improved. Source code highlighting has been added.
  - The trial version allows to load and to simulate applications scenarios that include snippets (programmable components).

- Design of Diffractive Optical Elements
  - The session editors for the design of diffractive optical elements (diffusors, beam splitters) now set the size of the aperture of the DOE automatically.

- Trial Version
  - The trial version does not require administrative rights to be started.
  - The trial version allows to load and to simulate applications scenarios that include programmable components.

- Handling
  - Now the user can extract any material from media or from coatings to be be put into the user defined materials catalog.
  - View of materials shows the state of matter.

  - One-dimensional diagrams can detect their minimum and maximum value, respectively.

- Miscellaneous
  - Some of the LZOS glass data have been corrected using the data at LZOS's homepage.
  - The ray tracing analyzer may require some more time to initialize when it is used in "'Rotatable"' mode.

14 Version 4.7

VirtualLab 4.7 (released March 2010) provides the following enhancements:

- Ray Tracing Analyzer
  - The brightness of rays is adjusted according to their intensity in the input plane (similar to the light view).
  - Rays that are close to an aperture can optionally be shifted (default setting) such that they touch the aperture. Further, rays of small intensity can be disabled via a user-defined threshold.
- Grating Simulations
  - Field Inside Grating Analyzer now works for non-perpendicular incidence.
  - Near Field Propagation now considers absorption coefficients.
  - The reflection channel of gratings accepts distances greater than zero.
- Parameter Run
  - If multiple parameters are varied at the same time, the parameter run now shows the corresponding values in a tooltip.
  - A parameter run set to "Programmable" copies now also the snippet and the global parameters from an already open parameter run.
  - Large parameter runs can be saved to hard disc again (bug in version 4.6).
- Catalogs
  - Fresnel and cylindrical Fresnel interfaces, several types of grating interfaces and the combined interface are now available as templates in the interface catalog.
  - For Standard Air, the Edlén formula is now used to describe the dispersion, it replaces sampled data.

- Programming
  - Consistence Check of Snippets within the Source Code Editor shows detailed information about the line where the snippet definition is invalid and the error message.
  - Improved handling for import and export of arrays within global parameters of snippets.
- Handling
  - The handling of homogeneous media is now consistent in the dialogs, e.g. dialog of the Optical Interface Sequence.
  - The selected element in the light path view are used as initial configuration for the LPD tools.
  - Multiple selection is enabled for the import of light path elements.
  - Multiple selection is enabled for the import of old materials and coatings in the catalog.
  - Interfaces with asphere or polynomial coefficients as well as the GRIN medium now use millimeters instead of meters as base unit. That is, the usage of catalog values is simplified.
  - The virtual screen now allows to show the polarization, including polarization ellipses.
  - In diagrams you can now calculate the minimum position, maximum position and the FWHM
  - Most tables now allow to copy their entries to the clipboard using the context menu. Certain tables also support pasting from the clipboard (for Aspherical Interface, Cylindrical Interface, Fresnel Interface, Cylindrical Fresnel Interface, Polynomial Interface, GRIN Medium, Zernike Seidel Aberrations).
  - Plane Waves Field View now allows to copy all items to the Windows clipboard.

15 Version 4.6.1

VirtualLab 4.6.1 (released February 2010) is a service release without additional features. The behavior of the dialog of aspherical interfaces has been improved.

16 Version 4.6

VirtualLab 4.6 (released January 2010) provides the following enhancements:

- Introduction of 3-D grating simulations
  - The electromagnetic analysis of 3-D index-modulated gratings has been enabled. In version 4.6, the index-modulation can be described by a pillar-type medium that can be used to simulate, e.g., artificial media.

17 Version 4.5.1

VirtualLab 4.5.1 (released December 2009) is a service release without additional features. The performance of programmable interfaces has been improved.

18 Version 4.5

VirtualLab 4.5 (released December 2009) provides the following enhancements

- Partially coherent light simulation
  - Partially coherent light of quasi homogeneous sources can be modelled by sets of harmonic fields (modes). In order to model light distributions with customized coherence function customized modes are required. A Programmable Mode Planar Source has been added that allows the specification of a customized mode by a small code snippet.
  - Planar sources are used in VirtualLab for the simulation of partially coherent light. Version 4.5 allows to define a customized global polarization for every planar source.
- Modeling of optical components with index modulation
  - LightTrans adds the modeling of index modulated optical components. These components consist of two freeform surfaces and an index modulated medium in between and can be realized using the new Double Interface Component.
  - The Double Interface Component allows for example the simulation of GRIN lenses, customized index modulated components and defects inside the substrate of optical components.
  - The Programmable Medium allows the specification of a three dimensional index modulation by a code snippet.
  - The XY-Index Modulated Plate is replaced by the Double Interface Component. When loading old light path documents with an XY-Index Modulated Plate, the conversion is done automatically.

- Diffractive and refractive freeform surfaces
  - A Polynomial, a Sampled and a Programmable interface have been added in order to model diffractive and refractive freeform surfaces. The interfaces can be used in the Double Interface, Single Optical Interface and the Optical Interface Sequence Components.
  - The Sampled Interface allows the specification of customized freeform surfaces by discrete height data points while the Programmable Interface enables the specification by a code snippet.
  - The component Aspherical Interface Sequence has been renamed to Optical Interface Sequence.
- Modeling of diffractive and micro structured optical elements
  - Diffractive and micro structured optical elements, as for example diffractive optical elements, phase plates, micro lens arrays, diffractive lenses, Fresnel lenses, hybrid lenses, can be modelled by the Double Interface Component.
  - The modeling of the surface profiles can be done using the new programmable and sampled interfaces.
- Ultra Short Pulse Simulation:
  - As part of the starter toolbox we introduce the simulation of ultra short pulses in version 4.5.
  - Generation of pulses using Gaussian pulse spectrum, propagation of pulses and an optical path length analyzer for sampling reduction are included.
  - The Fourier transformation between temporal and frequency domain is provided for pulses.
  - The Optical Path Length analyzer can be used to evaluate the optical path length between the active source and a user-defined element of the light path diagram. It can also be specified whether the absolut phase shall be calculated. Three different linear phase fits can be investigated.
- Analysis of Laser Resonators:
  - The eigenmode analyzer is provided for computing eigenmodes (both fundamental and higher modes) and eigenvalues of resonator setups. Fox-Li and Arnoldi algorithms are available.
  - The resonator session editor allows to import resonator systems from LASCAD.
  - A stored mirror function can be used to simulate micro-structured mirrors as part of the resonator. Customized apertures are available using stored functions.
  - The parameter run can be used to perform tolerance analysis of the resonator.

  - Outcoupling modes can be computed and simulated in exterior optical systems.

- Propagation:
  - The split step propagation (based on parabasal beam propagation methods) has been introduced for the simulation of index modulated media.
  - The parabasal geometrical optics operator has been added and is available in the double interface component and in the laser resonator toolbox. Other components in the starter toolbox will follow in forthcoming releases. It is an performance-optimized version of modes (AI, AII) provided by the geometrical optics operator.

- Catalogs:
  - VirtualLab implements a new concept for working with catalogs. The existing catalogs for materials and coatings are adapted. There are new catalogs for optical interfaces and optical media. More information can be found in the manual.
  - Coating handling is now full part of the VirtualLab catalog management. Additionally, it is now easier to create high reflection coatings with replicated layer sequences via automatic replication.
  - Materials do know their state of matter now.
  - The substrate is determined automatical if a coating is added to a optical interface.

- Improvements Related to Design:
  - The structure design provides the option to generate a light path diagram holding a Double Interface Component that contains the structure of the DOE.

- Improvements Related to Grating Simulations:
  - The Grating Efficiency Analyzer now shows also summed efficiencies and the absorption.
  - The new Field Inside Grating Analyzer allows to calculate the field inside a grating.
  - In the Holographic Volume Grating component the user enters the vacuum wavelength now instead of the medium wavelength of the interfering plane waves. Both vacuum and medium wavelength are shown.
  - TE and TM polarization for ideal plane wave light source work correctly now.

- Parameter Run:

  - The programmable Parameter Run enables the user to specify the progression of the selected parameters by a self programmed snippet. So not only a linear progression can be evaluated.
  - Zernike Fringe coefficients can be varied in the Parameter Run now.

- New and updated Light Path Elements and their features:
  - For Stored Lateral Field source, only globally polarized fields are admissible as lateral fields, the polarization is defined in the dialog, i.e. the polarization of the imported field is ignored.
  - New reference points are available for Single Optical Interface, Optical Interface Sequence and Spherical Lens: maximum extension of component defines the two new points.
  - In the customized propagation mode that is available e.g for the double interface component, it is now possible to define different propagation operators for different regions of a component.
  - The entries in the Optical Interface Sequence Component table can now be set up with a comment per interface.
  - An Ideal spherical Mirror has been introduced.
  - Now the Ideal Mirrors allow to define the reflectance.
  - Field Size and Sampling Manipulator excepts now "'1"' as sampling point for one directions which means that a 2-D field is converted to 1-D.
  - The fiber coupling efficiency detector allows to specify either the NA of the fiber or the diameter of the fiber mode.
  - The ray tracing analyzer has been added to visualize ray propagation through sequences of optical interfaces.

- Calculators:
  - Direction converter (calculator) can handle different media now.
  - Fresnel Effects Calculator can give diagram output with wavelength and angular dependency now.

- Programming:
  - The source code editor used to edit VirtualLabsnippets allows to check their consistency directly.

- Handling:
  - VirtualLab checks whether the document needs to be saved before closing the document. This is implemented for modules, design problems, spreadsheets, light path diagrams and parameter runs.
  - After closing a session editor the user can specify whether all subsequent documents, generated by the session editor, shall be closed or not.

  - Detector results are logged in an extra table on the bottom of the VirtualLab main window. This leads to a more well-arranged overview of all detector results produced by VirtualLab.
  - The menu item "'Windows - Close All but Current"' all windows except the current one can be closed.
  - Zoom into diagrams is possible via mouse wheel and toolbar now.
  - Windows can be arranged in different ways (cascade, tile horizontally, tile vertically, arrange icons)
  - The axes of data series diagrams can be adjusted via the property browser now.
  - Files with extension .csv can now be imported directly.

- Tools:

  - Data Field Diagrams can now be replicated periodically.
  - The Light Path Diagram Tools (Toolbar) are available also if the Light Path View is the active document window. The toolbar of VirtualLab provides a standard button to start or stop an active Light Path Diagram (window as well as editor) and an active VirtualLab Module.
  - The Field Evaluation Tools provide methods to evaluate harmonic fields. By extraction of a point or a line profile, VirtualLabprovides a diagram where the field quantity is selectable.

19 Version 4.2.1

VirtualLab 4.2.1 (released May 2009) is a service release without additional features.

20 Version 4.2

VirtualLab 4.2 (released May 2009) provides the following enhancements

- New Light Path Elements:

  - Evanescent Field Filter. The filter eliminates the evanescent part of the field. Only propagating plane waves remain in the spectrum of plane waves representation of the field.
  - Polarization Detector. This detector shows the E_Rho and E_Phi component of fields. This is available in the light path only.
  - General Jones Matrix - please do not use - is being removed in version 4.2.1.

- Enhancements for Spheres and Aspheres
  - Collins integral by ABCD matrix propagation has been added for the spherical lens, single interfaces and sequence of interfaces within the AIS. This is restricted to plane and conical interfaces.
  - A 3D view of the interface sequence has been added. It shows the interfaces of these components in a real 3D view. Some edit function are available directly from the view window.
  - ZEMAX import: image and object surface are imported as 2 additional interfaces of the AIS. If the ZEMAX file contains DISZ INFINITY as distance, then the distance is replaced by 1m and a warning is given.
- Grating Toolbox
  - It is now possible to specify the number of diffraction orders used for FMM calculations directly. Previously, only the number of evanescent orders could be set (customer request).
  - A programmable grating component is available. This allows you to program snippets which give the refractive index at a certain lateral position. Global Materials can be used to consider dispersion effects.
- Other enhancements:
  - Harmonic fields and field sets are defined in some medium. In the main window all fields are generated in vacuum. Fields that are generated by a virtual screen in a light path diagram may be defined in another medium which is now handled correctly in the main window, e.g. during interpolation and handling of the spherical phase in the view.
  - For Data Series Diagrams it is now possible to zoom in and out via the toolbar.
  - Results of the Parameter Run which represent harmonic fields can now be swapped on hard disc.
  - The Color Detector (available in the spreadsheet) has been removed and is replaced by Virtual Screen.
  - The automatic sampling has been improved for spherical and ideal lenses, quadratic and spherical waves and the lateral shift component. In particular the estimates take into account the lateral offset in connection with a spherical phase radius and are more robust for non-paraxial problems.
  - For the reflection channel of lenses, AIS and single interfaces the spherical phase radius of the field is now computed correctly. Further, the estimate of the phase radius has been improved for non-paraxial fields.
  - Transmission Design Document does simulate the energy conservation for 2f-setups and 1d-fields in a correct way.

21 Version 4.1

VirtualLab 4.1 (released February 2009) provides the following enhancements

- New Light Path Elements:
  - Programmable Light Source: The Programmable Light Source enables the user to program the lateral mode used in the VirtualLab-light source concept. The required program is a C# snippet that defines the lateral mode as a point-wise complex value. The user can introduce global parameters that can be varied in the Parameter Run.
  - Programmable Transmission: The Programmable Transmission element can be used in the Light Path Diagram to specify a user-defined point-wise complex function. The use of this Light Path Element is completely embedded in the VirtualLabframework.
- Propagation:
  - Improved field size estimates for SPW, Fresnel and Far Field Operator have been introduced resulting in more robust automatic mode especially for non-paraxial fields.
  - The deviation threshold used within the Automatic Propagation Operator can now be set in the dialog and in the Globals Options.
- Light Path:
  - New Light Path Tool: The Light Path Tool "Convert to Starter Tool Box LPD" enables the user to convert the given LPD which was generated by a session editor, into a Light Path Diagram where all modification can be done. This tool is only available for Light Path Diagrams generated by the Diffractive Optics Toolbox, the Starter Toolbox is required.
  - In the Light Path View, we have introduced a comment (editable) and the name of the Light Path Element can be changed by the user (customer request).
- Improvements for the Parameter Run:
  - It is now possible to start parameter runs with negative steps (customer request).
  - Now it is possible to create animations for the Parameter Run outputs, using the Light Views of selected single Harmonic Fields.
  - The Parameter Run can now show data series diagrams in the result table. This effects mainly the grating efficiency analyzer.
  - Other enhancements:

- Grating Transmissions can work chromatically now.
- The detectors Fiber Coupling Efficiency and Diffractive Optics Merit Function can be configured to evaluate their merit function relatively to the initial input field of the Light Path Diagram.
- New Accelerated Sinc interpolation operator. It is used for field-field or field-transmission operations. Its accuracy is comparable to Sinc interpolation but it avoids out of memory errors that occur for Sinc-FFT interpolation in case of operations between large and small (aperture) fields or transmissions.
- The Field Size and Sampling Component has been changed. Now it is a one step operation using the Accelerated Sinc interpolation.
- Copy to Clipboard is now possible for the Light View of Harmonic Fields Sets (customer request).
- The Scaling Factor has been removed from the dialog of spheres and aspheres.
- VirtualLabnow applies Windows Visual Styles resulting in an improved GUI design.
- The power spectra used in source dialogs (list of wavelengths) now use double precision (previously number of view-digits was used).
- For spherical lens, single aspherical interface and AIS the reflection channel is now handled correctly (previously wrong assignment of propagation direction).

22 Version 4.0.2

VirtualLab 4.0.2 (released January 2009) provides the following enhancements:

- New Ideal Component:
  - Phase Shift. A Phase Shift adds a phase difference to E_x and E_y.
- New Detectors:
  - Two Point Contrast Detector: By the help of the new Two Point Contrast detector in the Light Path Diagram, the contrast of a specified field quantity in two location can be measured. The user have to specify the field quantity he likes to evaluate and the two location where this field quantity shall be measured.
  - Value Monitoring Detector: The new Value Monitoring detector is available in the Light Path Diagram and allows the user to access the field quantities like amplitude and phase on a user defined location of the incoming field.

  - Power Detector: The Power Detector was added to the elements of the Light Path Diagram. This detector can be used for evaluating the power in a specified region of the field which is used as input of the detector. (customer request)
  - Angular Spectrum Visualizer: works similar to the Virtual Screen but shows the angular spectrum.

- Improvements for the Parameter Run:
  - It is now possible to vary more than one parameter at the same time (all with the same number of steps). Negative step sizes are not yet allowed.
  - You can now select whether the Parameter Run gives Harmonic Fields Sets or animations – diagrams as combined output for Harmonic Fields.
  - It is now possible to save the results of the Parameter Run.
  - The results of the Parameter Run are now shown in a more convenient order.

- Enhancements of the Virtual Screen:
  - If a Virtual Screen shows the Data View, it is now possible to set the view size. Furthermore setting the selection within the Virtual Screen now works correctly.
  - The Virtual Screen can now show Summed Squared Amplitudes and polarization.

  - Other enhancements:
  - The Multi Mode Gaussian Source now considers constant Rayleigh length for the higher order modes (constant waist was used before which is physically less meaningful).
  - General surface gratings are now always adapted to the specified modulation depth period - it is no longer necessary to first select *Rescale Modulation Depth* or *Rescale Period*.
  - The 1d-mode selection for the Grid Gaussian source now works correctly.
  - For a New Material, the Cauchy Formula can now be entered correctly.
  - Stored Transmission can be applied to 1d,2d fields independent of the dimension of the stored transmission. By definition, a 1d-stored transmission is constant in the missing dimension.

23 Version 4.0.1

VirtualLab 4.0.1 (released December 2008) provides the following enhancements:

- Further improvement of the Geometrical Optics Operator especially of the handling of channels along apertures.
- Improved performance for the Automatic Propagation Operator.
- Parameter run can now handle multiple used detectors.
- Improved sampling estimate for SPW propagation.
- Improved automatic sampling for Zernike Seidel Aberration.
- Generate Spreadsheet is now available as AIS Tool (customer request).
- The dialog of the Coating Analyzer now works correctly.
- The dialog of the Ideal Plane Mirror now works correctly.
- Single aspherical interfaces consider their relative distance within the light path now correctly.

Additionally version 4.0.1 provides several minor improvement and fixes of bugs.

24 Version 4.0.0

The new version 4.0 of VirtualLab (released November 2008) provides you with a new optics modeling and design software package, which combines the matured technology of versions 3.x with lots of powerful and user-friendly new features. Some of them are:

- The most amazing new feature is our Light Path Diagram. Instead of using spread sheets to configure an optical system, you specify the light path through an optical system using a flow chart concept. Of course the former spread sheet concept is still supported. Thus, you gain an extremely user-friendly concept without losing what you have worked with before. It's your decision, what you prefer. But we expect you will like the new way that we provide you. It is fast and easy to use and it will save you time and money in your work.
- With the Light Path Diagram we have introduced ideal and real components in VirtualLab. Each component is combined with the modeling techniques suitable for it. And we will add more techniques in 2009. That gives you the flexibility, which our concept promises.

- We have added new propagation techniques. There is a fascinating geometrical optics technique for propagation in free space and through lens systems that is similar to ray tracing software, but we do it in combination with an electromagnetic field representation. Therefore, we combine the power of geometrical optics and access to all parameters of a light field. The technique is equipped, as typical in VirtualLab, with an automatic sampling feature. You can concentrate on optics instead of numerics. And if you have a better idea than we have at LightTrans, then you can switch over to a manual control and adjust sampling in a way you think is optimal to your problem.

- Absolutely innovative is our new Automatic Propagation Operator for free space. It compares for you the accuracy of geometrical optics, paraxial Fresnel technique, far field approximation with the rigorous spectrum of plane wave method. The technique which fulfills the accuracy criterion and has the minimum numerical effort is automatically selected. That is a great benefit for you to save time of tests and comparisons. In particular, it helps you to decide if your modeling should be paraxial or non-paraxial.

- We understand, that you as a user needs to know what your software is doing. Thus, we added a full logging of what VirtualLab is doing for you. You can get the information directly or export it as a complete protocol as an xml document. That is our way to provide transparency to your modeling with VirtualLab. Our protocols give you a vast amount of modeling information.

- VirtualLab offers now a Parameter Run Document, which allows you to specify and run a series of virtual experiments. It will be the basic starting block for upcoming optimization and tolerancing features in VirtualLab.

- Also in source modeling we added some important new features. With VirtualLab 4.0, you have a multimode laser source as well as a customized partially coherent planar source model. A combined source allows generation of locally polarized light, like an azimuthally polarized donut mode.

- We have improved our color representation. Moreover, now you may switch between a photon counting detection and your visual perception of polychromatic light.

- For the analysis of gratings we added the rigorous Fourier Modal Method (FMM). We combined it with the structure definition of surface and holographic volume gratings. That allows you to analyze diffraction efficiencies, near fields and Rayleigh coefficients. And you can do all that in the framework of your VirtualLab platform.

- We added various wizards, our new Session Editors, to simplify specifying your modeling and design task. In particular you will benefit from that in diffractive optics. We used our outstanding skills in that area to

provide you with easy-to-use ways to design beam splitters, diffusers and laser beam shapers.

- We know, that you often do not need all of the power of VirtualLab for solving your modeling and design tasks and making strides in optics innovation. Just some tools may be enough for you. Thus, we offer our technology in toolboxes. VirtualLab 4 comes with several toolboxes including Starter, Diffractive Optics and Grating Toolbox along with other toolboxes such as Beam Shaping and Laser Resonator that are under current development. That gives you the choice to concentrate on what you need.

We could give you many more examples of innovative features of VirtualLab 4 but maybe it is more important for you to know, that we, the team at LightTrans, are continuously working on serving you better in technical and user-friendly features. Being a customer of VirtualLab gives you access to an amazing development in optics software technology. But we also know that something is always missing. Thus, we ask you to send us your ideas and demands for the future development of VirtualLab.