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Effiziente Designverfahren für optische Laser- und Beleuchtungssysteme

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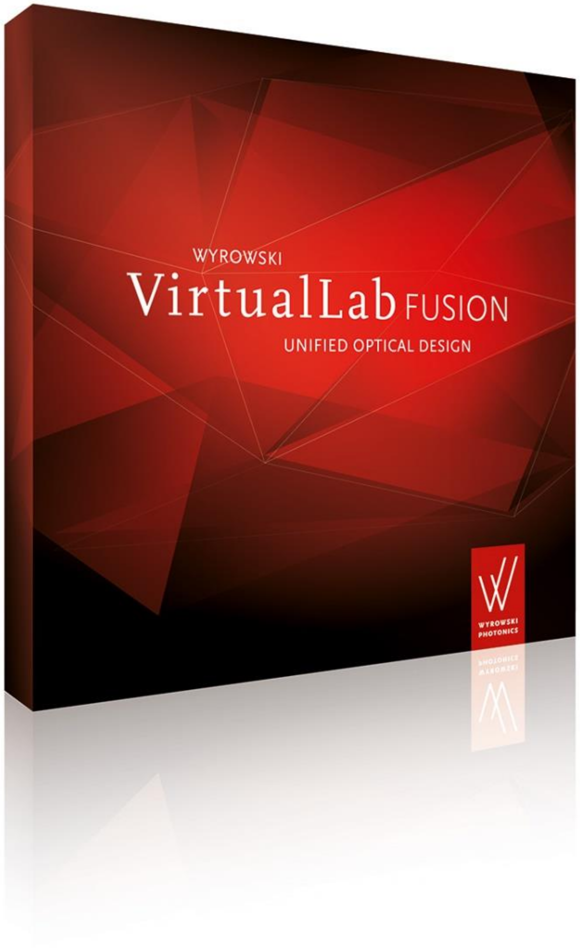
LightTrans – A Short Overview

- Founded in 1999
- Offices in Jena
- About 20 employees (together with Wyrowski Photonics)
- Distributors world-wide
  - Europe, United States; Japan, China, Korea
- Customers in more than 30 countries world-wide.

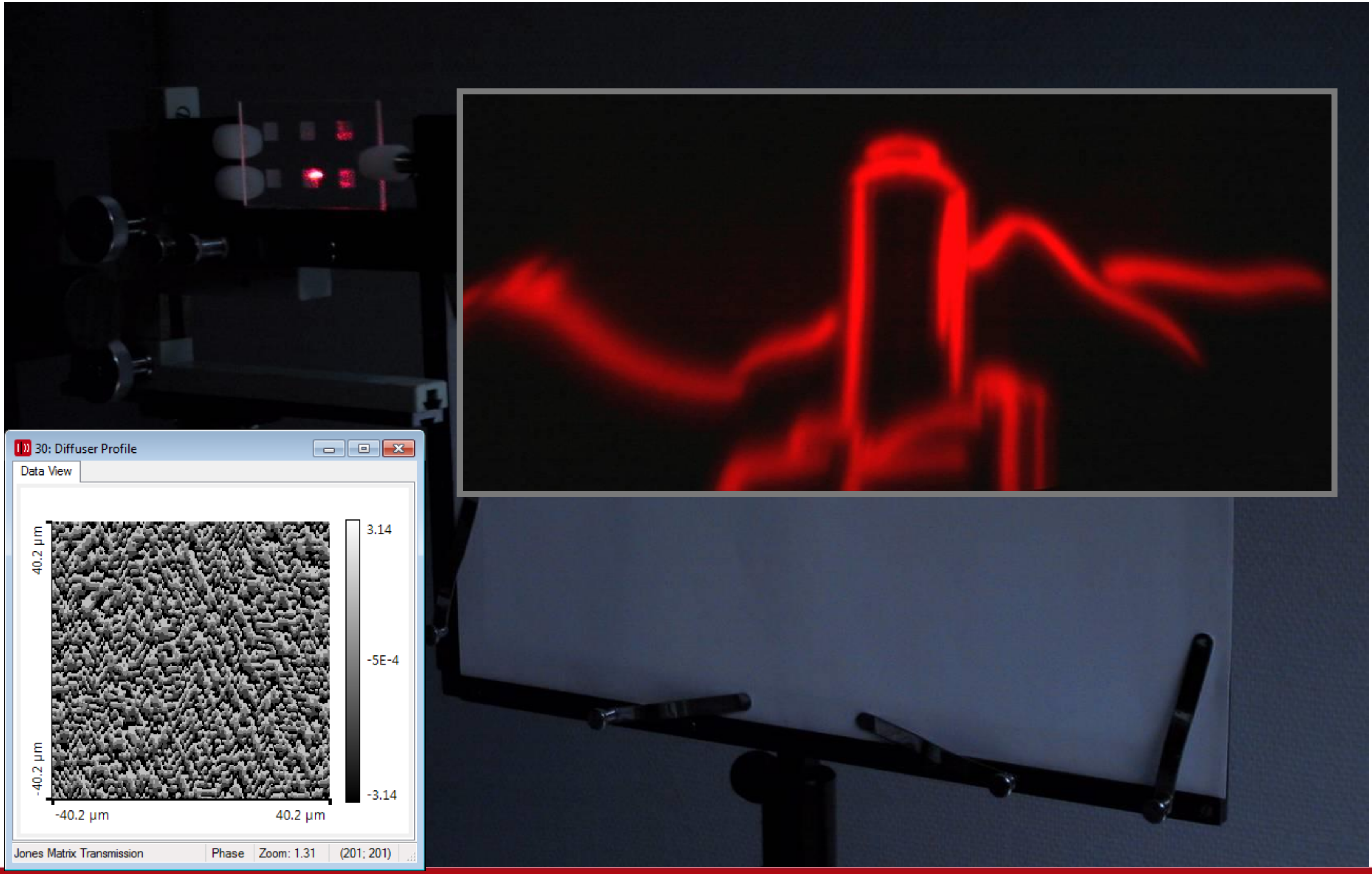
LightTrans

LightTrans - Products

- **VirtualLab Fusion** – software for optical modeling and design.
- **Optical design** and engineering, consulting.
- **Prototyping** of optical components, especially micro-optics.
- **Training** and support for VirtualLab including software and design courses.



Diffractive Diffuser



Holographic Screen

- Master-DOE for recording of a holographic screen side by side with a white paper screen in a airplane Mock-up. The light reflected by the master DOE is clearly brighter than the light reflected by the paper screen.
- Similar technologies can be applied for head up displays.

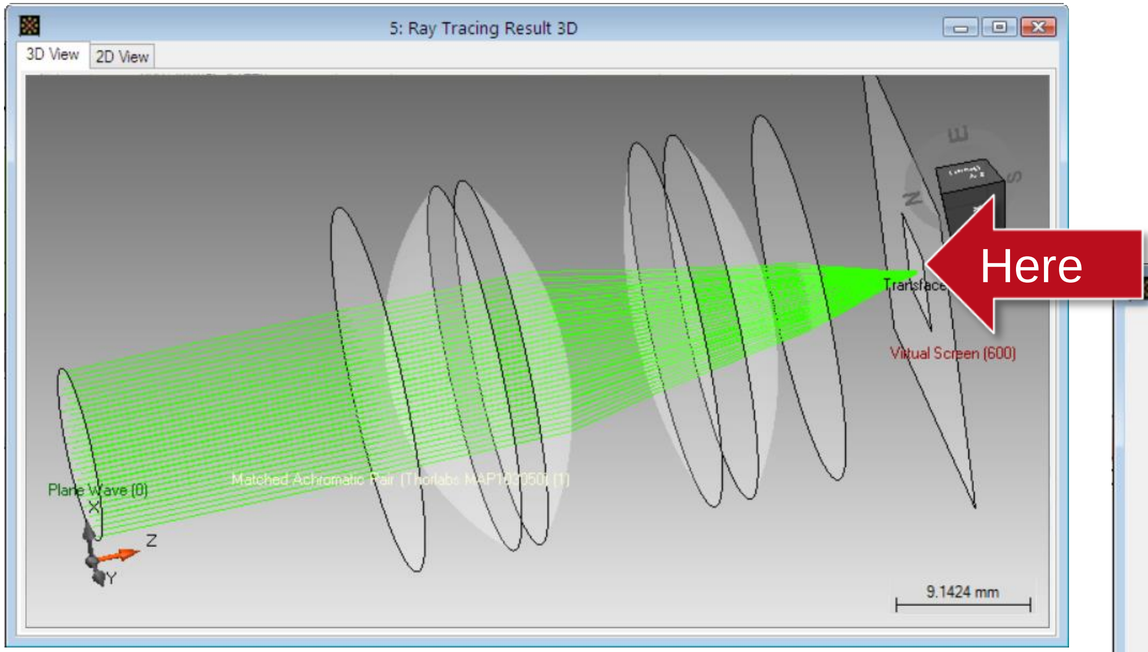
Pictures by courtesy of EADS, Innovation Works

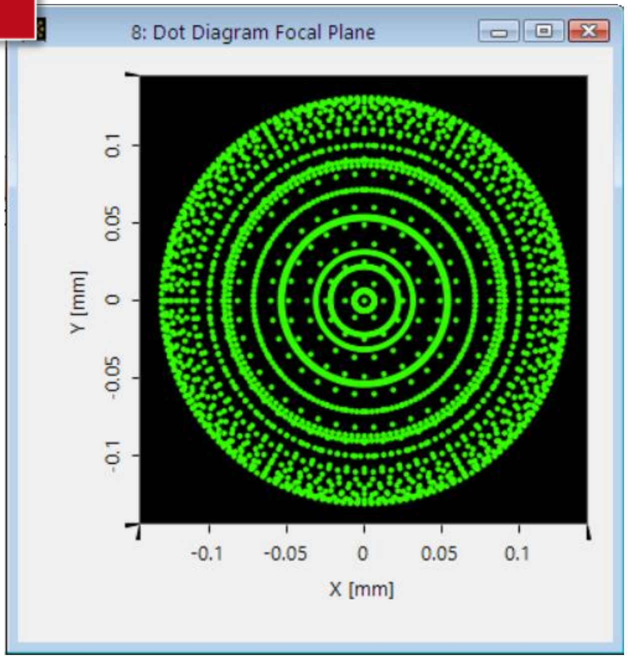
Integration VirtualLab + optiSLang

- Dynardo and LightTrans have partnered to integrate the optics design software **VirtualLab** into the multidisciplinary robust design software **optiSLang**.

- Partnership has been started in 2015.
- Targets and benefits: robust design of **optical and opto-mechanical** problems

Design of Lens Systems: Ray Tracing

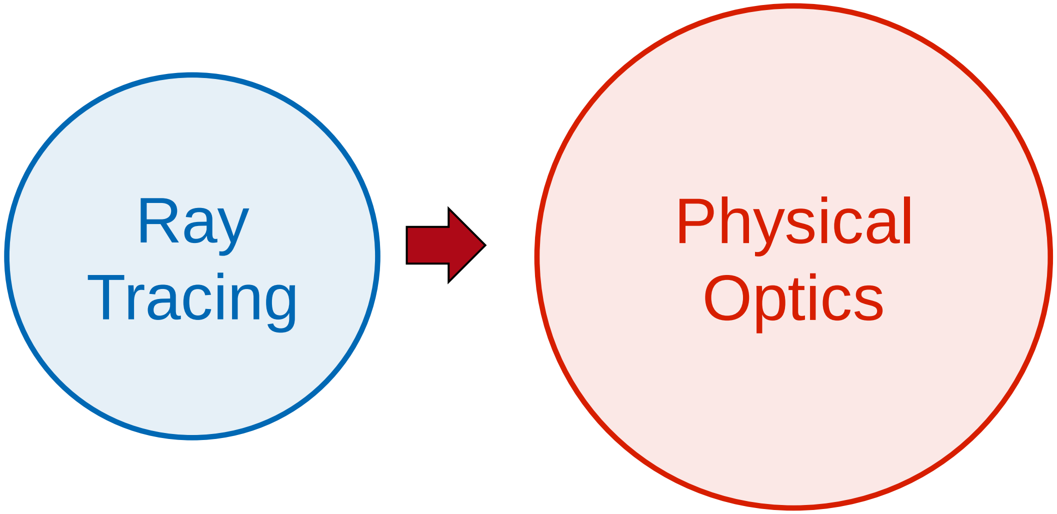




Dot diagram

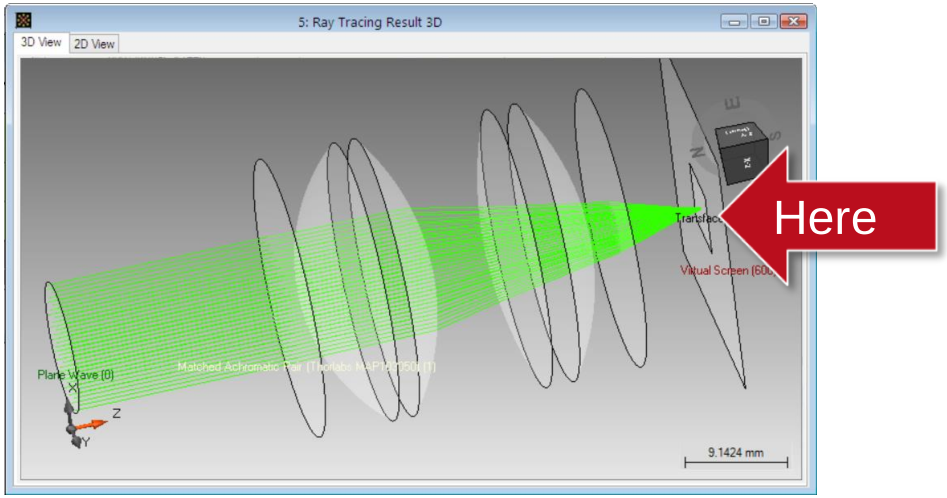
Geometrical and Physical Optics Modeling

- Ray tracing is powerful method for optical design. Most of the commercial tools are based on ray tracing only.
- Ray tracing has many physical limitations. We have to model on the basis of physical optics!

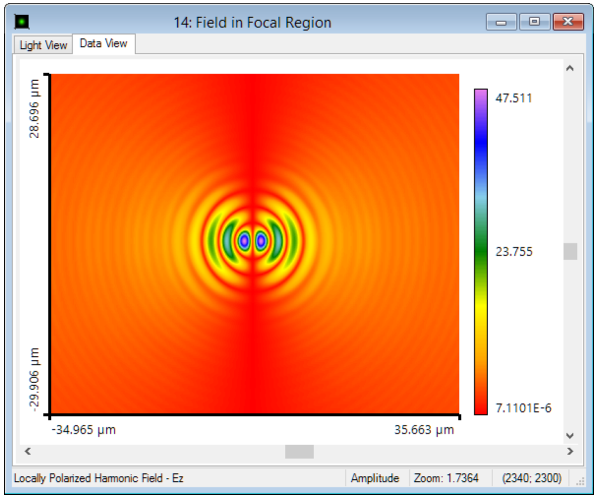


- VirtualLab Fusion provides both, **ray tracing and physical optics** field tracing methods **in one software**.

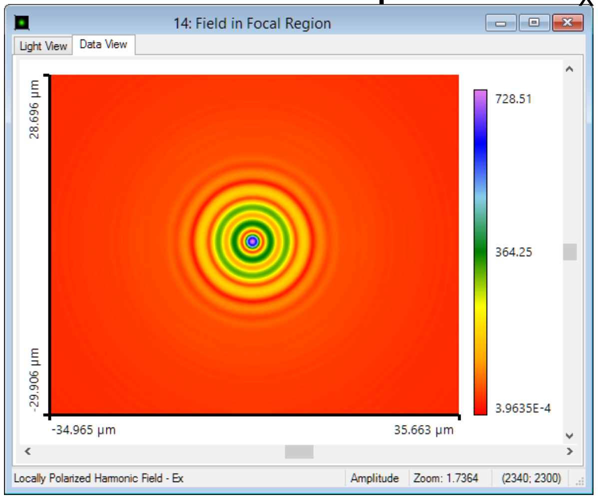
Design of Lens Systems: Physical Optics



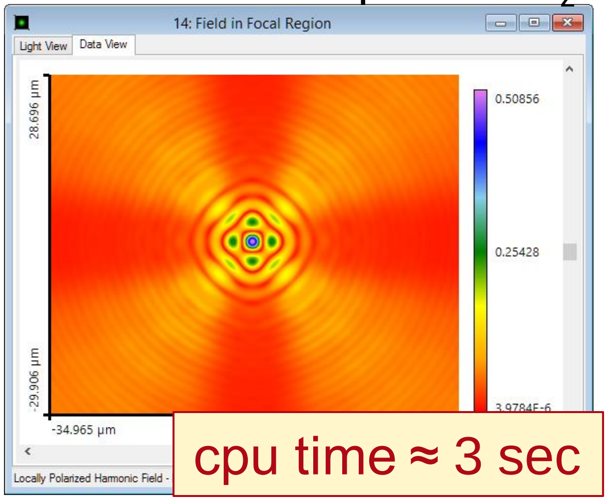
Electric field amplitude: E_y



Electric field amplitude: E_x

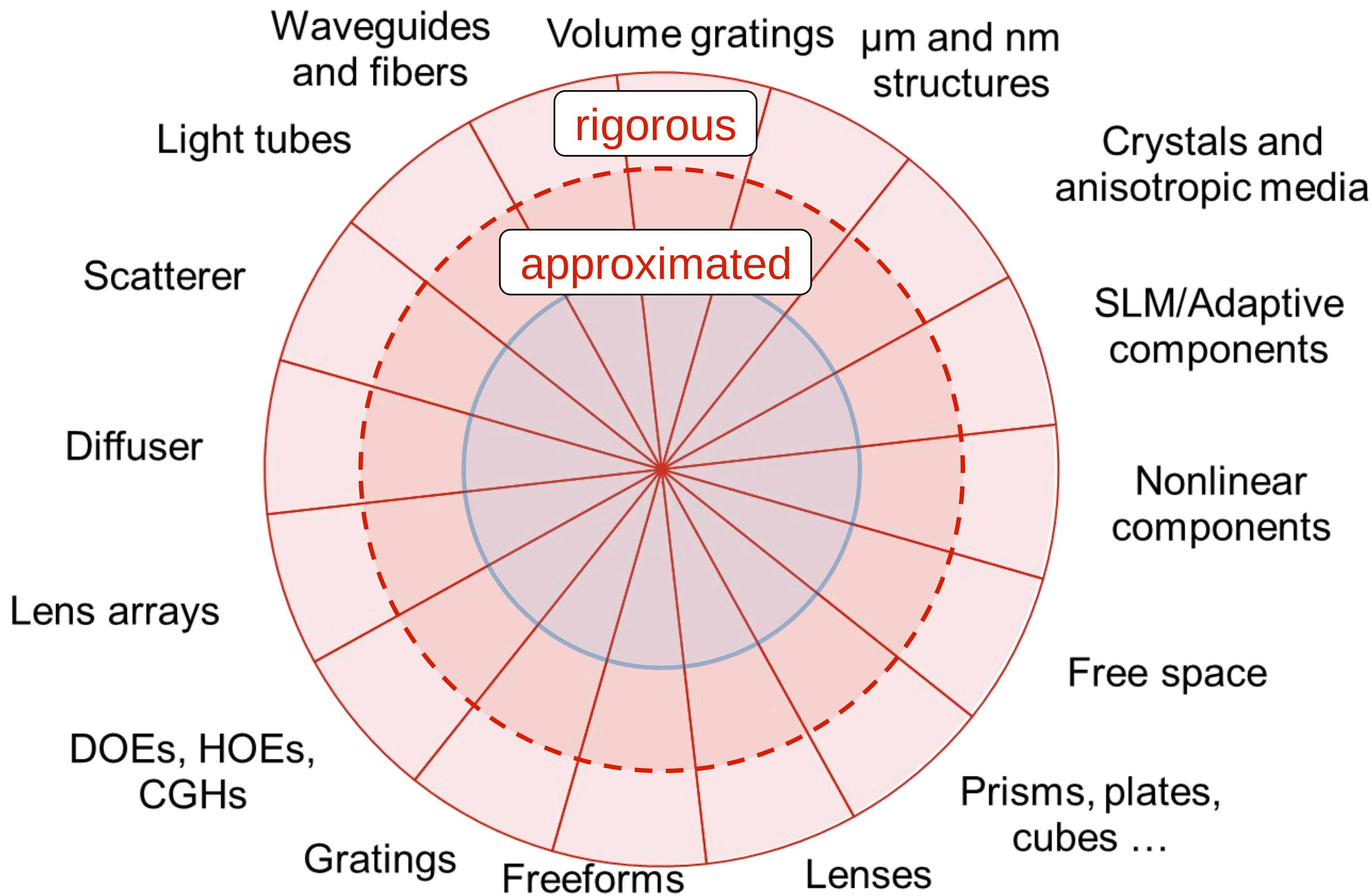


Electric field amplitude: E_z



cpu time ≈ 3 sec

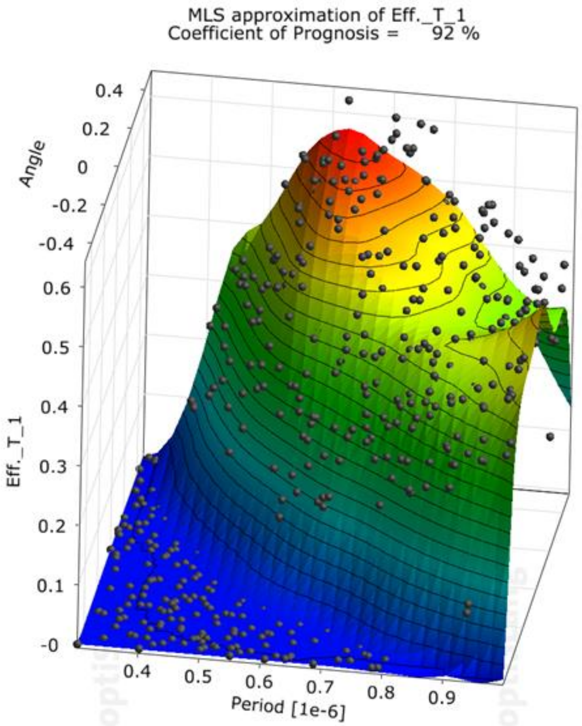
Applications Enabled by Field Tracing



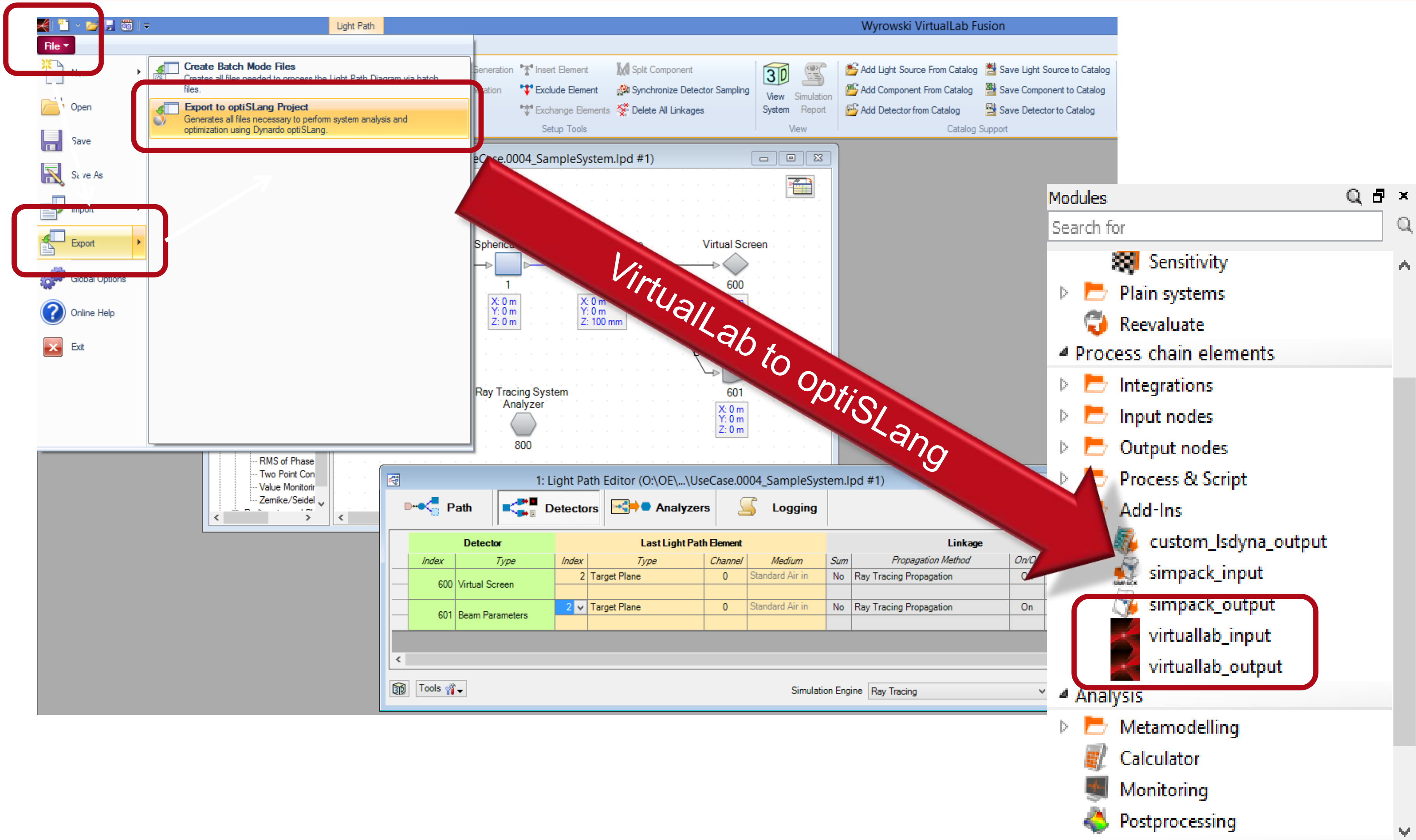
Improvements by VirtualLab + optiSLang

- Access to
  - Benchmark-winning optimization algorithms
  - Advanced statistical methods for data analysis
- Justified workflows including sensitivity analysis, optimization, robustness analysis
- Additional options as
  - Optimization with coupled parameters
  - Usage of derived target functions
  - Pareto design
- Increased performance by meta-models
- Multidimensional visualization
- Cluster computing
- Last but not least:

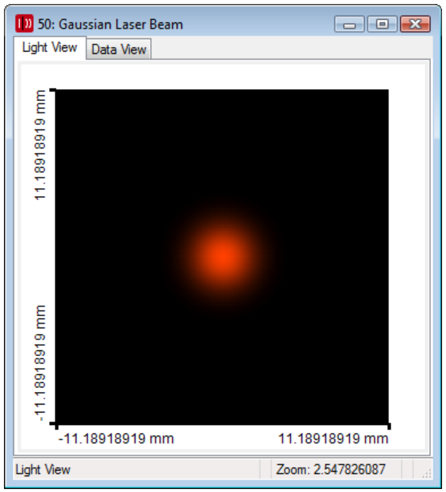
Get insight to the optical design task.

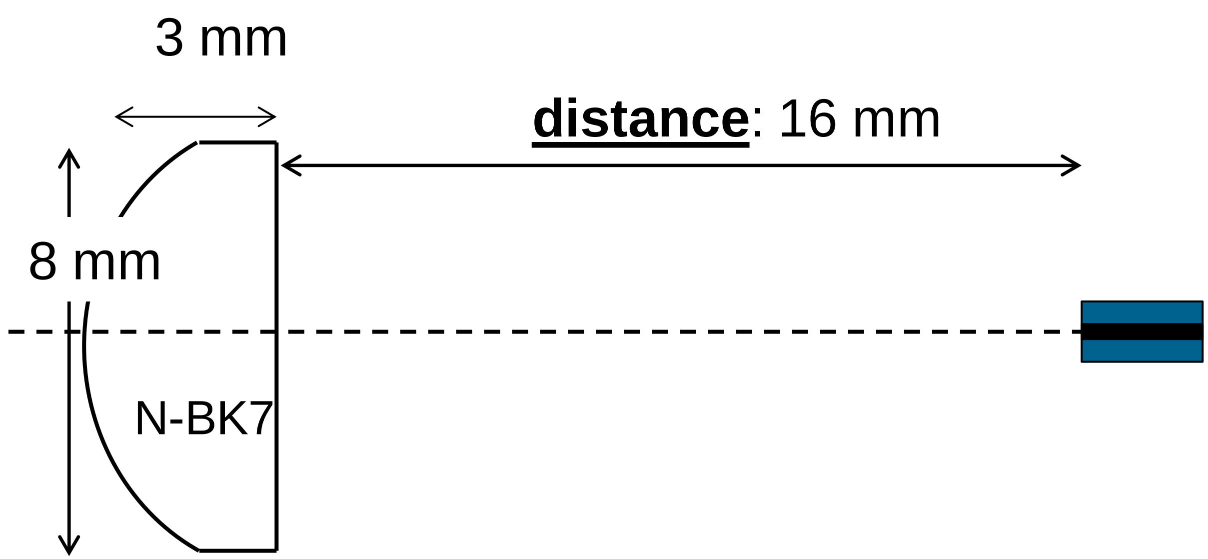


Connecting optiSLang and VirtualLab



Design Task: Fiber Coupling Laser System





Laser beam,
Diameter 4 mm
Wavelength 632 nm

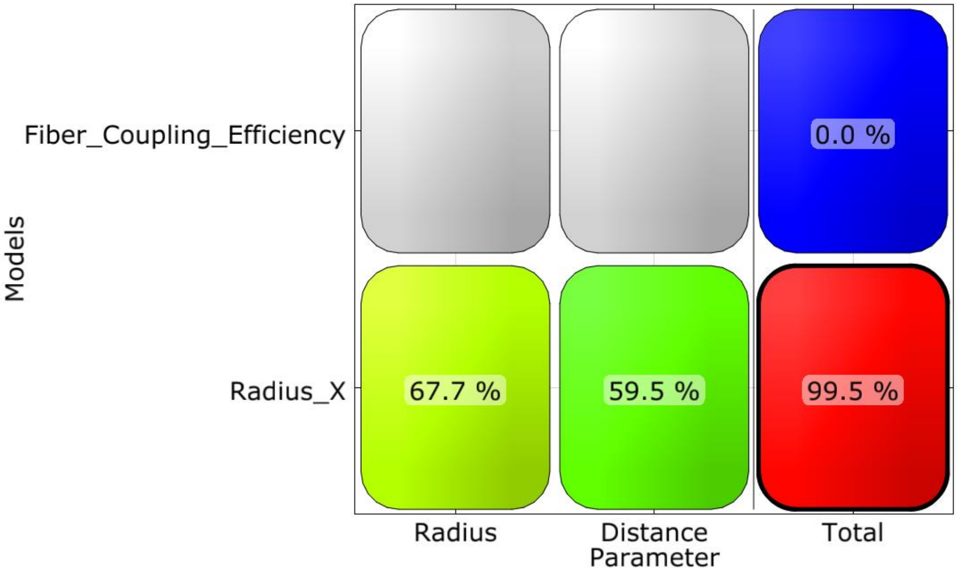
Aspherical lens with
radius of 8 mm and
conical constant 0.

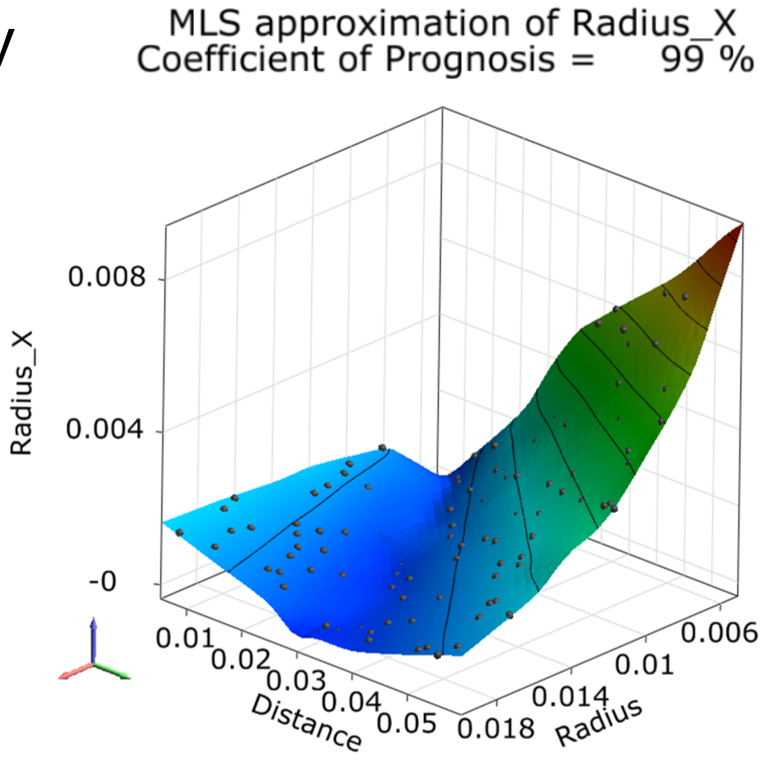
Single
mode fiber
NA = 0.12

Free parameters: distance, radius, conical constant.
Target function to be optimized: fiber coupling efficiency.

Sensitivity Analysis I

- No model for the *Fiber Coupling Efficiency* available.
- Model for *Radius_X* (Beam Radius) is very good (CoP = 99.5%)
- Beam Radius is minimal in valley → necessary to obtain high fiber coupling efficiency





Modifications of the Parameter Space

- Dependence between distance and radius in order to achieve high fiber coupling efficiency. The incoupling plane has to be in the focus of the lens.
- From lens design, the formula

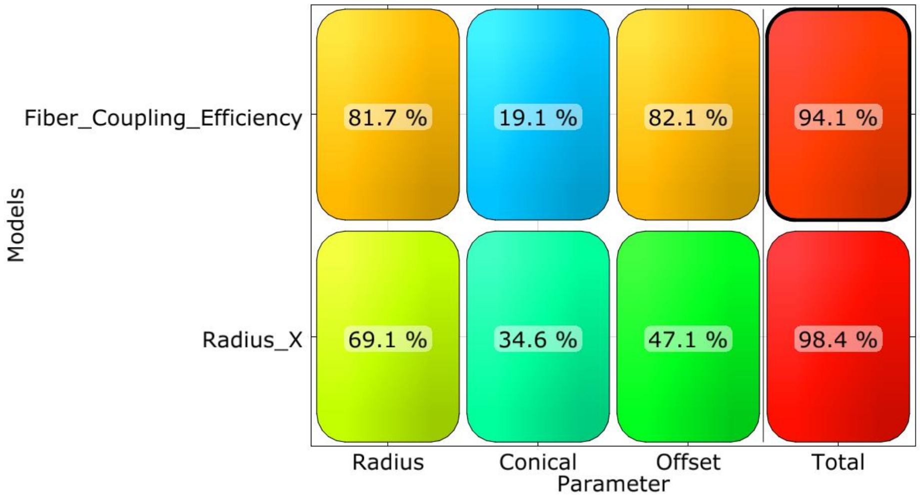
  $$\mathbf{FocusDistance = (n-1) * 1 / R}$$

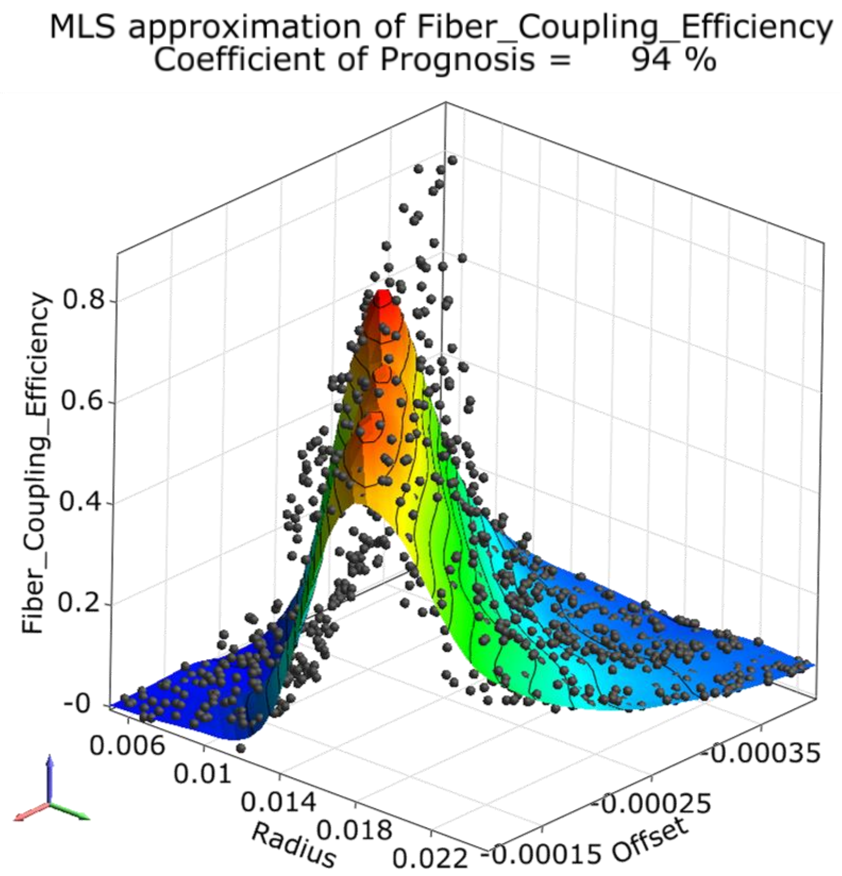
  is known for a convex-plane lens. Here, n=1.52.
- Further improvements that have been introduced iteratively after a subsequent sensitivity analysis.

Distance	Dependent	0.0138846	☐	(Radius/0.52-0.0015)+Offset

Sensitivity Analysis II

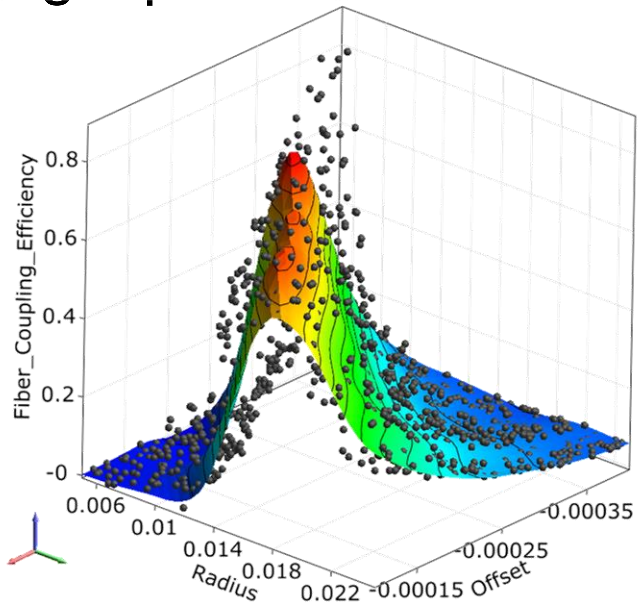
- Introduction of dependent variable leads to a model for *Fiber Coupling Efficiency* with high CoP.



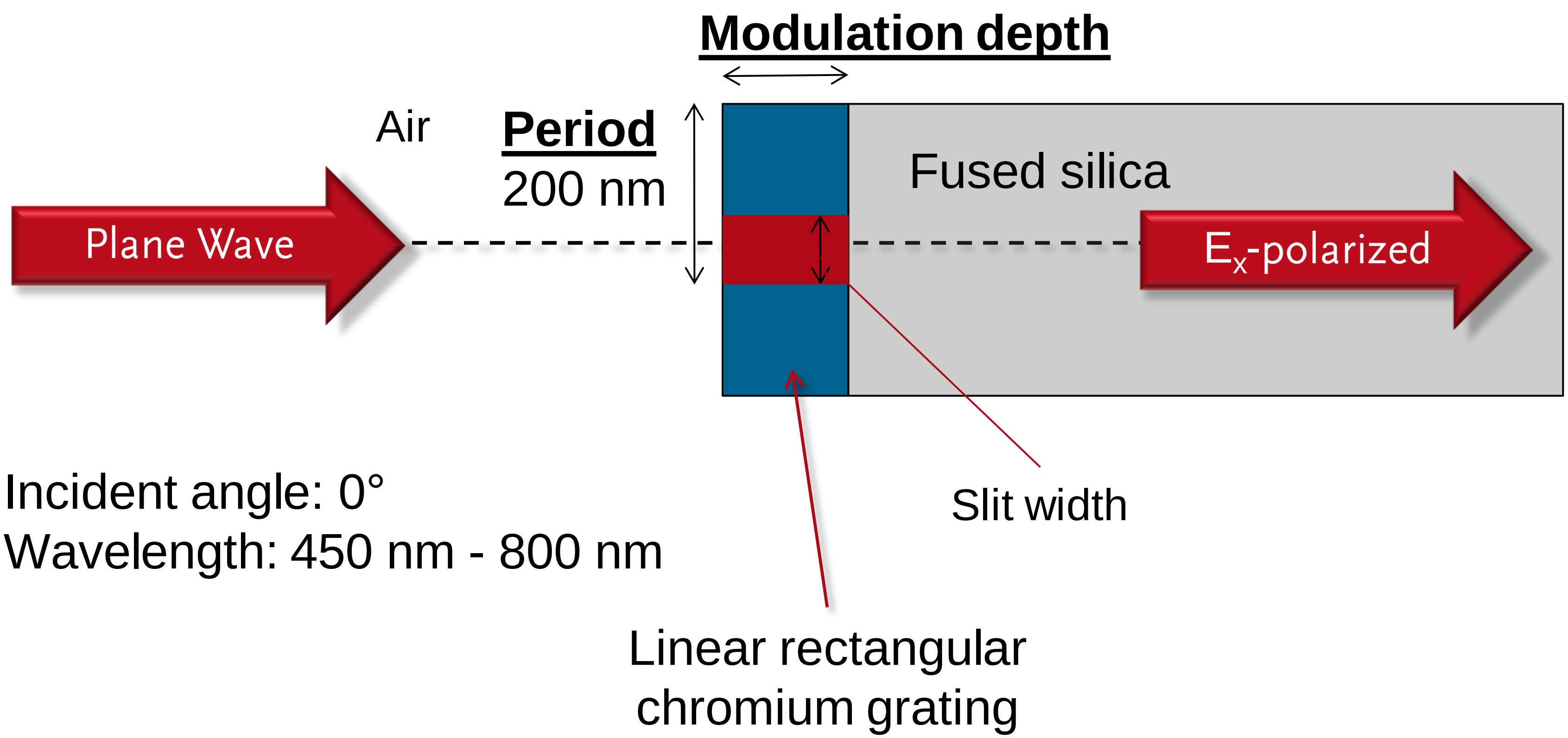


Approach with optiSLang

- Sensitivity analysis gives us an insight to the topology of the design problem.
- We are enabled to formulate a well defined design problem.
- We learn about the influence of the single parameters on the target function.
- Further robustness analysis is available.



Design Task: Grating Polarizer



Incident angle: 0°

Wavelength: 450 nm - 800 nm

Transmission efficiency of E_x : η_x

Transmission efficiency of E_y : η_y

Design Task

- Free parameters for optimization:
  - Slit width: 10-190 nm
  - Modulation depth: 20-200nm
- Merit functions:
  - Transmission efficiency

$$\eta_{x,\,min} \longrightarrow \text{max}$$

  - Uniformity error

$$U = \frac{\eta_{x,\max} - \eta_{x,\min}}{\eta_{x,\max} + \eta_{x,\min}} \longrightarrow \text{min}$$

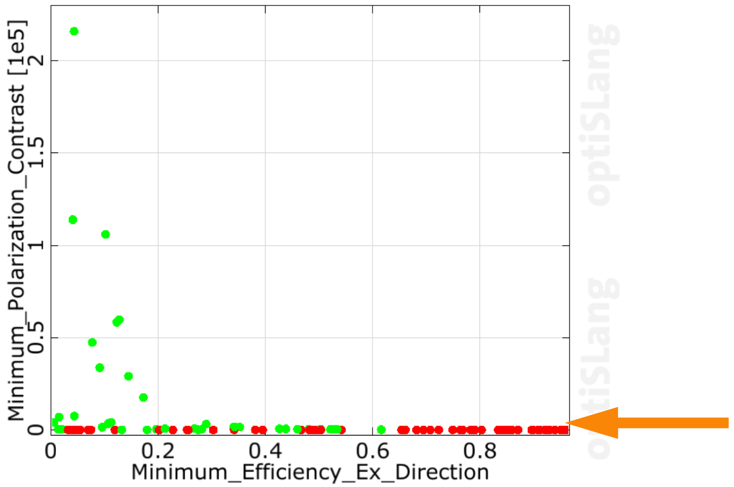
- Constraint
  - Polarization contrast

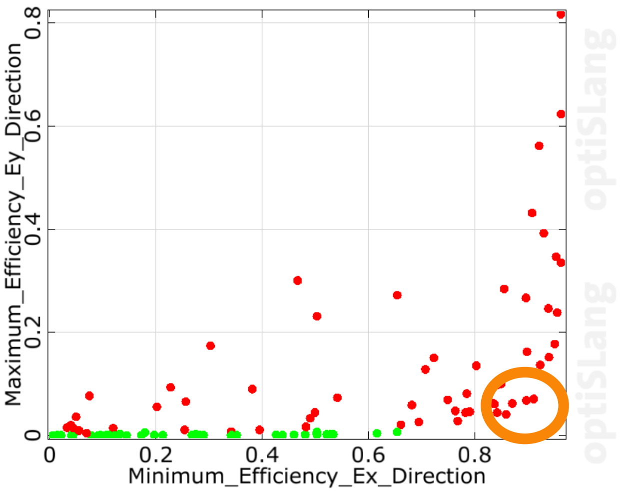
$$C = \eta_x / \eta_y \quad > \quad 50$$

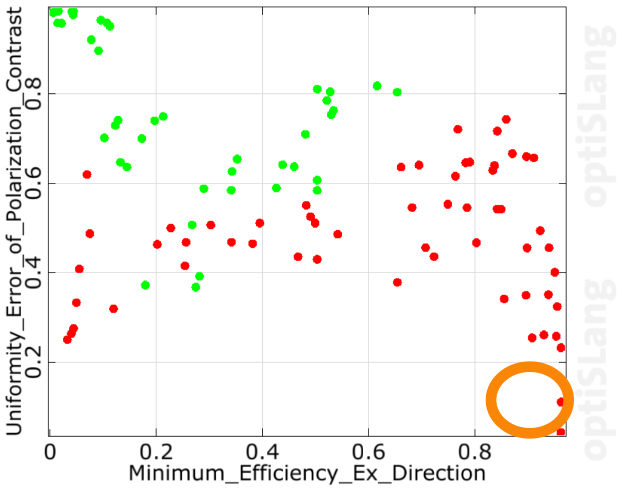
Approach without optiSLang

- Optimizer can handle single merit functions only.
- Multiple objective have to combined to a weighted merit function.
- Constraints have to be added as penalty terms to the merit function.

Sensitivty Analysis I: Objectives



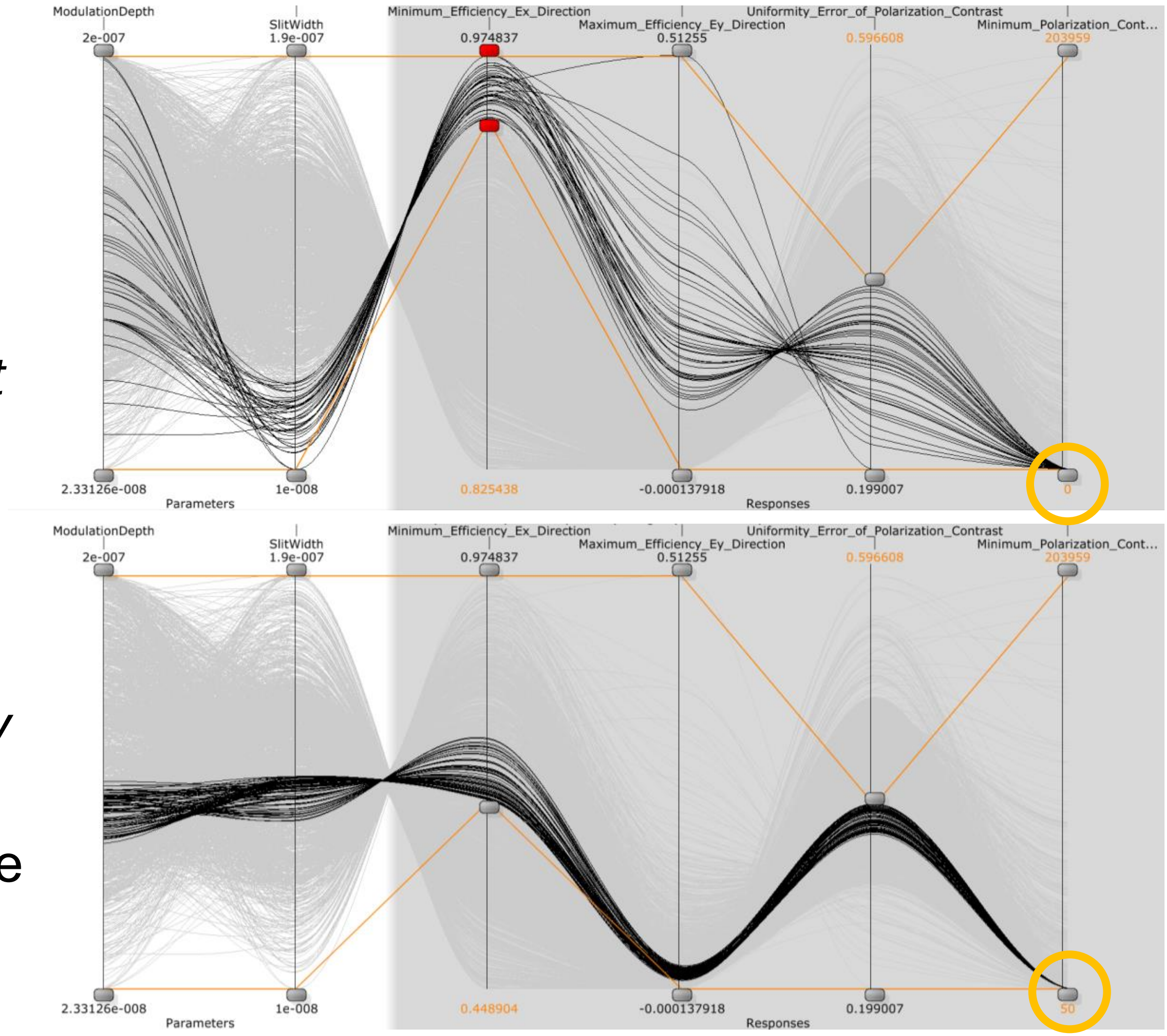




- Admissible Values: green dots (satisfy the constraint)
- Objectives are contradicting
- → Pareto optimization required

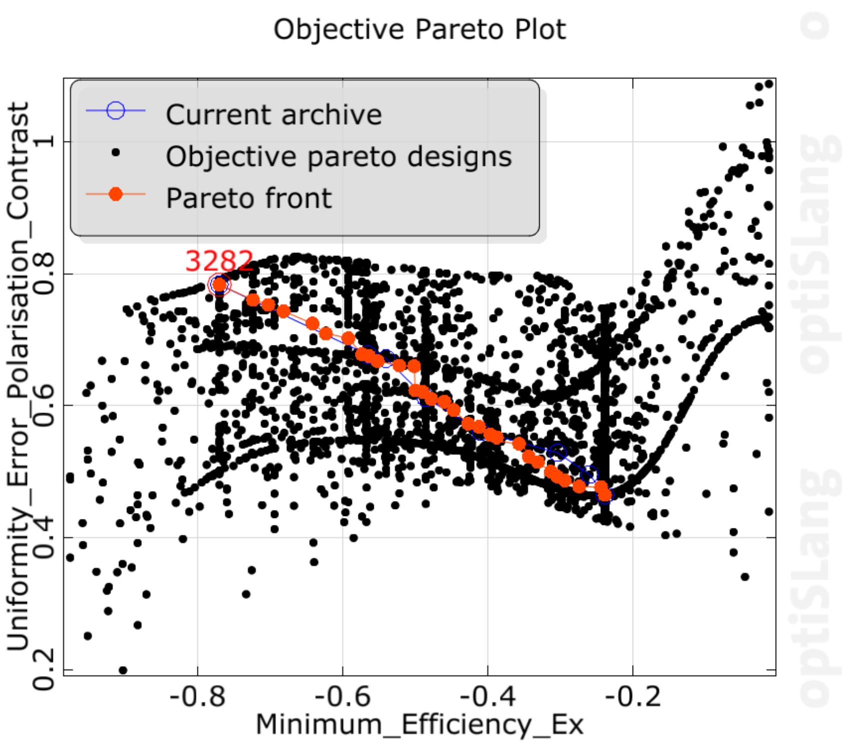
Sensitivty Analysis II

- Parallel Coordinates Plot helps to understand your design
- *Polarization Contrast* is set to 0, a *Minimum Efficiency* E_x of 97 % can be obtained; if set to 50 a *Minimum Efficiency* E_x of 60% $\rightarrow$ effect on input side can be immediately seen

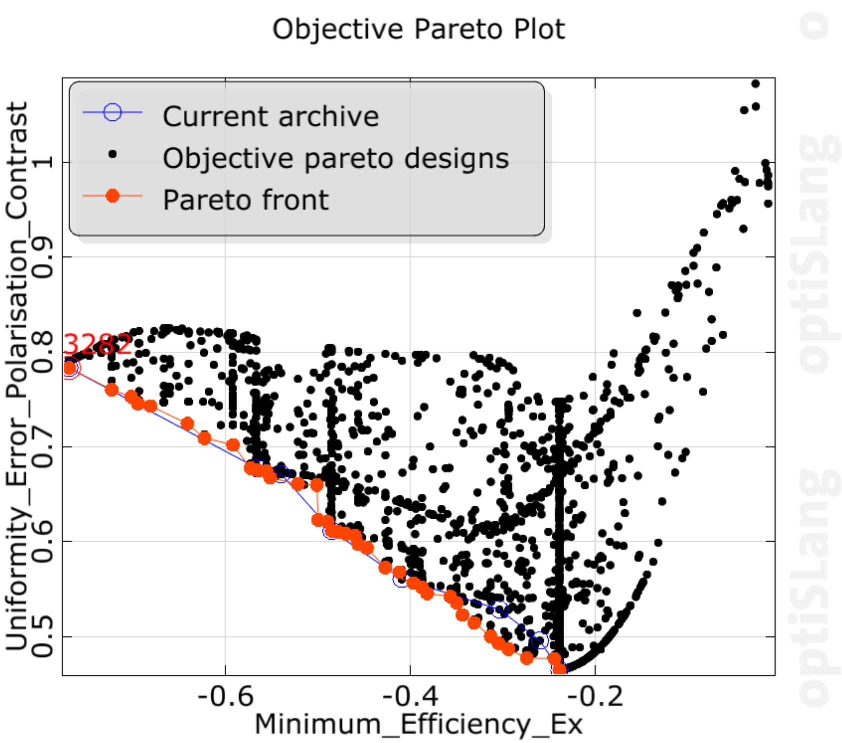


Pareto Optimization Results

All designs.



Feasible designs.



Approach with optiSLang

- Understand the behavior of multiple objectives
- Understand the influence of constraints to objectives
- A char of "good designs" as a compromise between both objectives is given
- Decision which design is best for application of interest can be set after optimization

	Start Design	Best Design Sensitivity Analysis	Best Design Optimization
Maximum Efficiency E_y	0,0073	0,0065	0,0143
Minimum Efficiency E_x	0,3419	0,6541	0,7231
PolContrast	47,0	100,7	156,0
UniformityError	0,4682	0,8038	0,7602

Summary

- optiSLang and VirtualLab together allow a powerful approach to design problems:
  - Optical simulation engines include ray tracing and physical optics
  - Optimization with continuous and discrete parameters
  - Multi-objective optimization (Pareto design)
  - Solving “Understand your design” by sensitivity analysis
  - Make use of optimization and robustness tools which are well established in mechanical engineering for many years.
  - Solution of opto-mechanical design tasks