# PlanOpSim

## Meta Optics Design Software & Services

PlanOpSim

Enlightened Planar Optics

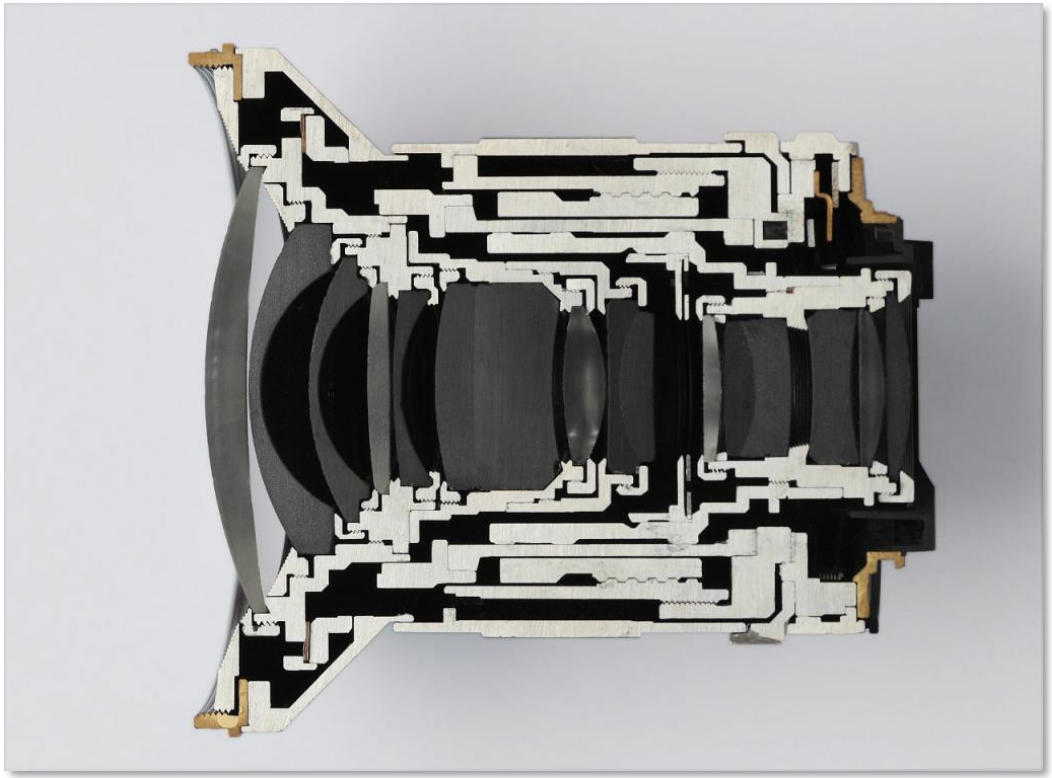
WWW.PLANOPSIM.COM

06/11/2023

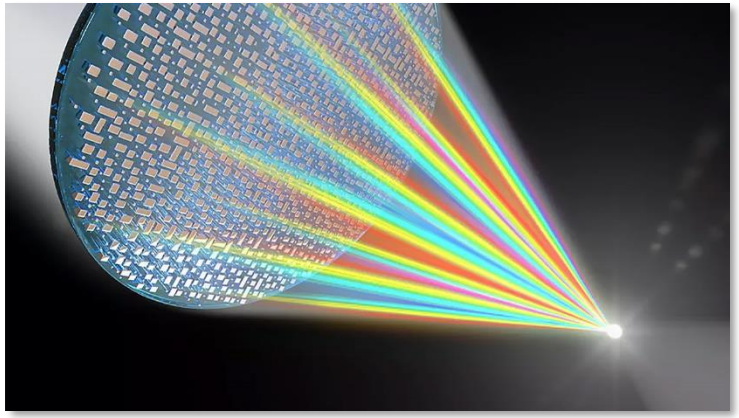
# Today

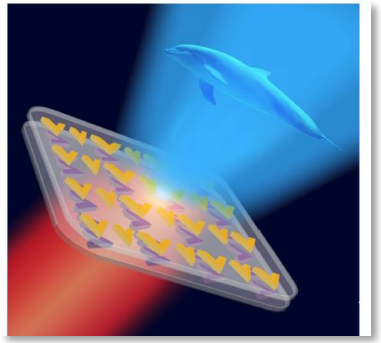
# Future: Nano-enabled

PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

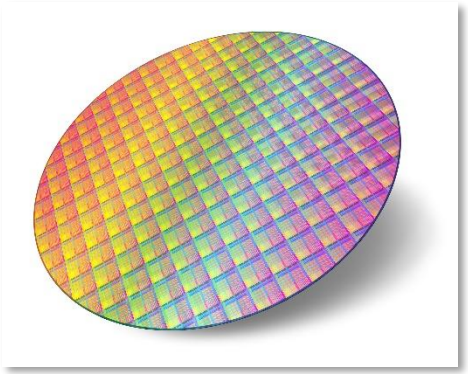


Higher Performance
Simplified
Miniaturized
New Applications



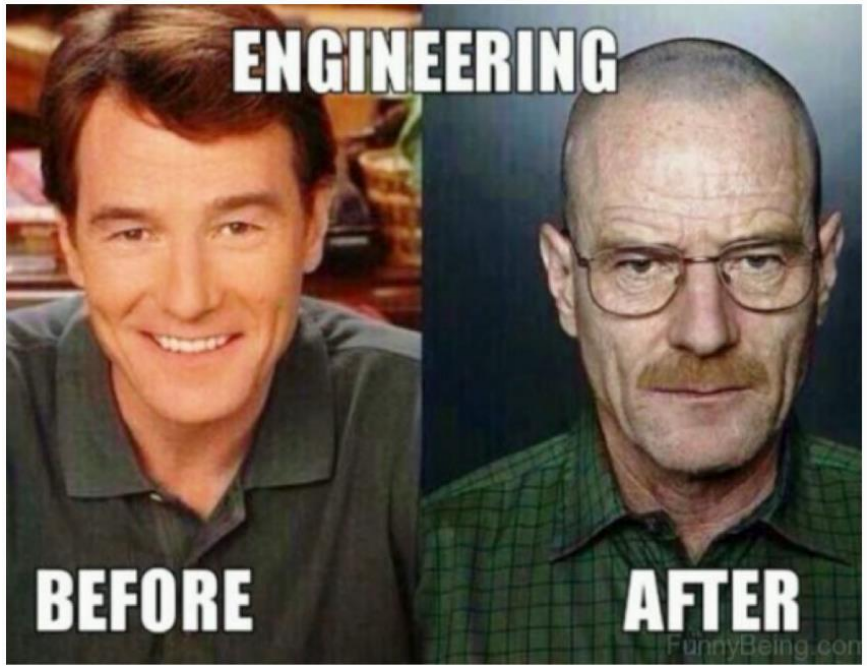


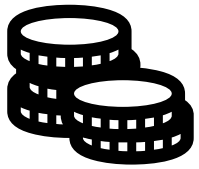

Art to Industry
Lower Cost



# Engineering is HARD work

PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM



Design is costly

- **Expensive** staff
- **Large investment** needs

Design is complex

- **Multiple** specialists required
- **Multi-party collaboration** required

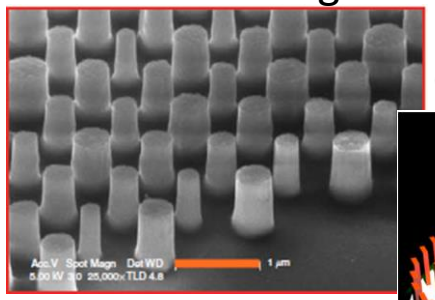
Design is time consuming

- R&D cycle is **long**
- **Slow** simulation speed

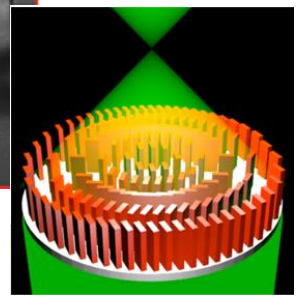
# PlanOpSim

PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

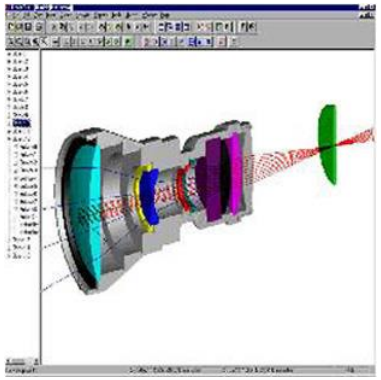
Nano-scale design



Component design



System Integration



**Planopsim's mission**

**Planopsim** supplies **R&D tools** to **engineers** & **scientists** that allow to unlock the maximum benefit of **flat optics** in a **user-friendly** way.

- Computer Aided Design **software** for Planar Optics & metasurfaces
  - All-in-one design workflow
- **Design service** for metasurfaces and photonics
  - In-house and 3$^{d}$ party tools
- Custom **training** course

# Unique tool for meta-surface design

PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

| | PlanOpSim Enlightened Planar Optics | Ansys Lumerical | LightTrans | Synopsys |
|---|---|---|---|---|
| **CLOUD** OR LOCAL | ✓ | ✗ | ✗ | ✗ |
| **INTUITIVE** LEARNING CURVE | ✓ | ✗ | ✗ | ✗ |
| **LARGE AREA** | ✓ | ✗ | ✗ | ✗ |
| INTEGRATION WITH **RAY TRACING** | ✓ | ✓ | ✓ | ✓ |
| SCRIPTING | ✓ | ✓ | ✓ | ✓ |
| EXPORT TO **MANUFCATURING** | ✓ | ✗ | ✓ | ✓ |
| **FULL** METASURFACE **WORKFLOW** | ✓ | ✓ | ✗ | ✓ |
| DEDICATED META-SURFACE **SUPPORT** | ✓ | ✗ | ✗ | ✗ |

- **Dedicated** meta-surface **UI** and design **workflow**
- High speed & large area simulation:
  - **18x faster** than FDTD
  - area up to **4000x larger**
- **Multi-scale** simulations from **nano- to macroscale**
  - Meta-atom -> full wave RCWA
  - Components -> Physical optics
  - Systems -> Integration to ray-tracing

# The Real Results

PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

## Customers:


## User feedback

Thank you very much! I'm **really enjoying the application** already; the examples are great. The metacell portion is **very intuitive** for anyone familiar with modeling periodic structures.

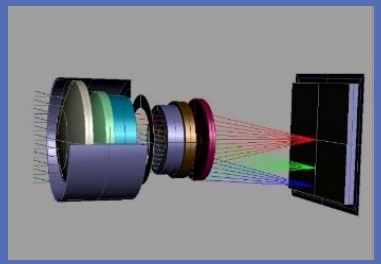
I found the PlanOpSim Software **most useful and appropriate for designing metalenses**. It really helped me to design the required lenses **with ease and instantaneous results**.We would like to continue using the software for our research. We are interested in both meta cell and meta component modules.

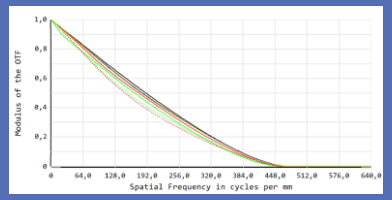
I think the software is a **real time saver**, I will be happy to use it in the future, thanks again!

# Meta-surface design workflow

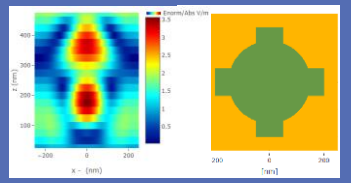
PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

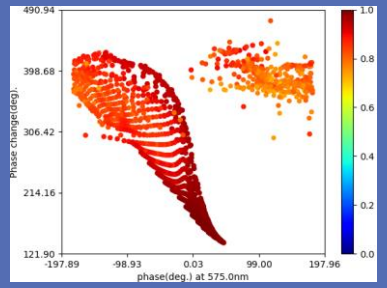
## System model
- Ray tracing
- Hybrid Design



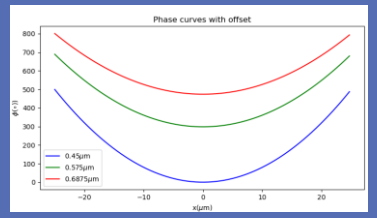


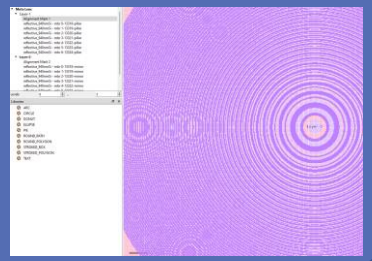

## Library building
- Structure library
- Extract dispersion



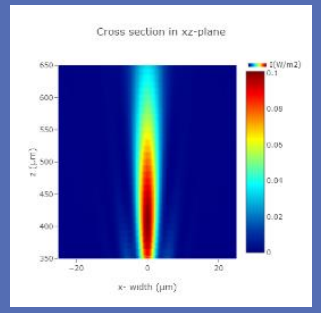


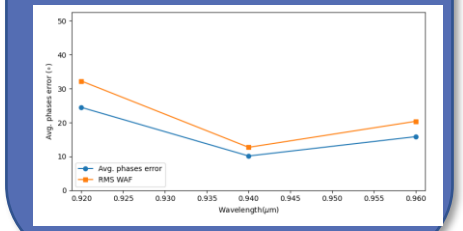

## Component Design
- Target matching
- Mask generation



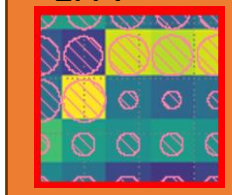
## Analysis
- Chromatic focal shift
- Efficiency & PSF



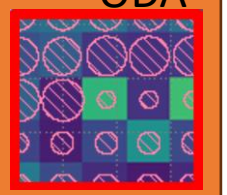



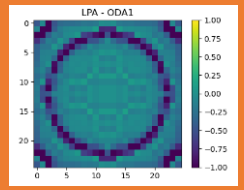

## ODA analysis
- Verify local periodic approximation

LPA



ODA



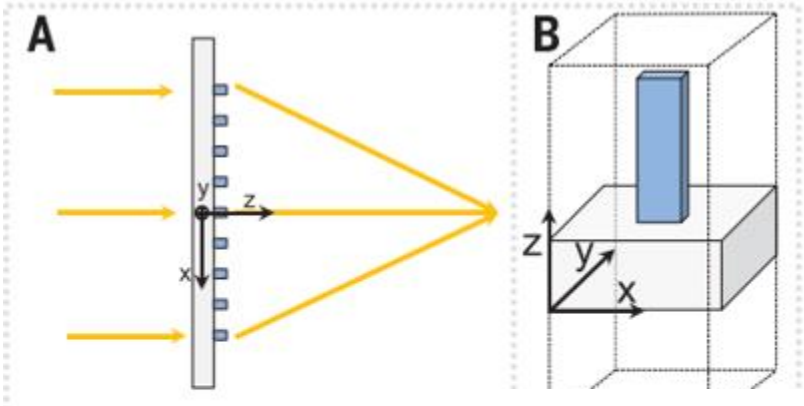


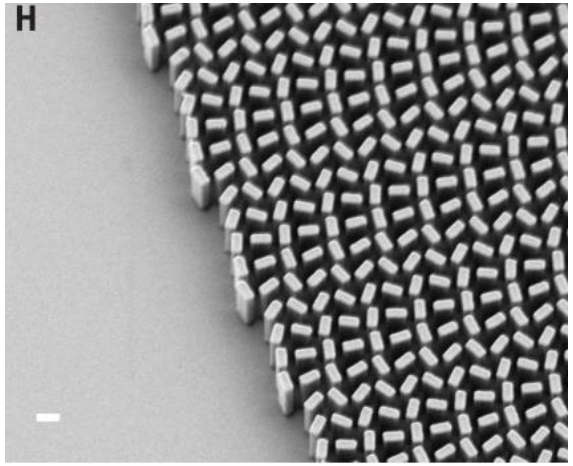

## System analysis
- Actual metalens back in raytracing

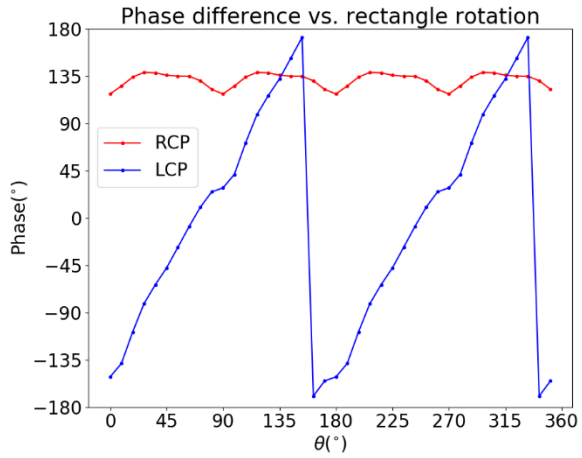
# Example: metalens design

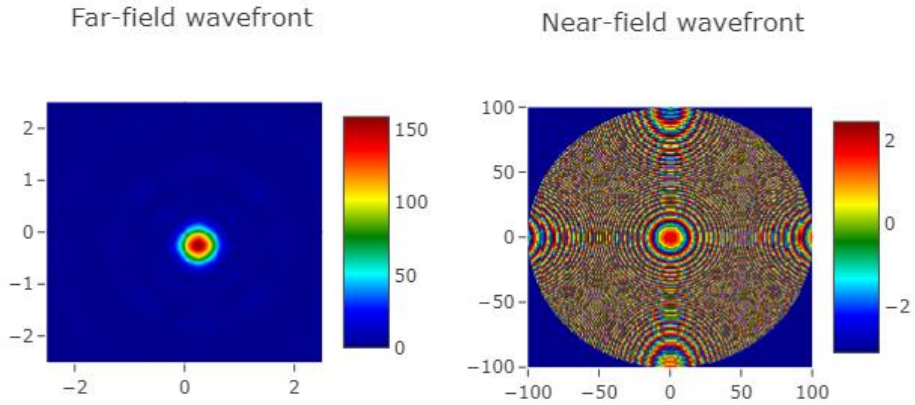
PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

- Design of a metalens with diffraction limited focusing and NA 0.55 for 632nm
- Structures with TiO2 on glass
- Integrated workflow:
  - Tuning of nano-pillars
  - Design of full metalens



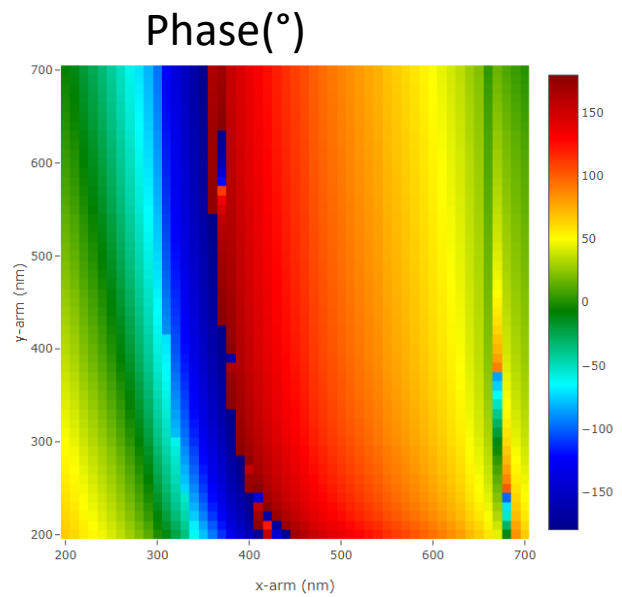




Focal spot and phasefront

# Meta-atom optimization

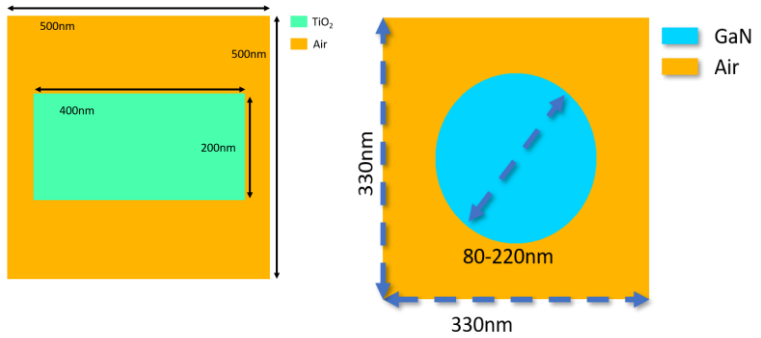
PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

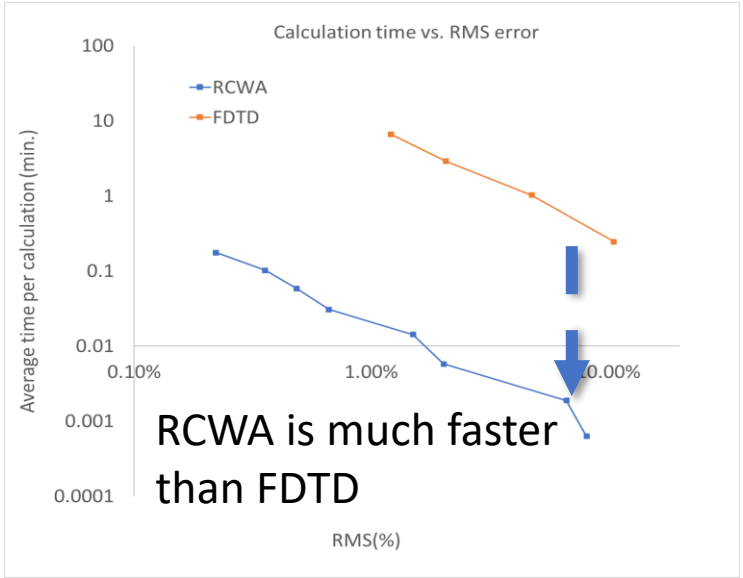
- Full maxwell solution using Rigorous Coupled Wave Analysis
  - ➢ Sub wavelength features
- Thousands of nano-structures in parameter space
- Benchmark PlanOpSim (RCWA) to FDTD
  - ➢ RCWA is much faster for meta-atom calculations
  - ➢ Full wave result RMS error < 0,65%

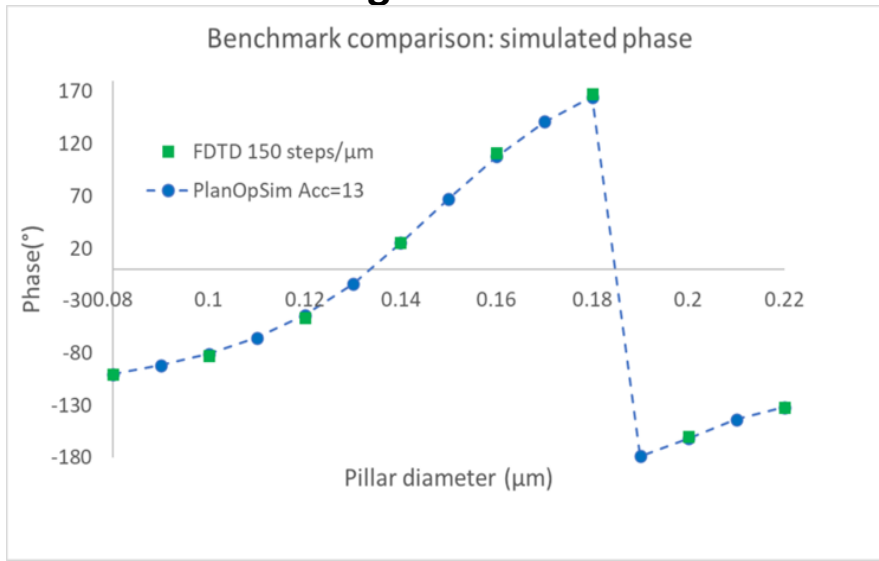



**RCWA (PlanOpSim) and FDTD calculation in agreement**

Test structure



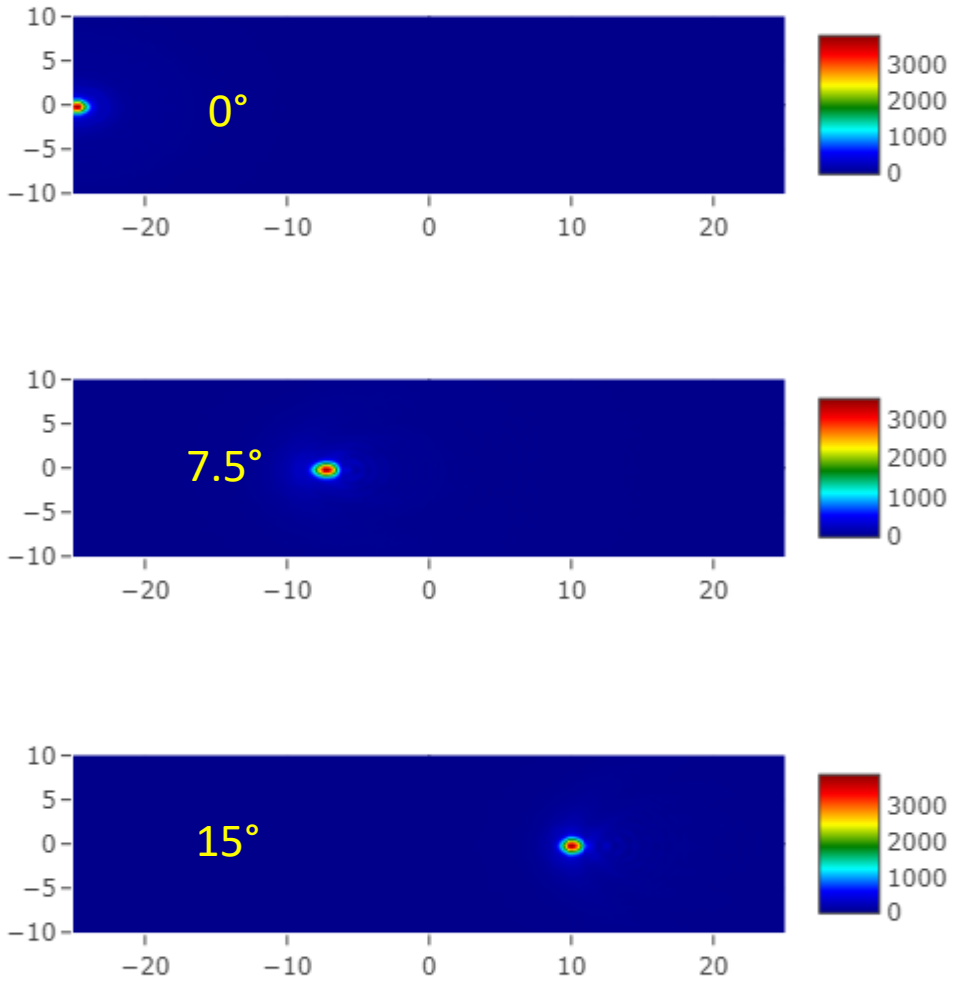



# Example: meta-lens & analysis

PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

*X. Luo, *Engineering Optics 2.0*. 2019.

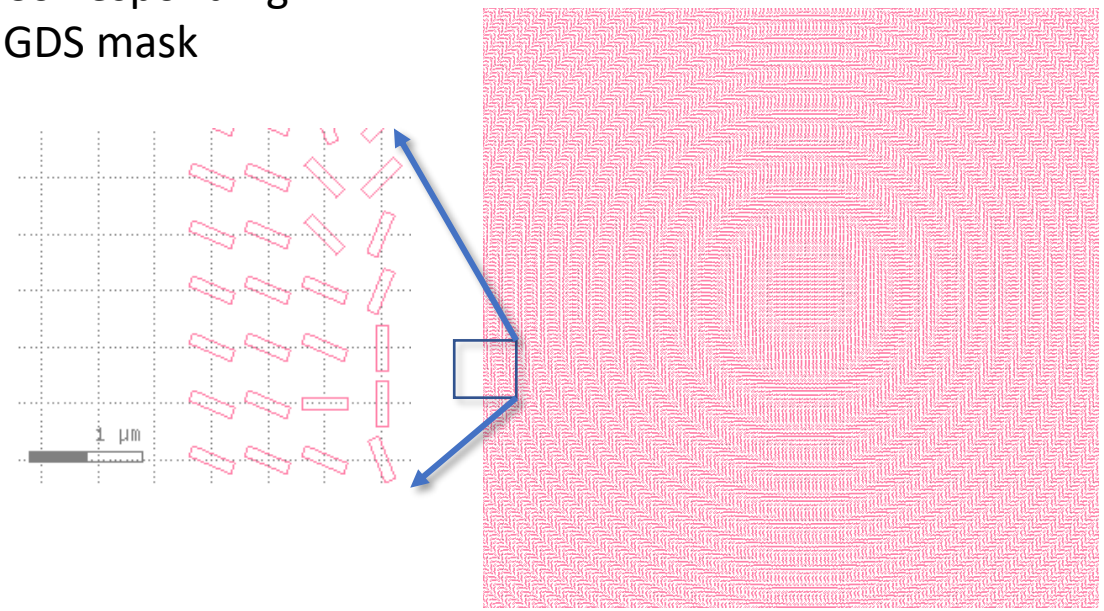
Meta-surface Focal spot vs. Field-of-view




Meta-lens performance analysis

- Physical optics regime
- Flexible and fast **parameter variations**
- Direct **output to manufacturing**
- Seamless integration to full wave calculation

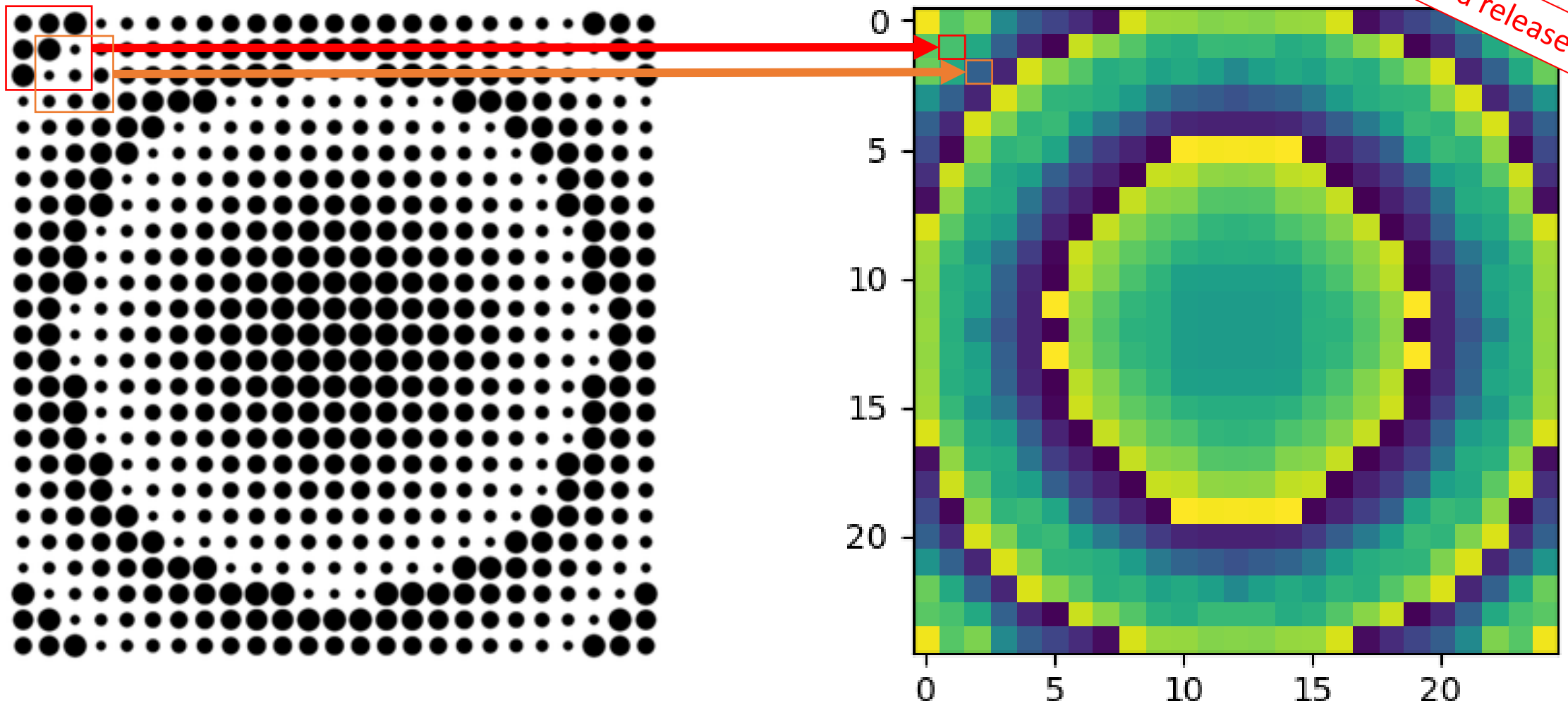
Corresponding GDS mask



# Advanced methods

PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

**Overlapping Domain Analysis** accounts for **interaction of meta-atom with neighbouring structures**. Local calculation **avoids memory restriction** of full wave calculation.

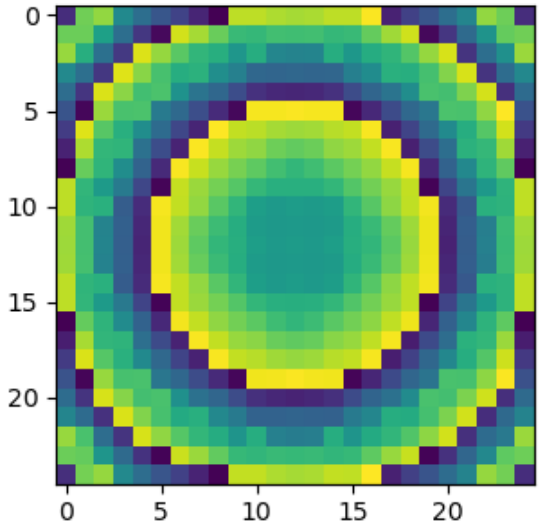



Beta release November 2023

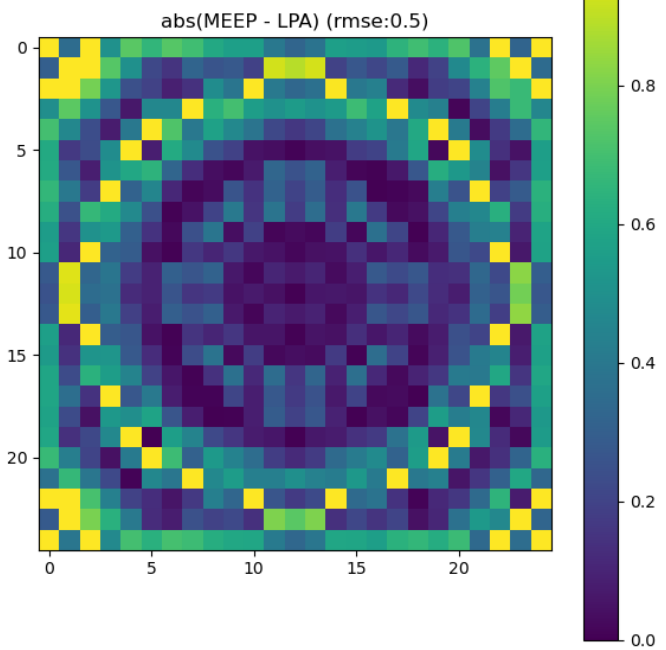
# Benchmark: component level

PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

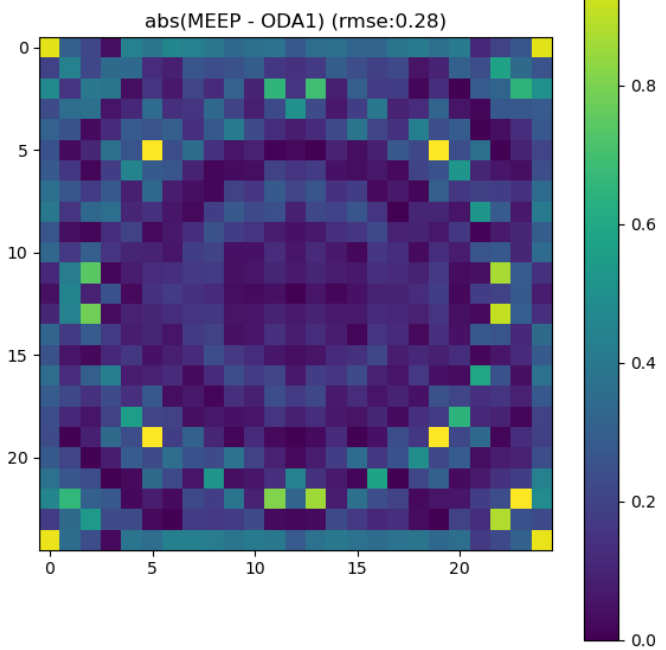
## Full wave ‘ground truth’




## LPA error map




## ODA error map




**Overlapping Domain Analysis** improves meta-surface calculation accuracy and is **18x faster than full wave calcultion**

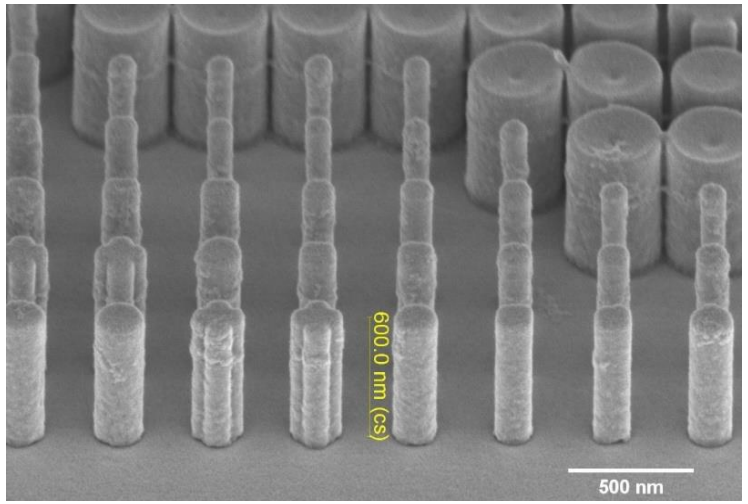
| | Calculation time* | Memory usage | rmse | Max. diameter* |
|---|---|---|---|---|
| LPA | 1 minute | <1Gb | 0,5 | 6000 µm |
| ODA | 20 minutes | 8Gb | 0,28 | 120µm** |
| Full wave (meep) | 6 hours | 32Gb | | 10µm |

*10µm diameter metalens
Core i9, 64Gb RAM PC
** Time limited to 24h calculation

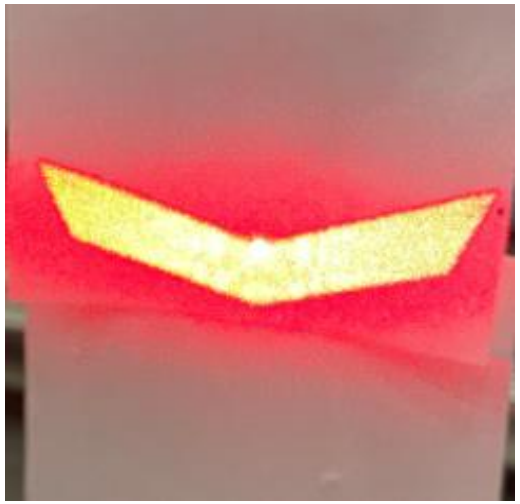
# The proof of the pudding

PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

- Apllication example: image projecting meta-surface
- Design fabricated from PlanOpSim software
- Fabrication by e-beam lithography and RIE
- Wide full cone opening angle 40°




SEM of fabricated sample



High brightness projection
(hologram efficiency 70%)

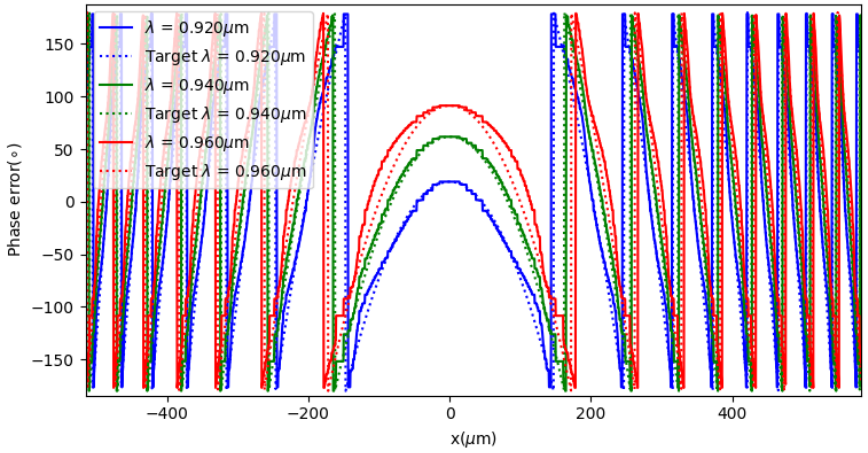
Application example

# Hybrid meta-system

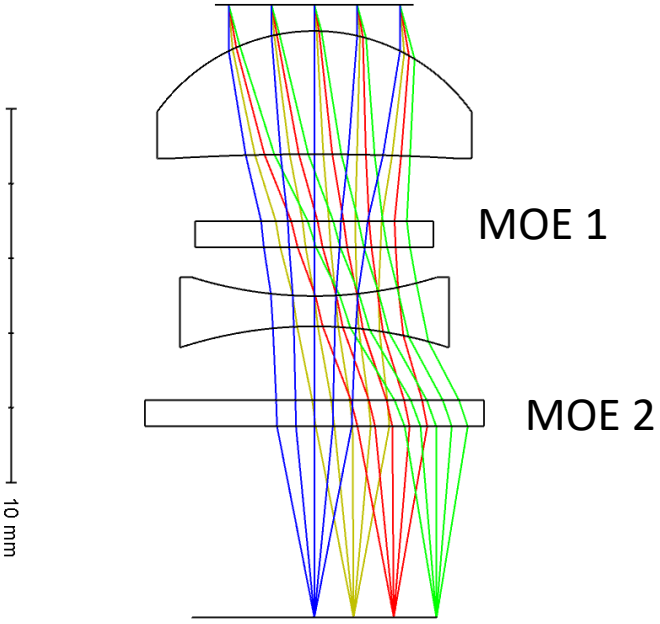
PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

- **Hybrid** meta-system: **classical + meta-surfaces**
- Meta-surface (PlanOpSim) & ray-tracing
- Dispersion engineered and multiplexed designs
- Nano-structure informed system optimization
- Import from and export to system design

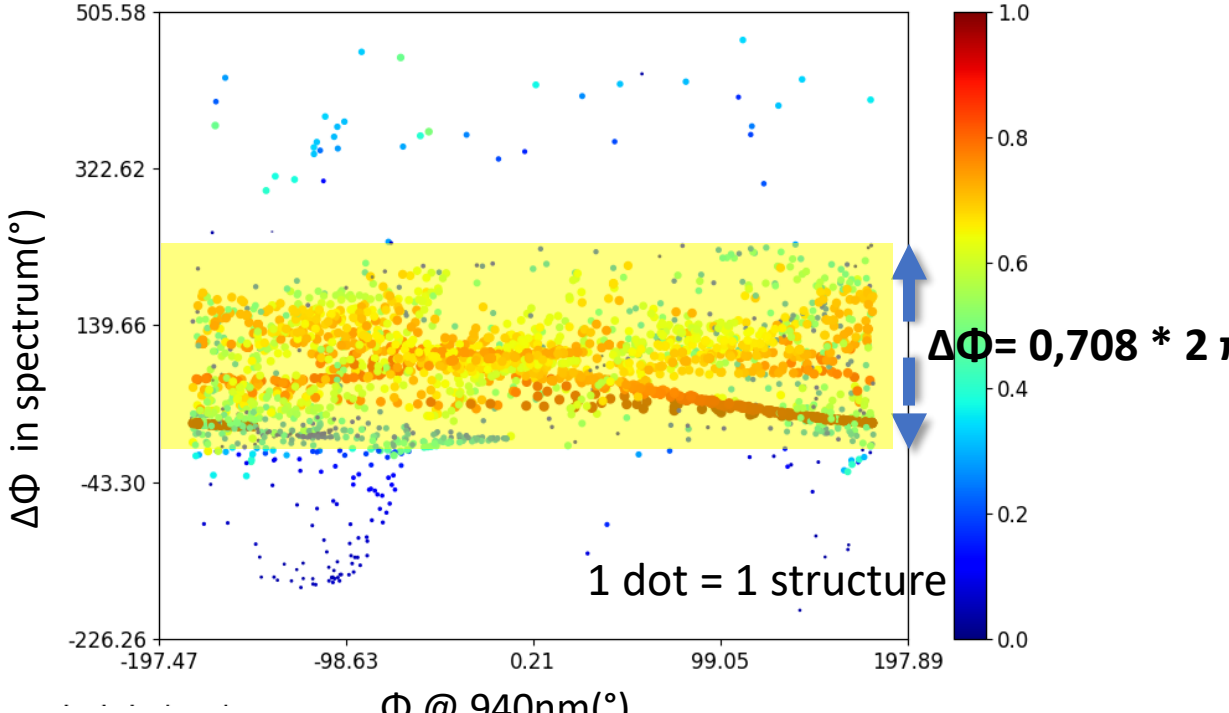
**Target vs. Meta-surface phase**




**Hybrid design capabilities**




**Dispersion engineered library**



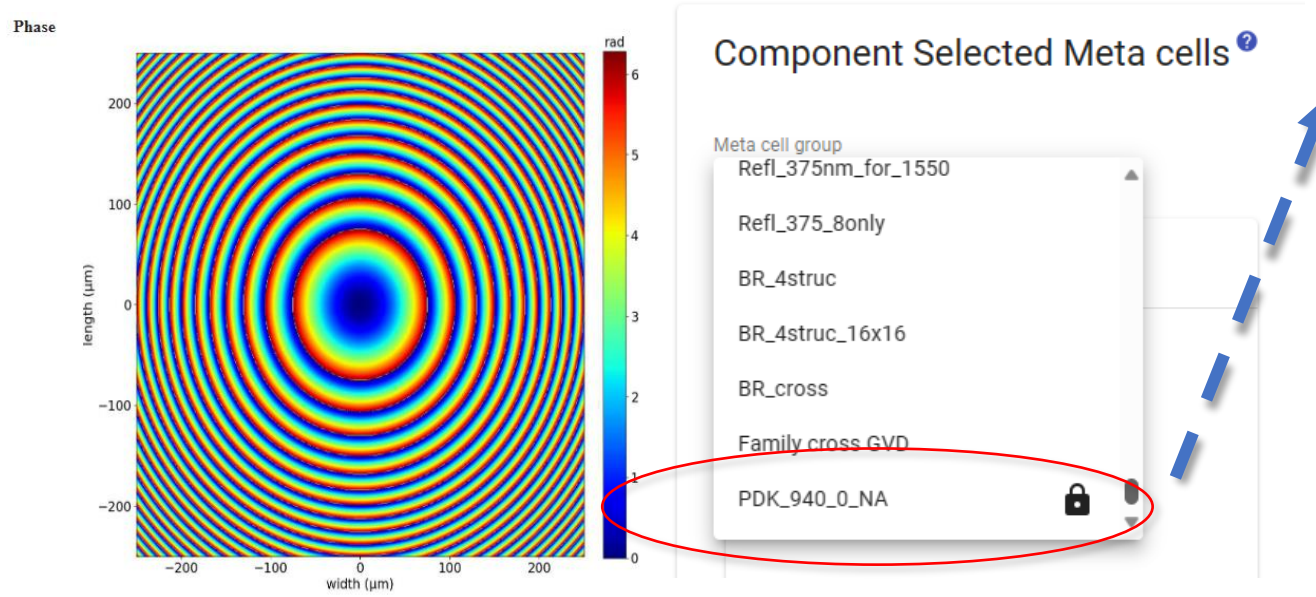
# Meta-surface PDK

PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

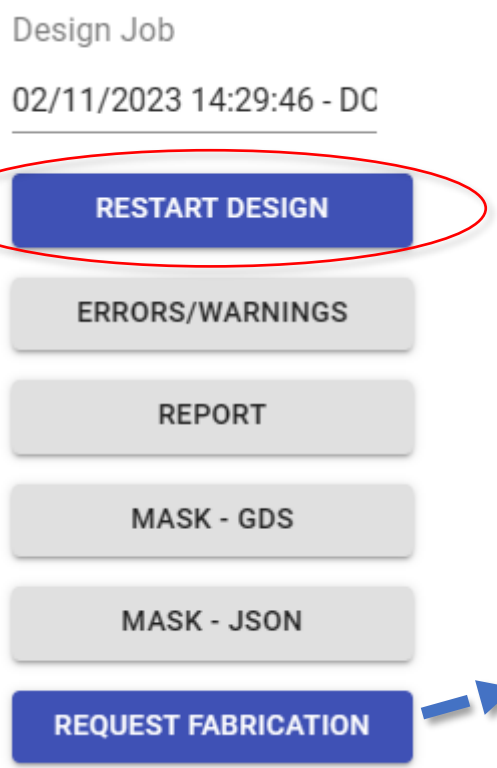
*In collaboration with Alpha Cen

- Coming soon: **Multi-project wafer** service
- **Submit** meta-surface designs **to manufacturing from PlanOpSim***
- Supported wavelength 940nm and size up to 5x5 mm

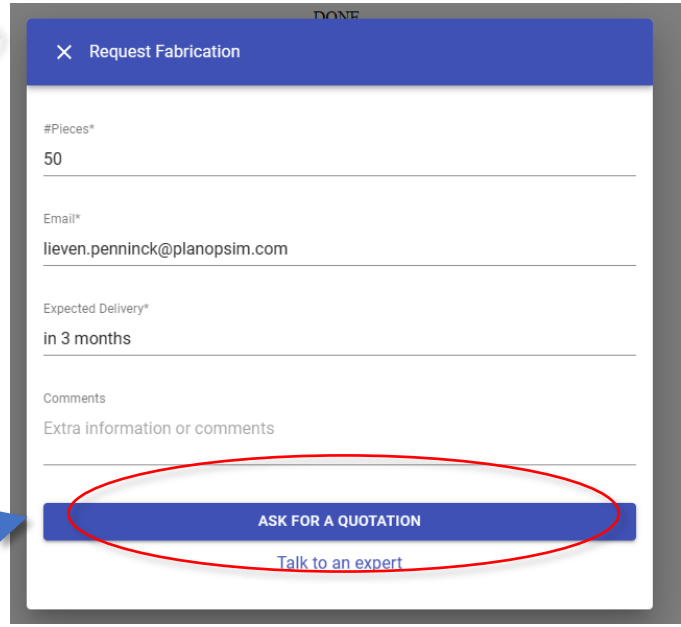
Step 1: select PDK and optical target




Step 2: run design

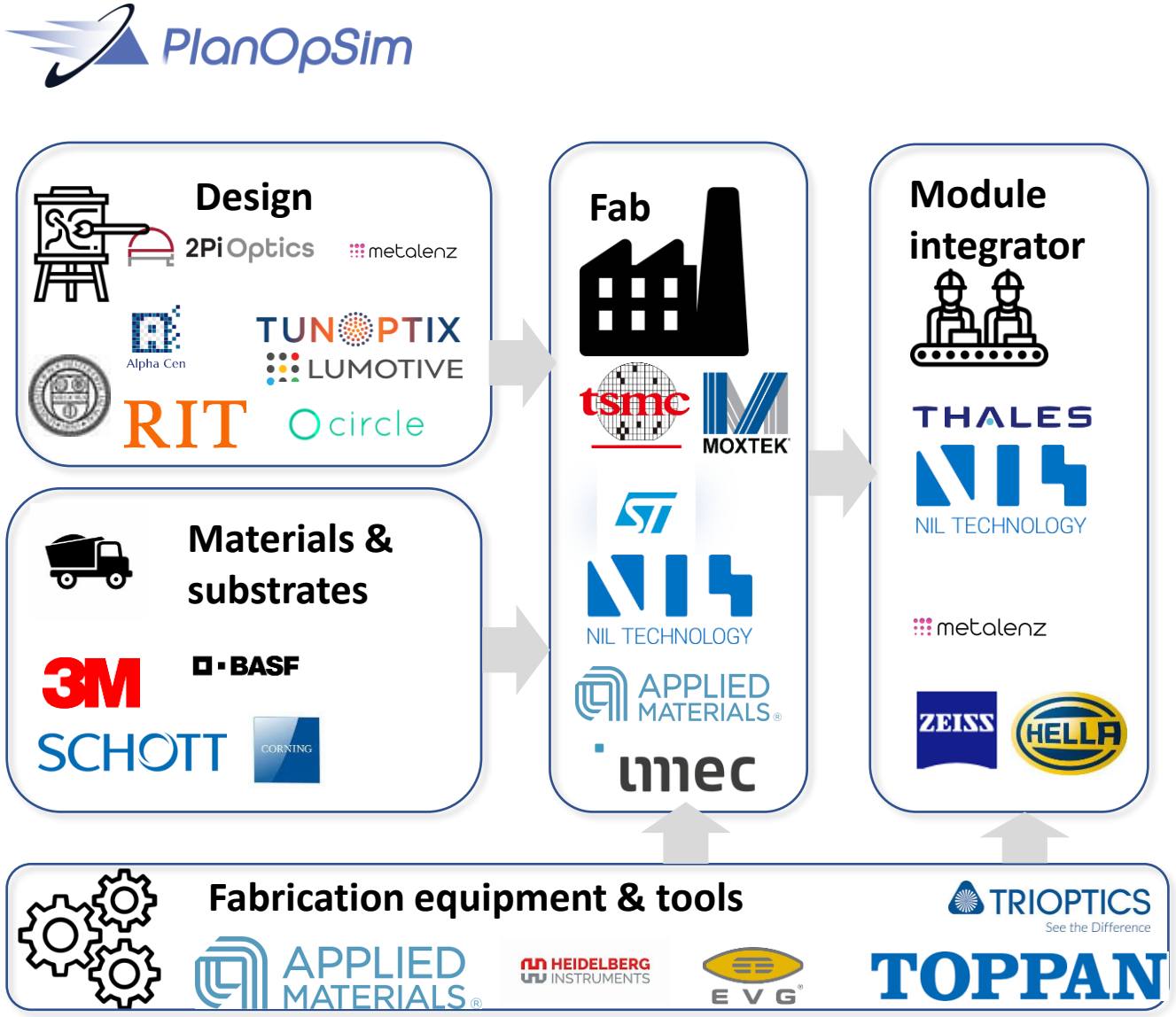



Step 3: submit design



# Let's work together

PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM




- PlanOpSim is a **catalyst for optics and photonics R&D**
- Build the best value chain for meta-surfaces
  - Looking for partners in all aspects of meta-surface development
- **Work together on**:
  - Meta-surface **aplication & design**
  - **Design for manufacture**
  - Cutting edge **simulation** methods
  - Demonstrating full circle R&D

PlanOpSim
Enlightened Planar Optics
WWW.PLANOPSIM.COM

OPTICA
Formerly OSA

EPIC
EUROPEAN PHOTONICS INDUSTRY CONSORTIUM

## Contact us for a software demo!!


www.planopsim.com
lieven.penninck@planopsim.com
+32 485 565 772


Distibution partners

PHOTONIKBIZ
Leads & Sales Organization

HTTR

ASI

Supported by

imec istart

European Commission
Horizon Europe
2021-2027

nextcorps
LUMINATE

AGENTSCHAP INNOVEREN & ONDERNEMEN