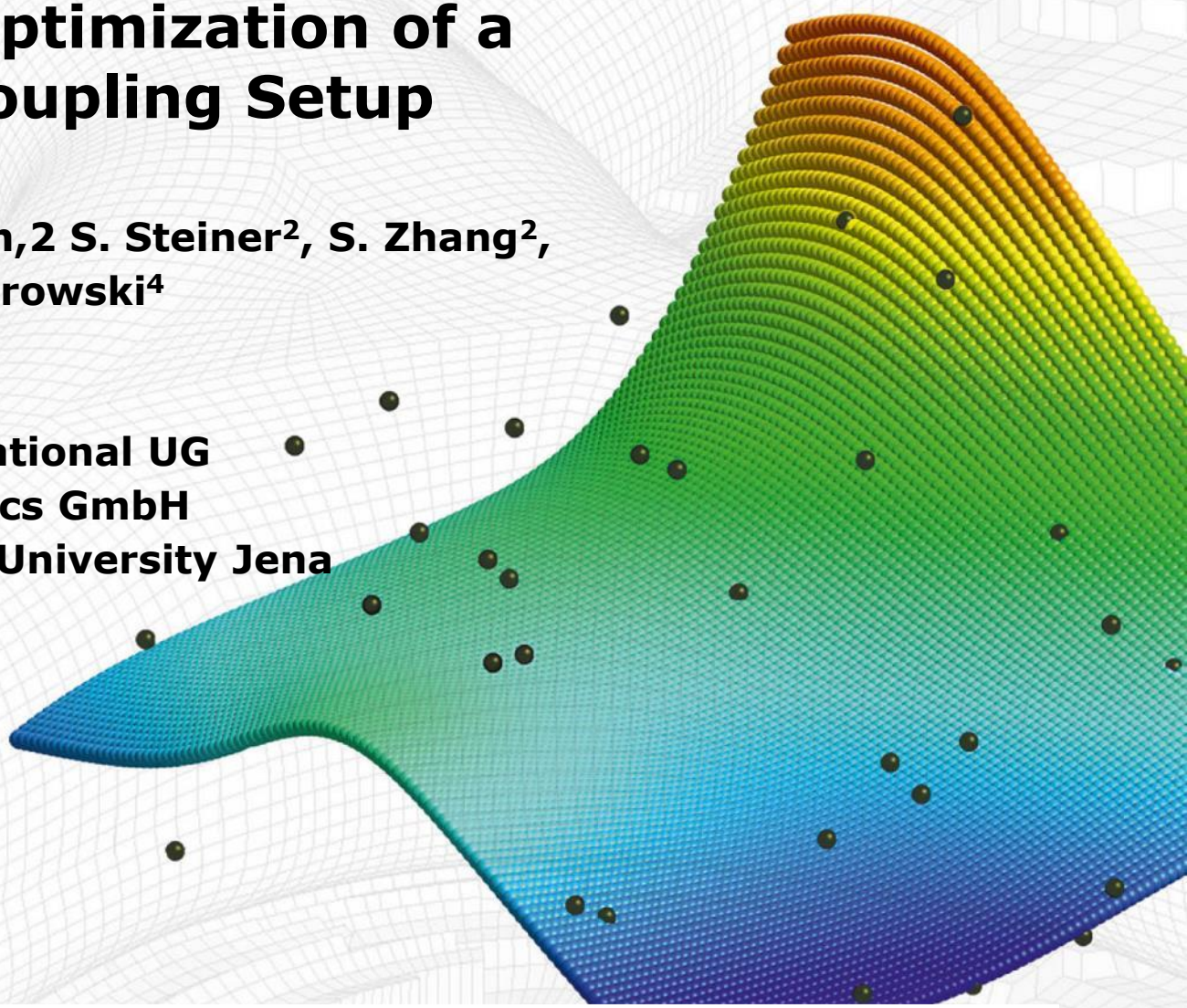
Systematic Optimization of a Lightguide Coupling Setup

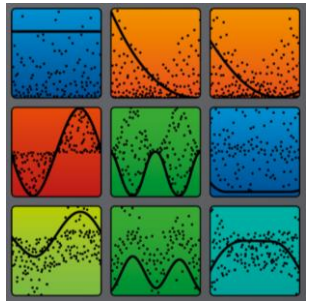
S. Kunath,[1] R. Knoth,2 S. Steiner[2], S. Zhang[2],
C. Hellmann[3], F. Wyrowski[4]

[1] Dynardo GmbH
[2] LightTrans International UG
[3] Wyrowski Photonics GmbH
[4] Friedrich-Schiller-University Jena

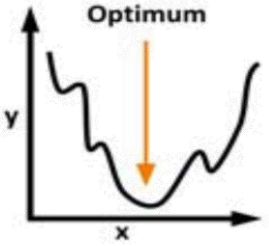


Motivation

- The **optimization of advanced optical designs** is very challenging due to their
  - complexity,
  - nonlinearity,
  - a huge number of input parameters and
  - interactions between them.

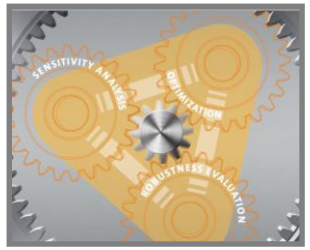


- The demands for the system's **performance** are
  - versatile and
  - very high and even get higher concerning optimization and robustness criteria.



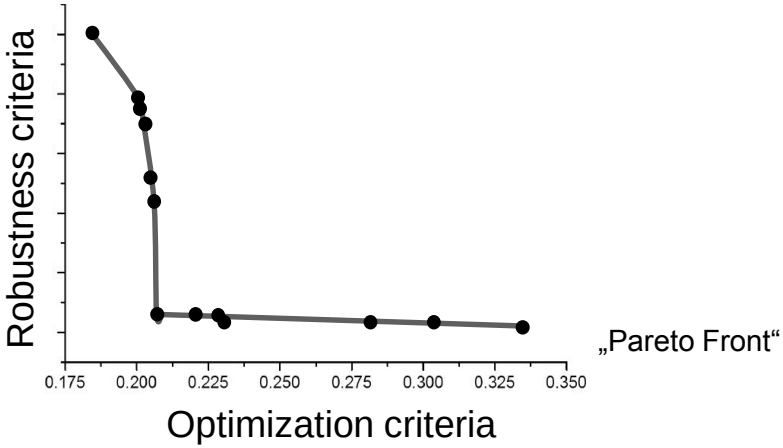
- Furthermore, **totally new developments**, like
  - new materials,
  - manufacturing possibilities and
  - very short product development times,

  simultaneously, require advanced methodologies to develop competitive optical products.



Solution: Software optiSLang

- Dynardo supports the whole virtual product development process with software solutions including
  - **Process integration** (e.g. VirtualLab, SPEOS, Zemax, Matlab)
  - **Building workflows** (e.g. coupling several physical domains)
  - **Automation**
  - **Robust Design Optimization**



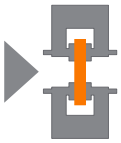
„Pareto Front“

Robust Design Optimization for Product Development

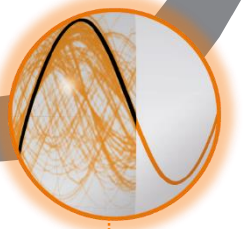
Design Understanding
Investigate parameter sensitivities, reduce complexity and generate best possible meta models

Design Improvement
Optimize design performance

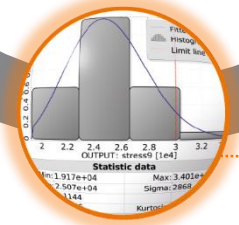
CAE-Data



Measurement Data

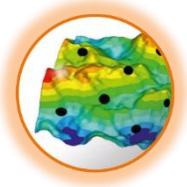


Model Calibration
Identify important model parameter for the best fit between simulation and measurement



Design Quality
Ensure design robustness and reliability

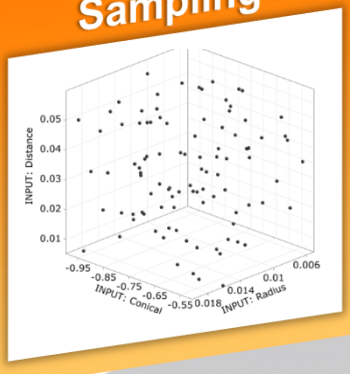
Robust Design



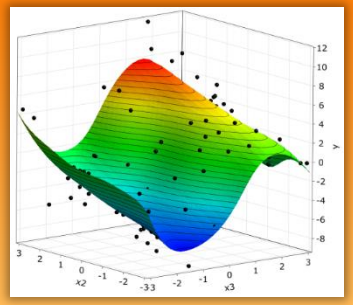
Sensitivity Analysis

Understand the most important input variables!

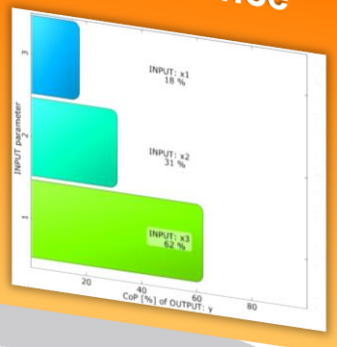
Latin Hypercube Sampling



Metamodel of Optimal Prognosis

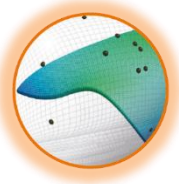


Input parameter importance



Automatic workflow
with a minimum of solver runs to:

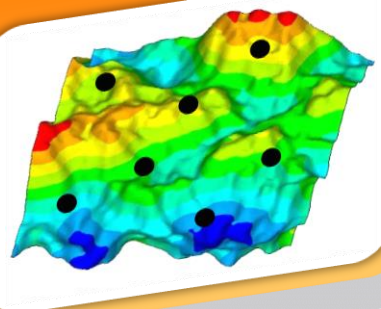
- identify the important parameters for each response
- Generate best possible metamodel for each response
- understand and reduce the optimization task
- check solver and extraction noise



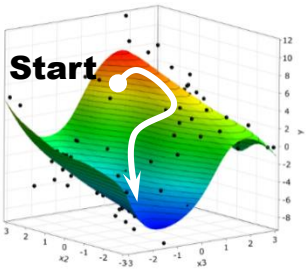
Optimization

Optimize your product design!

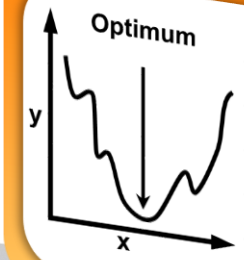
Sensitivity analysis



Optimization using Metamodel



Direct Optimization with algorithms:



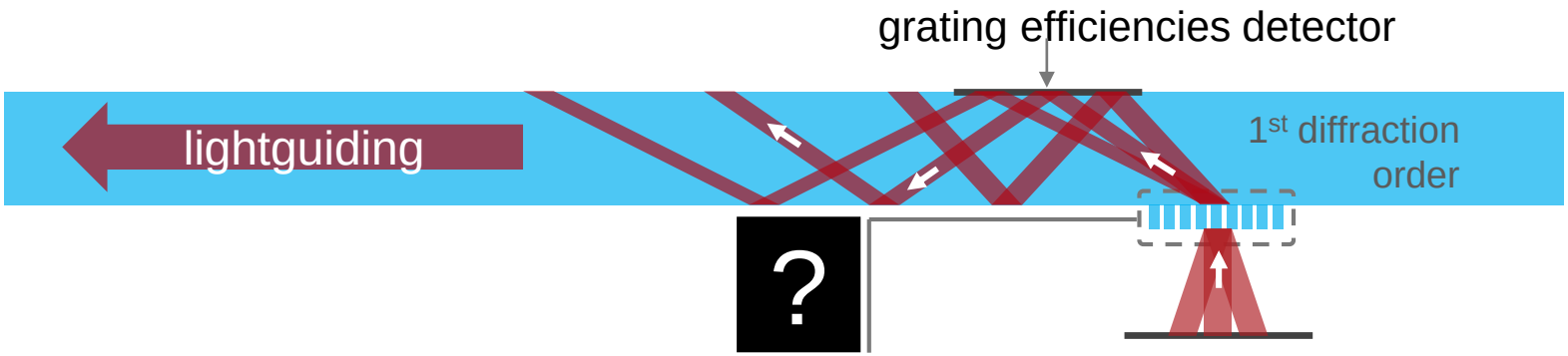
- ✓ NLPQL
- ✓ ARSM
- ✓ Simplex
- ✓ EA
- ✓ PSO

- **work with the reduced subset of only important parameters**
- **pre-optimization on meta model**
- **optimization with leading edge optimization algorithms**
- **decision tree for optimization algorithms**

Example: Binary grating for lightguide coupling

Optimization Task: Binary Grating Coupling

- How to design a binary grating structure to couple a set of plane waves into a planar lightguide?

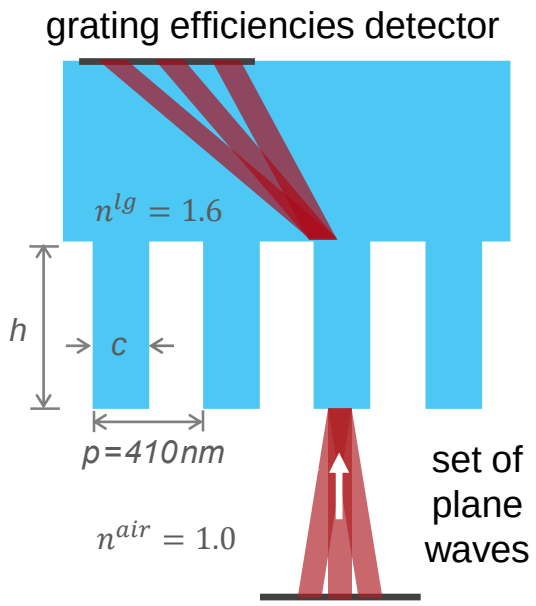


set of plane waves

- field of view (-15..15, -10..10)°
- wavelength 532nm
- linearly polarized along x-axis

Problem description: Inputs

- Parameters to be varied for optimization



Inputs

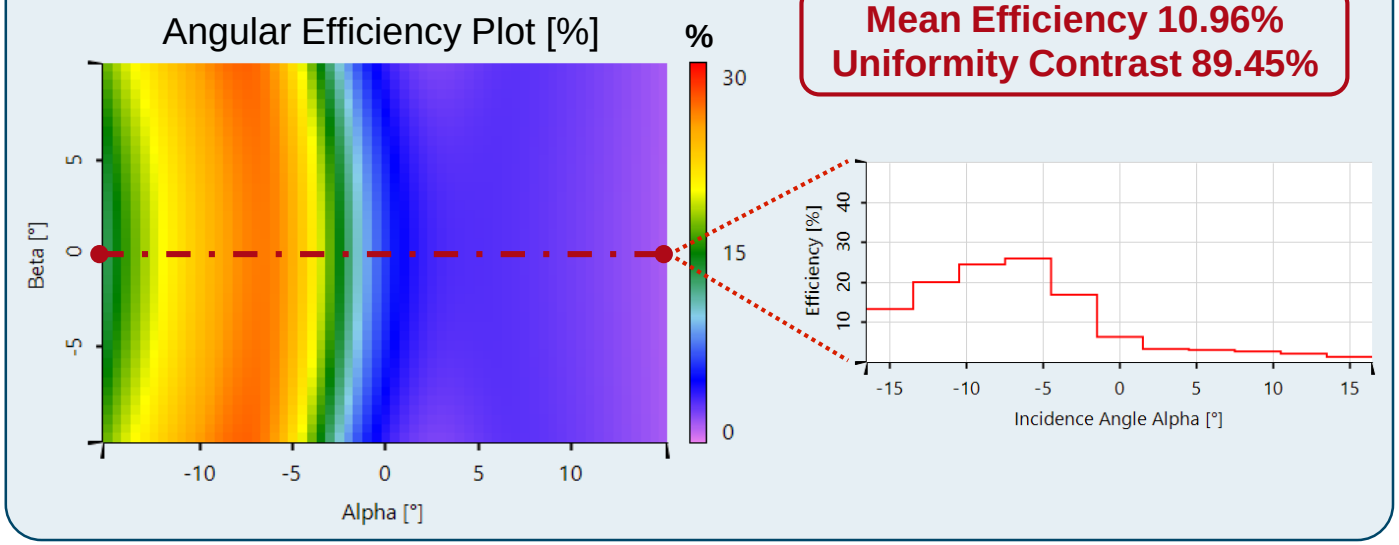
- variation of the **fill factor** *c/p* with the slit width *c* and the period *p*
  - ➢ **0.1% to 99.9%**
- variation of the **modulation depth** *h*
  - ➢ **50 nm to 1500 nm**

Initial Configuration of Grating	
fill factor	50.00%
modulation depth	400.00 nm
period	410 nm
operating order	1st transmitted

Problem description: Outputs

- Aim of the optimization over the desired FOV:
  - Maximize Mean Efficiency
  - Minimize Uniformity Contrast

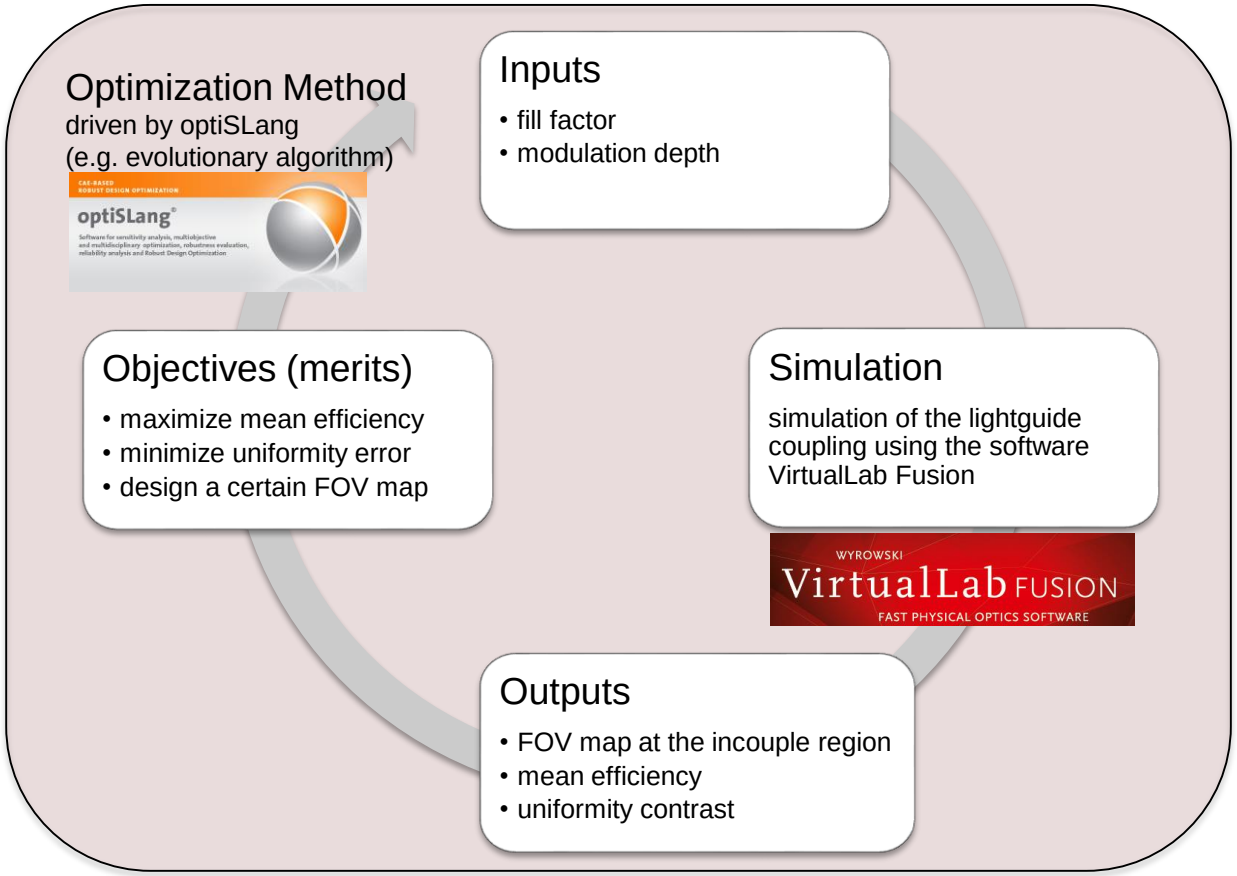
Detector Result: Grating Efficiencies



Mean Efficiency 10.96%
Uniformity Contrast 89.45%

Optimization Workflow

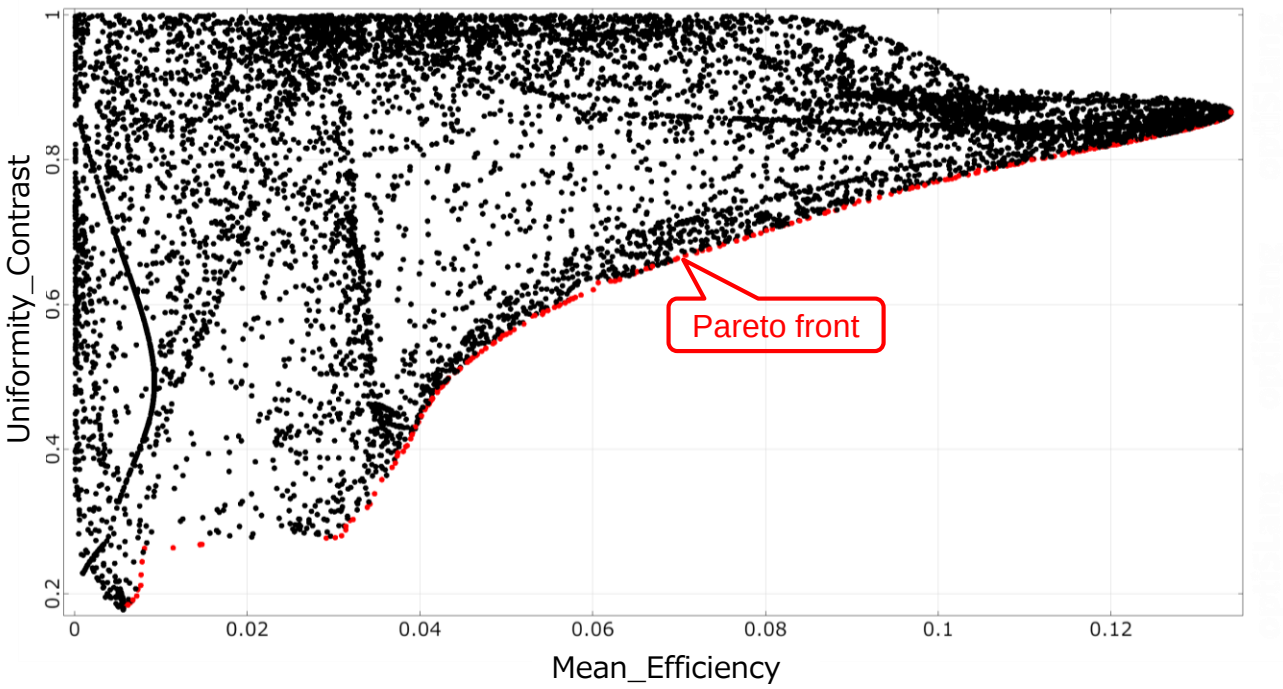
- Automation and optimization driven by optiSLang using VirtualLab Fusion for optical design simulation



Use Case: https://www.lighttrans.com/use-cases/feature-use-cases/grating-optimization-in-virtuallab-fusion-using-optislang.html

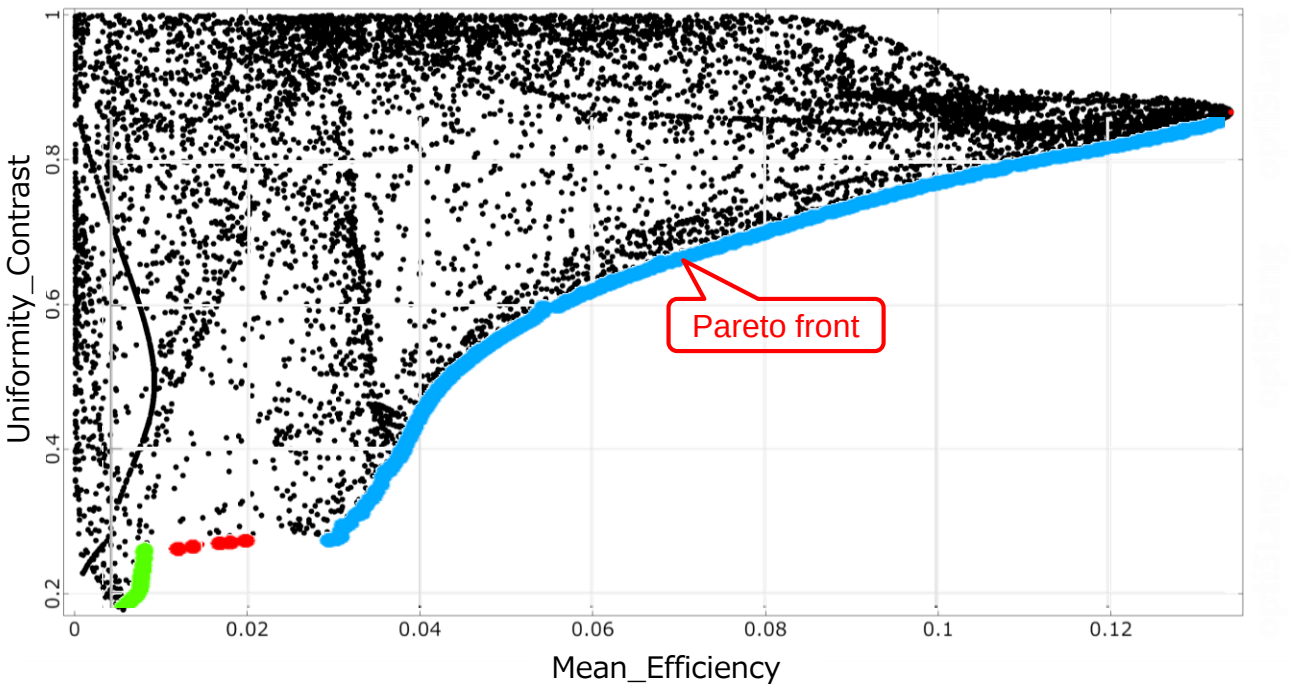
Optimization Results

- Pareto Front of two contradicting objectives:
  - Mean Efficiency
  - Uniformity Contrast
- Pareto Front illustrates optimal compromise between objectives
- Choice of best design depends on the needs of the optical designer



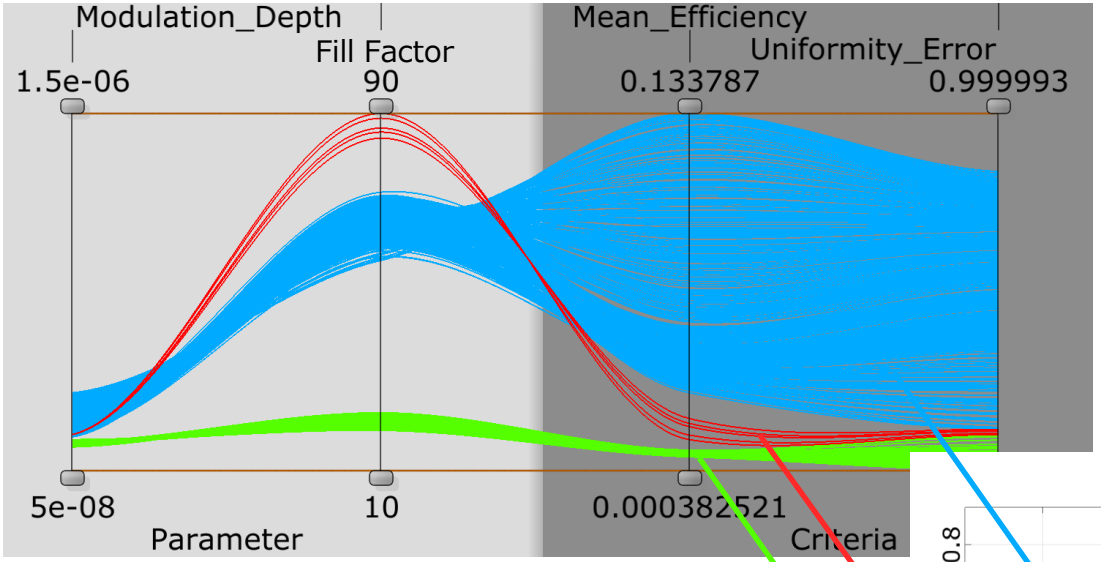
Optimization Results

- Pareto Front of two contradicting objectives:
  - Mean Efficiency
  - Uniformity Contrast
- Pareto Front illustrates optimal compromise between objectives
- Choice of best design depends on the needs of the optical designer



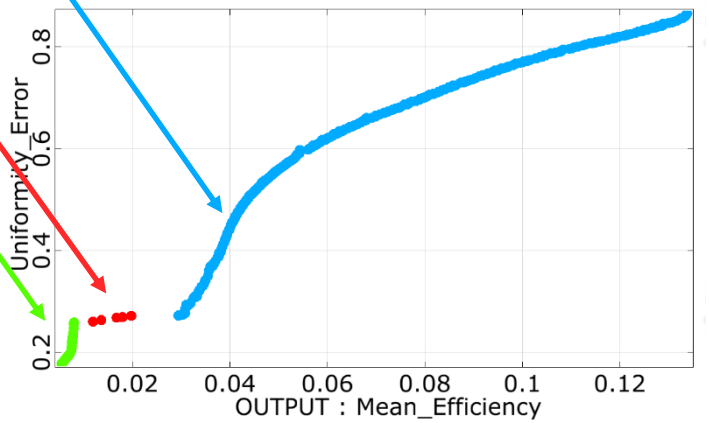
Optimization Results: Pareto Front Designs

- Cluster Analysis of Fill Factor (3 clusters)



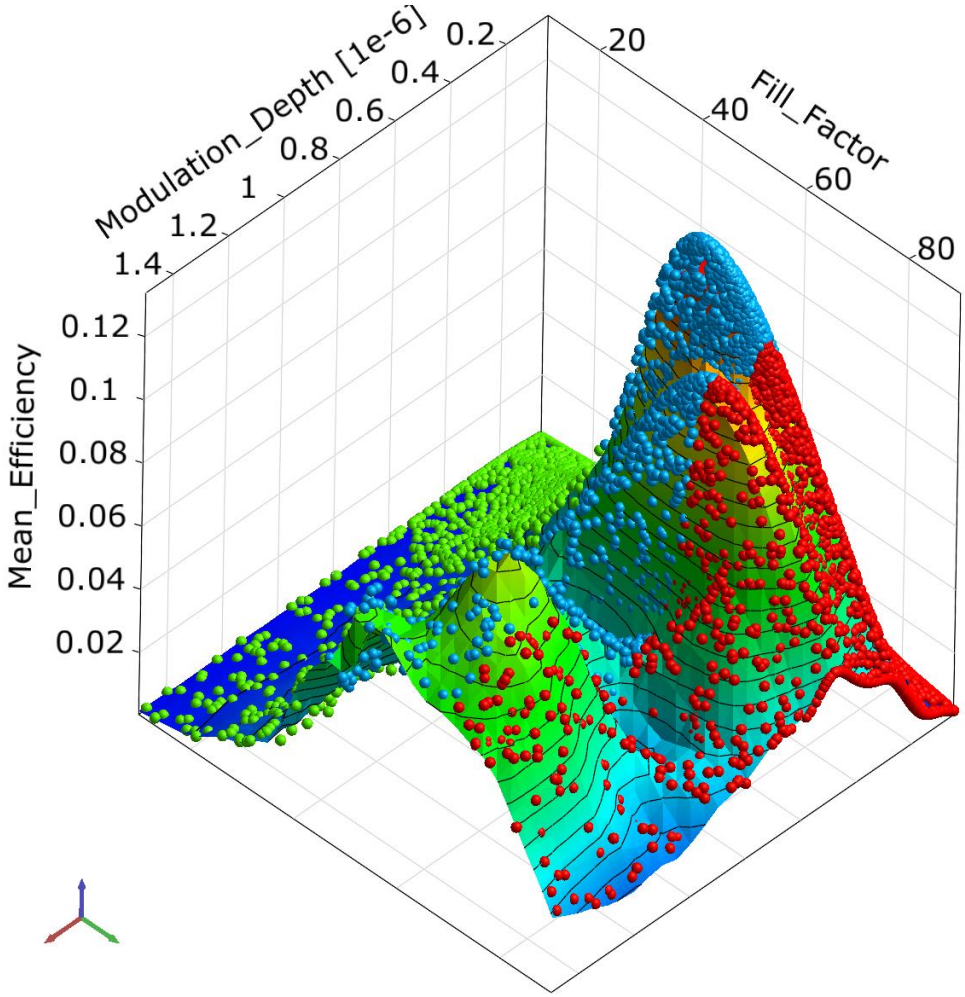
Parallel Coordinates Plot

Anthill Plot



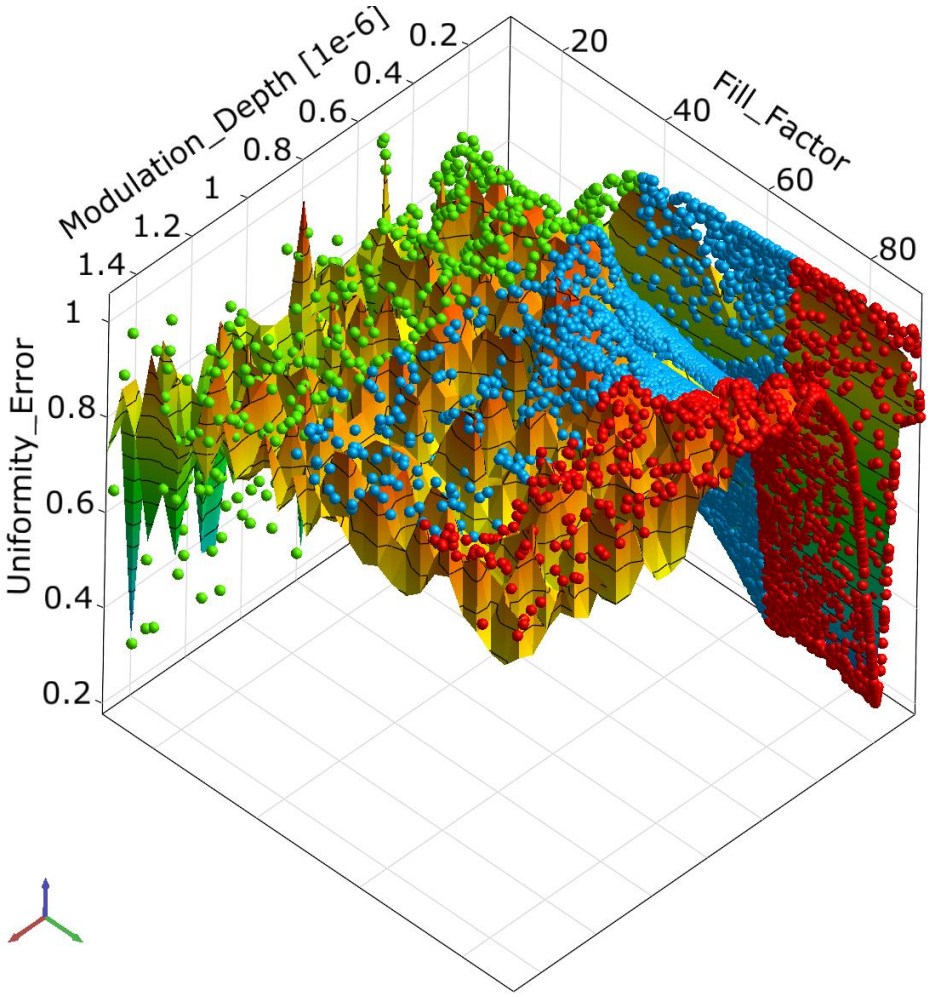
Optimization Results: Metamodelling

- **Metamodel of Optimal Prognosis** that shows the influence of the two input parameters **modulation depth** and **fill factor** on the **mean coupling efficiency** of the binary grating



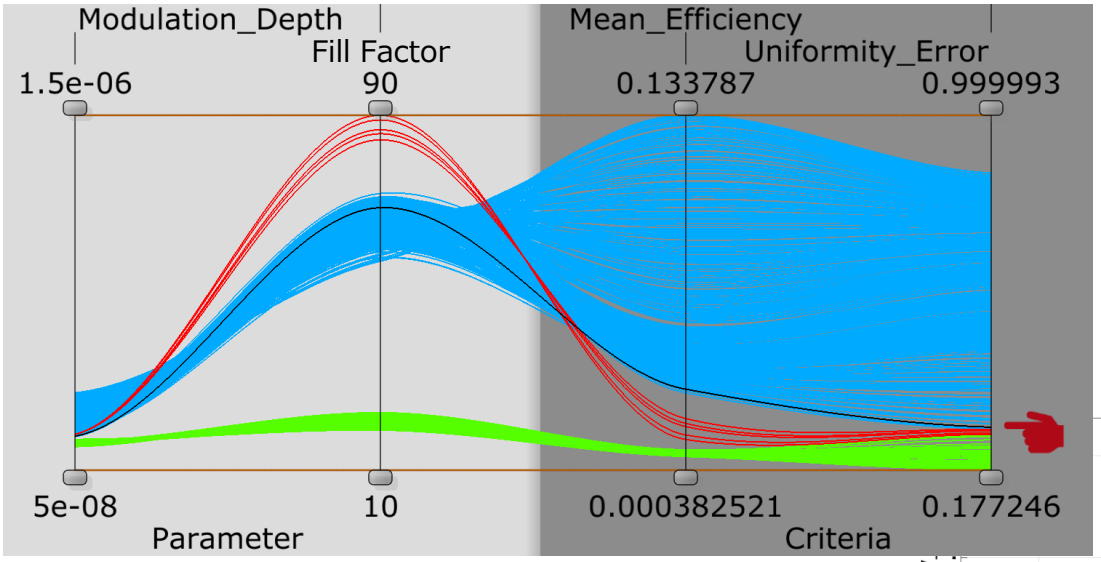
Optimization Results: Metamodelling

- **Metamodel of Optimal Prognosis** that shows the influence of the two input parameters **modulation depth** and **fill factor** on the **Uniformity contrast** of the binary grating



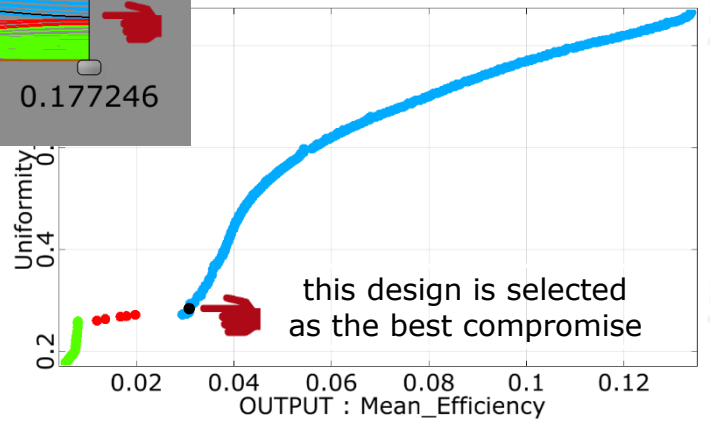
Optimization Results: Best design selection

- Best design selection: best compromise for a prioritized low uniformity contrast and an acceptable mean efficiency including manufacturable grating parameters



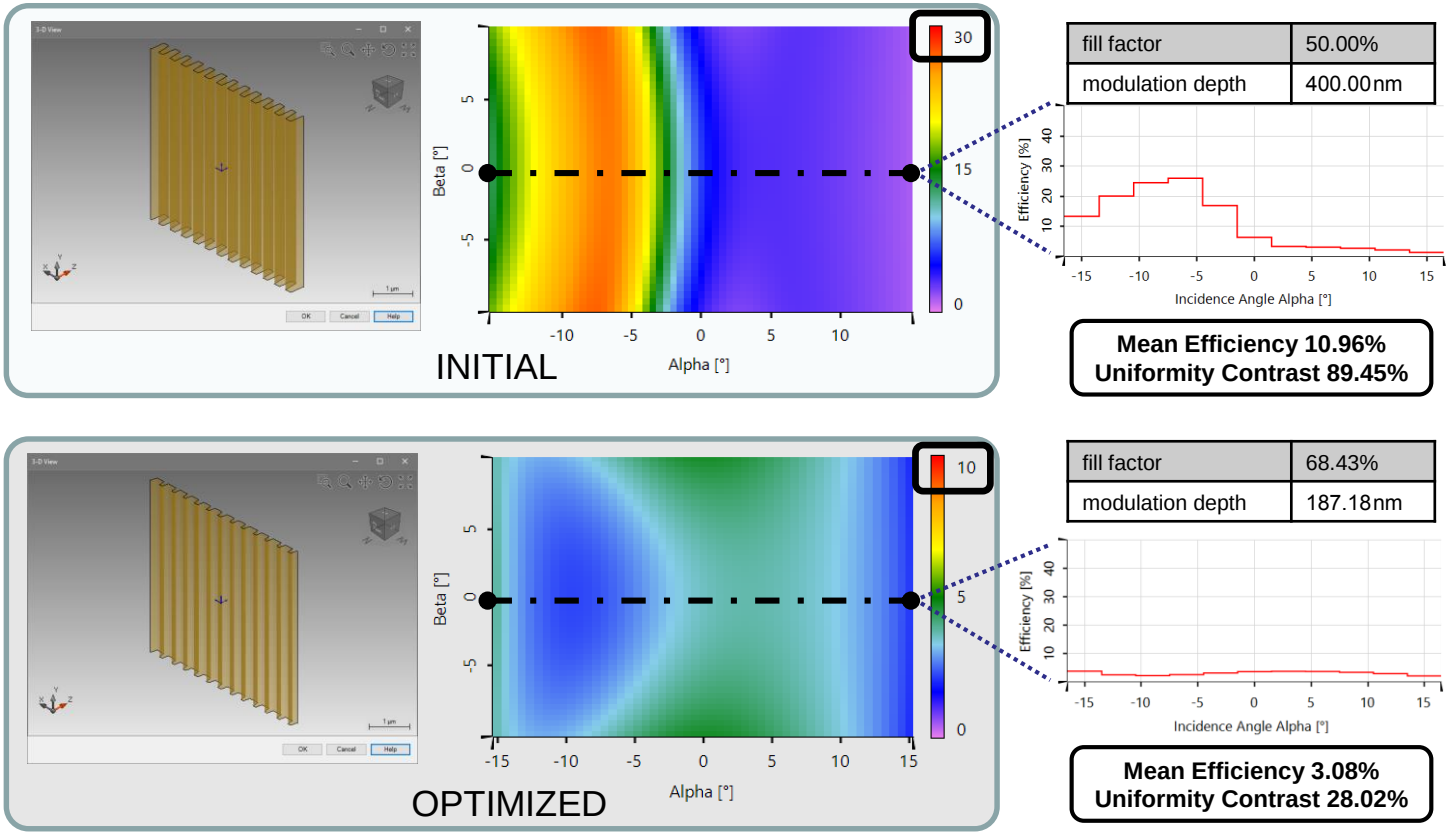
Parallel Coordinates Plot

Anthill Plot



Results: Coupling Efficiency after Optimization

- As a result, the uniformity contrast was significantly reduced but to the cost of the entire efficiency

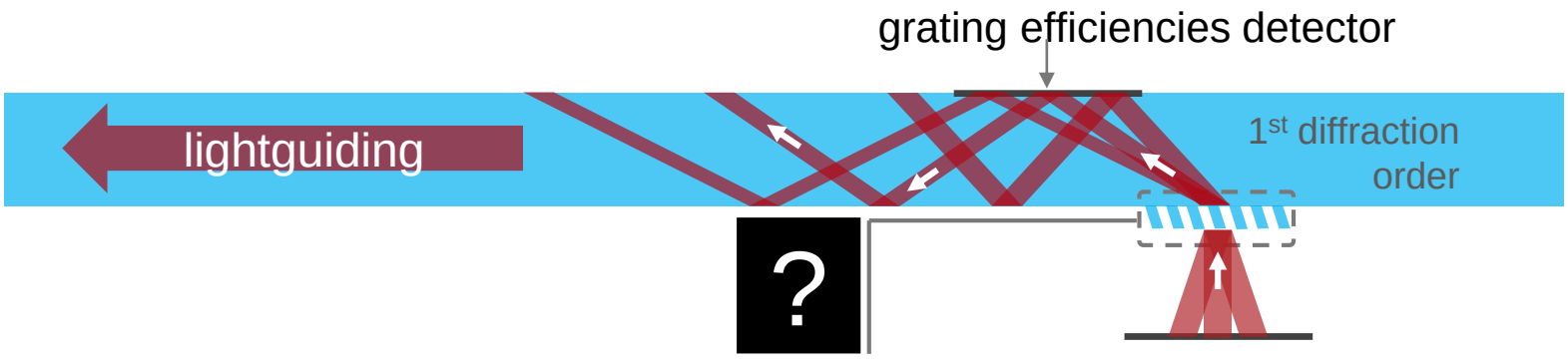


Use Case: https://www.lighttrans.com/use-cases/application-use-cases/optimization-of-binary-grating-for-lightguide-coupling-over-desired-fov.html

Example: Slanted grating for lightguide coupling

Optimization Task: Slanted Grating Coupling

- How does the additional free parameter of the slant angle affect the design of the incouple grating?

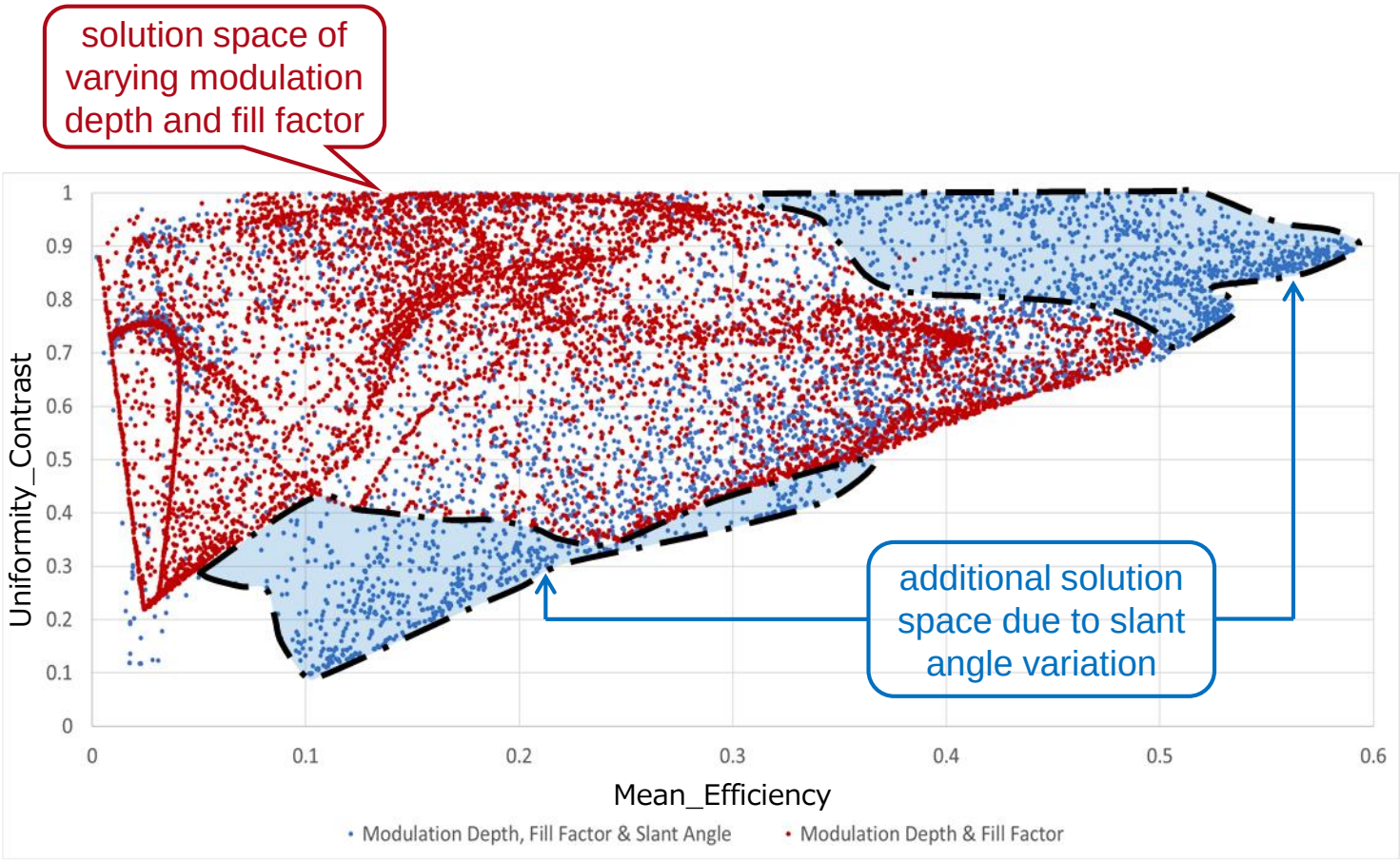


set of plane waves

- field of view (-15..15, -10..10)°
- wavelength 532nm
- linearly polarized along x-axis

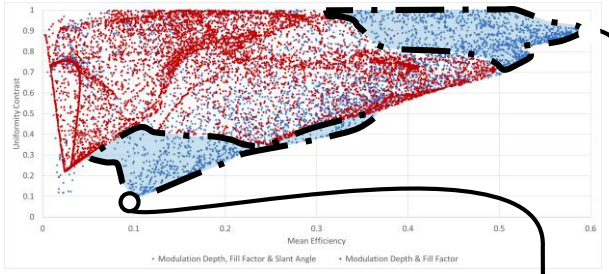
Optimization Result of optiSLang

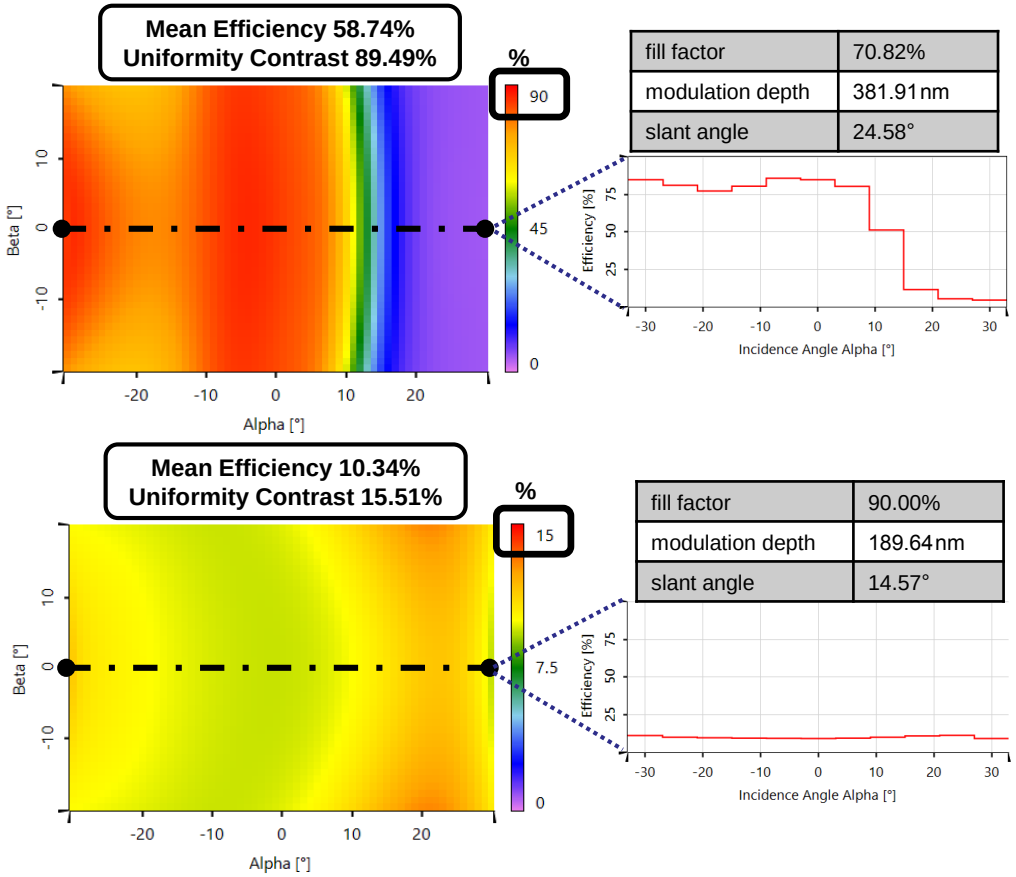
- The additional freedom of the slant angle provides additional solutions



Results: Coupling Efficiency after Optimization

- Best solution can be selected according specific constraints
- Either uniformity contrast or mean efficiency might be prioritized

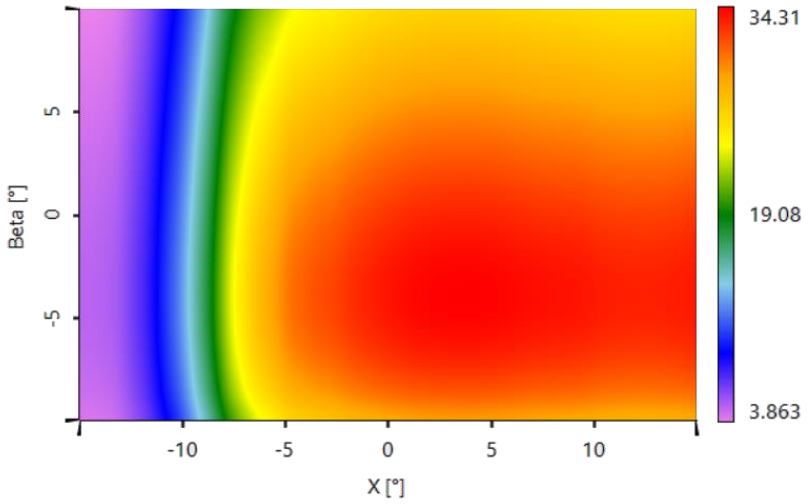




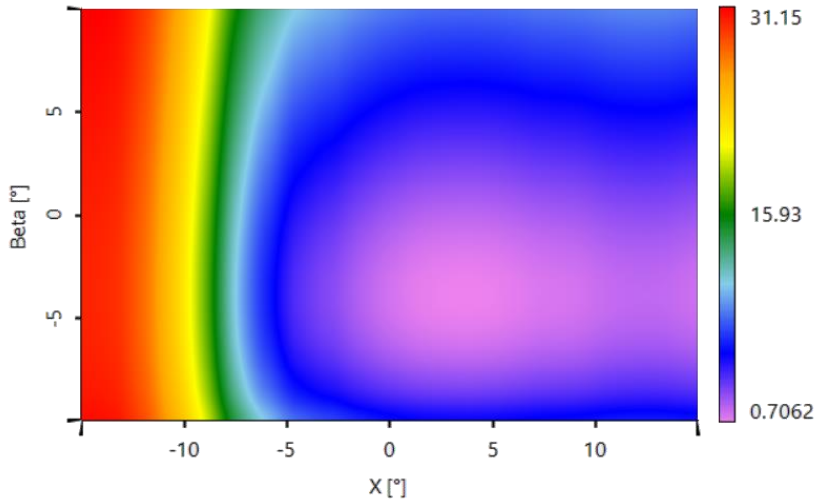
Use Case: https://www.lighttrans.com/use-cases/application-use-cases/optimization-of-slanted-grating-for-lightguide-coupling-over-desired-fov.html

Further work and outlook

- 2D data analysis for further understanding and improved optimization results, e.g. to obtain a desired angular efficiency

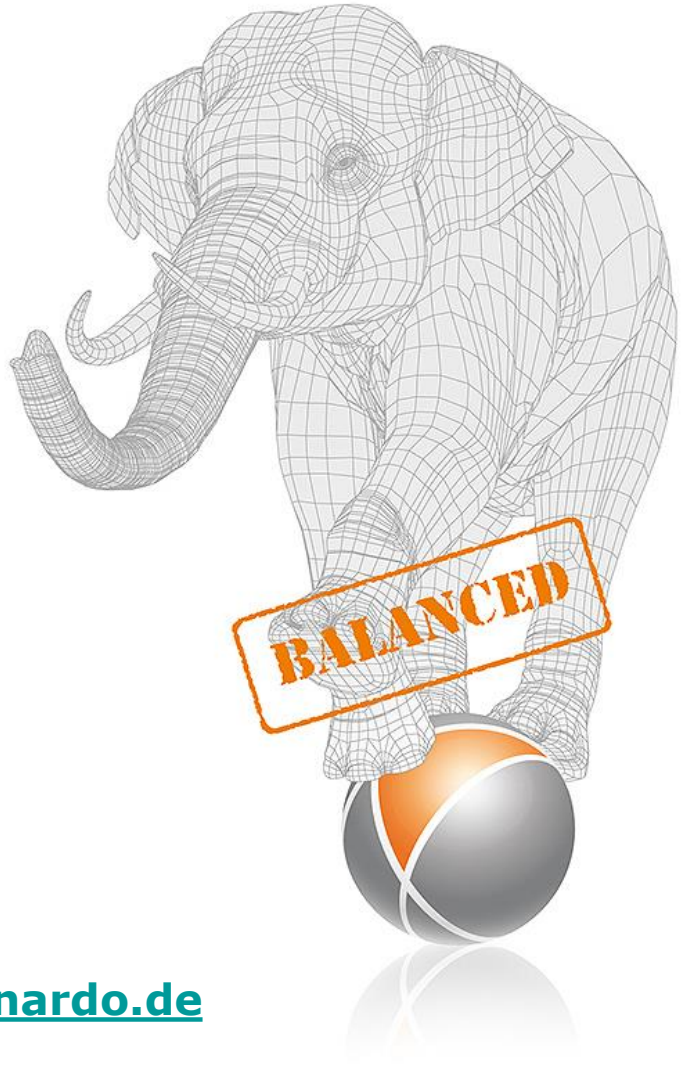


Calculated Angular Efficiency at Eye-Box



Assumed Desired Angular Efficiency at Incouple Region

Thank you for your attention!



Further information: www.dynardo.de

Contact information: stephanie.kunath@dynardo.de