SYNOPSYS®

Micro-Optics for AR/VR from design to manufacturing

Dr. Elias AKIKI

03-12-2024

Agenda

1 **OSG Synopsys Tools for Optical Design and Simulation**

2 Micro-Optics Design and System Simulation

3 AR/VR Photonic Devices

4 Manfacturing Impact and Optical Virtual Fab

Diving into our **OPTICAL SOLUTIONS**

A comprehensive portfolio

For OPTICAL design
ILLUMINATION design
PHOTONIC design
AUTOMOTIVE design
VIRTUAL prototyping

With proprietary optimization engines for **ACCURACY** and **SPEED**

The Most Advanced Optical Design & Simulations Platform

Design | Simulations

OPTICAL PLATFORM

CODE V | LightTools | RSoft | LucidShape family

Interoperable

HPC Enabled

Common Model Definition

Common Material and Optical Definitions

Expanding into more simulations

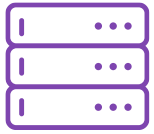
- Image Simulations — **ImSym**
- Visualization — **Stay tuned**
- Virtual Environment — **LucidDrive**

Accelerate Optical Simulation

Analyzing optical systems can require substantial computing power, as analysis can require **tracing large ray sets**, **performing high-fidelity FDTD calculations**, and **performing many other intensive optical analysis mathematics**.

Faster Hardware

- CPU speed
- Multi-core CPUs
- Multi-threading
- GPU



Distributed Hardware

- Multi-CPU computers
- Multiple computers
- Multiple GPUs
- Distributed Scanning

Efficient Flows

- Learn your tool
- Leverage innovative algorithms
- Self-paced learning options
- Talk to our engineering experts

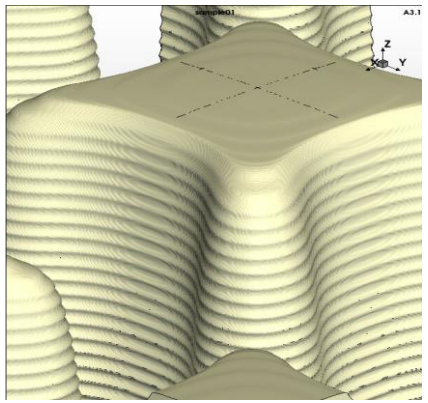
HOW CAN YOU GET YOUR JOB DONE FASTER?

Agenda

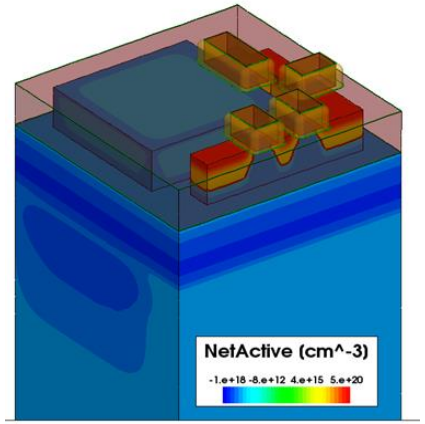
1. OSG Synopsys Tools for Optical Design and Simulation
2. **Micro-Optics Design and System Simulation**
3. AR/VR Photonic Devices
4. Manfacturing Impact and Optical Virtual Fab

TCAD Sentaurus – RSoft Flow Overview

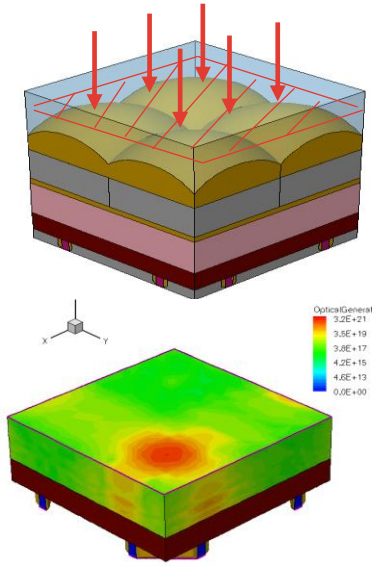
Litho Simulation



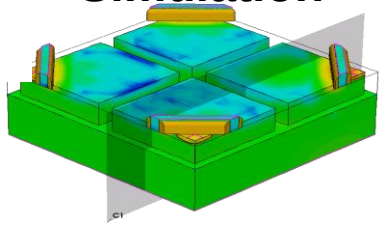
Process / Structure

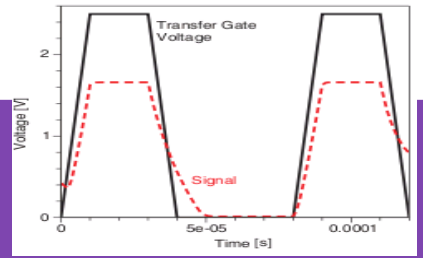


Optical Simulation



Electrical Simulation



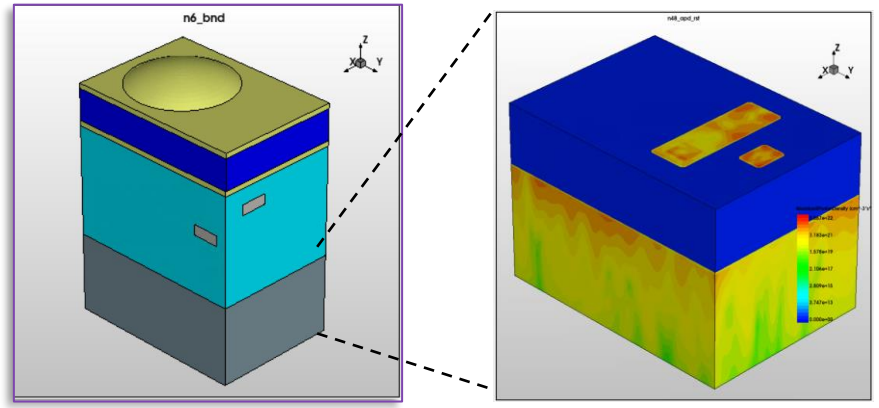


Workflow

	SPROCESS		SPROCESS	SDE		RSoft			SDEVICE	SVISUAL
		pixel	device		cfa		wavelength	intensity	rsoft_tool		
1	--	1	1	--	--	blue	--	0.475	0.1	FullWAVE	--	--
2										DiffractMOD	--	--
3						green	--	0.55	0.1	FullWAVE	--	--
4										DiffractMOD	--	--
5						red	--	0.65	0.1	FullWAVE	--	--
6										DiffractMOD	--	--

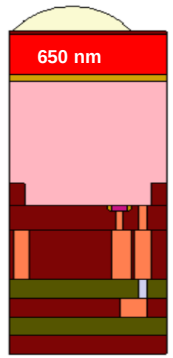
Optical Simulation for CIS

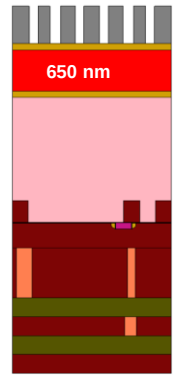
- **DiffractMOD RCWA** and **FullWAVE FDTD** to calculate reflection, transmission, absorbed photon density, BSDF, …
- Micro-Optics variation: Replace Micro-Lens Array (MLA) with a Metalens using **MOD MetaOptic designer**
- Analyze stray light due to reflections from the CIS in a camera system using **LightTools** and **Rsoft BSDF utility**



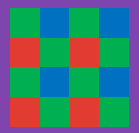
Absorbed Photon Density

Spherical Microlens

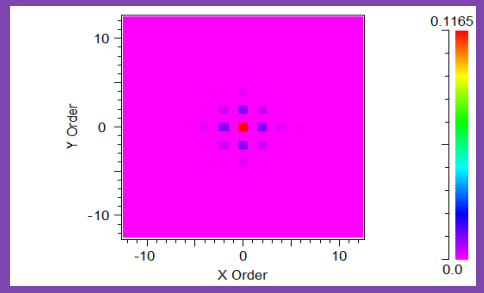


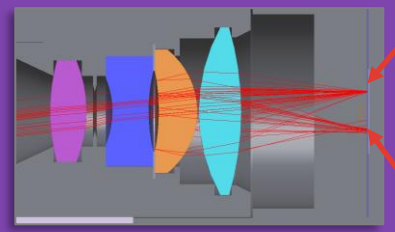


Metalens

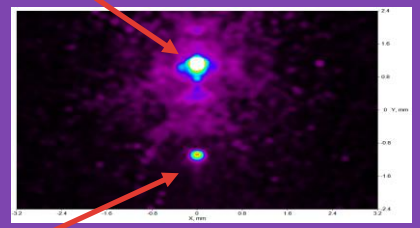


Bayer Pattern Sensor Reflection





Primary Image Location



Ghost Image

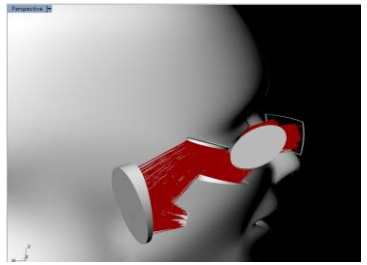
Agenda

1. OSG Synopsys Tools for Optical Design and Simulation
2. Micro-Optics Design and System Simulation
3. **AR/VR Photonic Devices**
4. Manfacturing Impact and Optical Virtual Fab

Key Optical Systems in AR/VR Devices

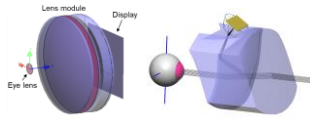
Display

- µLED
- µOLED
- Light Engine
  - LCOS
  - LCD
  - DLP

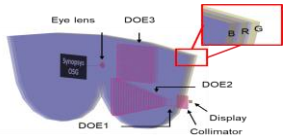


Combiner Optics

- Regular combiners
  - Fresnel Lens (video see through)
  - Pancake Lens (video see through)
  - Birdbath
  - Freeform
  - Geometrical Waveguide

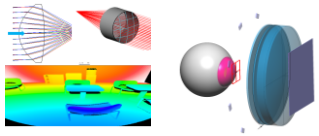


- Waveguide combiners
  - Surface Relief Grating
  - Volume Hologram Grating
  - Polarization Volume Grating



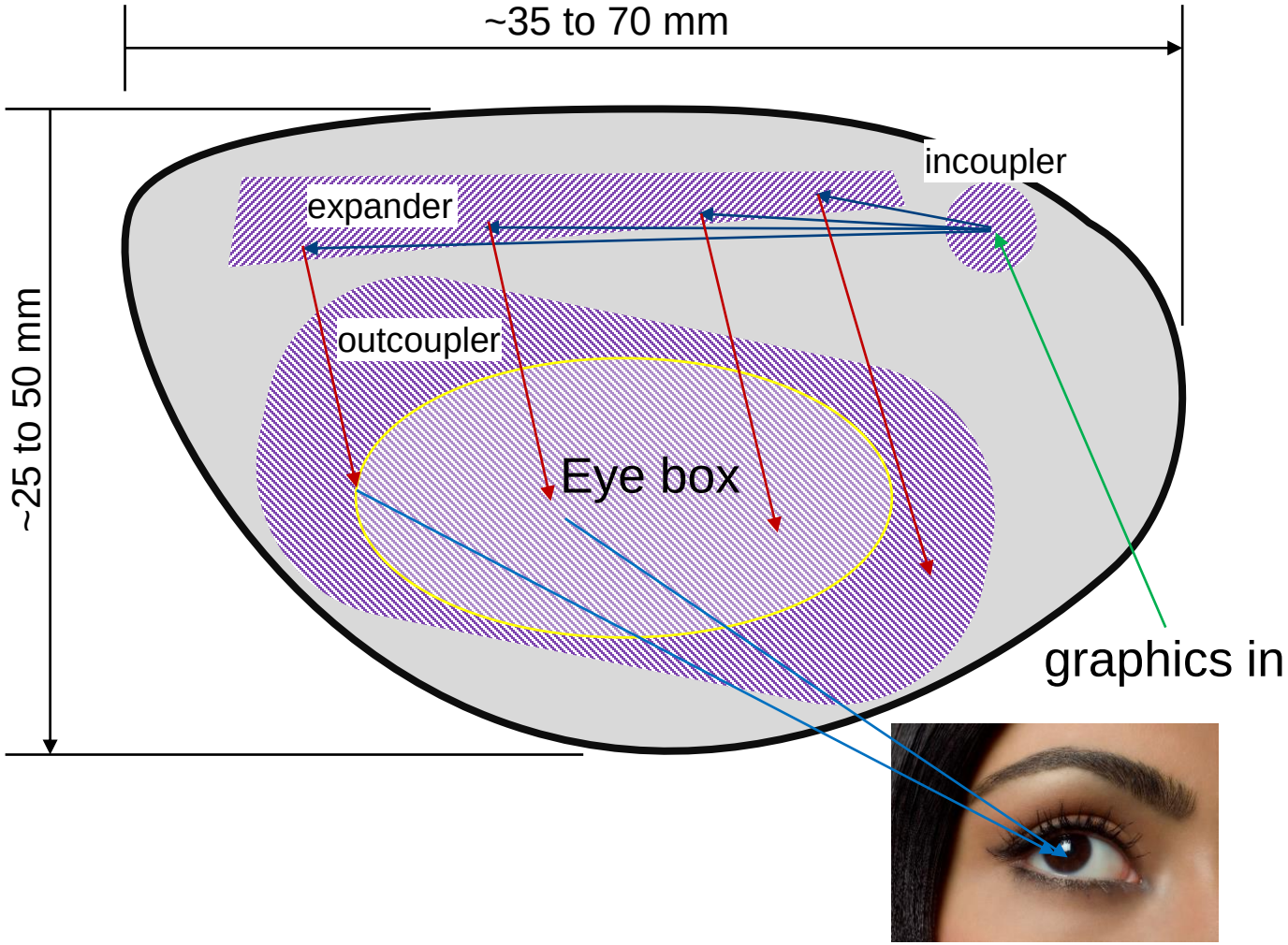
Eye

- Eye Model
- Eye Tracker
- Environment Camera
- Optical Sensor



Waveguide Optical combiner

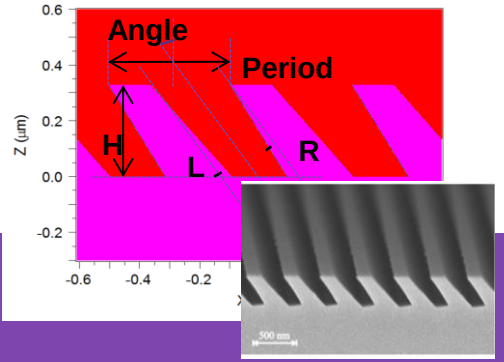
Expands graphics and places them in the eye box

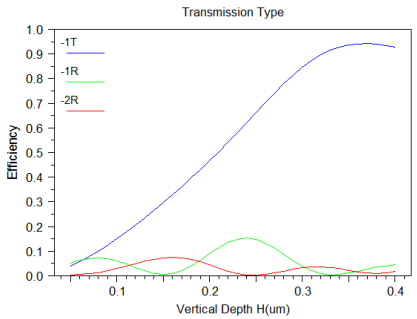


- The **Waveguide Optical combiner** is a series of **waveguides**
  - **Incoupler** transmits the input graphics to the expander
  - **Expander** magnifies the graphics and transmits them to the outcoupler
  - **Outcoupler** overlays the graphics on the real scene for viewing
- The **eye box** is the intended viewing area of the outcoupler
- Surface Relief Gratings (SRG) is a type of Diffractive Optical Elements (DOE) having a periodicity ~λ

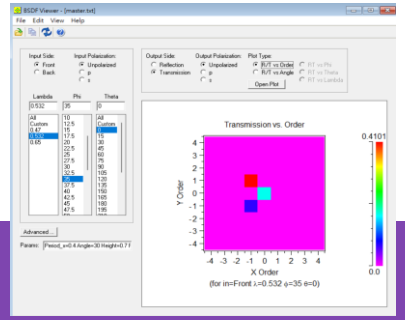
Waveguide AR Design Flow

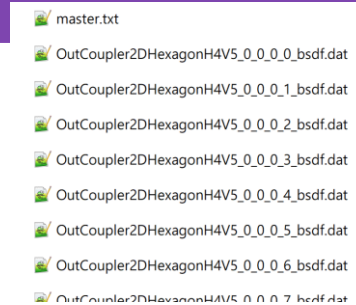
RSoft DiffractMOD RCWA



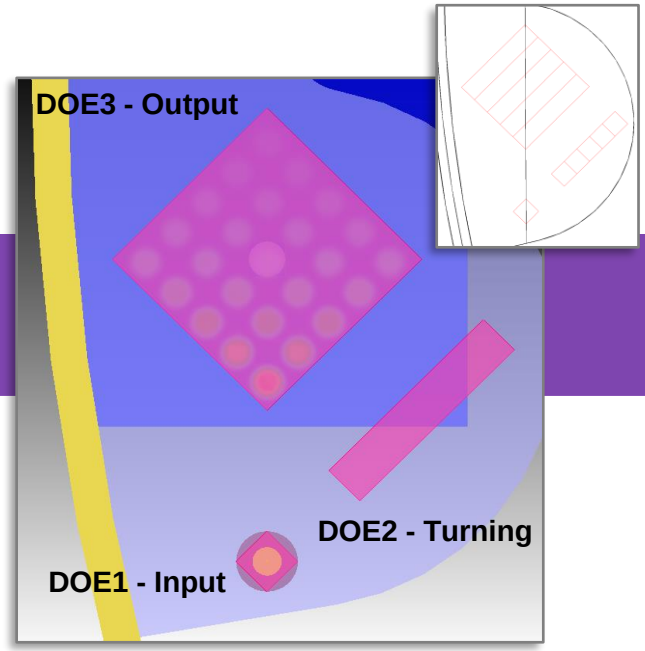


RSoft BSDF Scanning



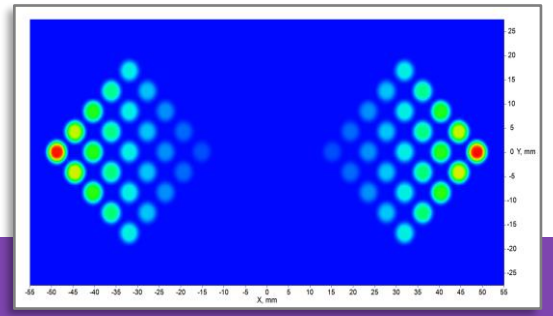


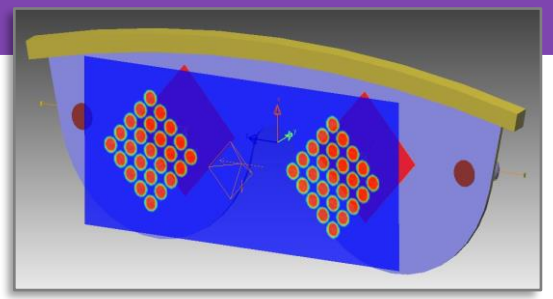
LightTools



LightTools Optimization (Collimated)

Before





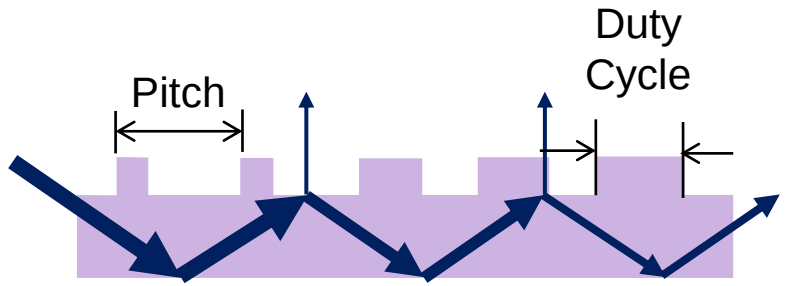
After

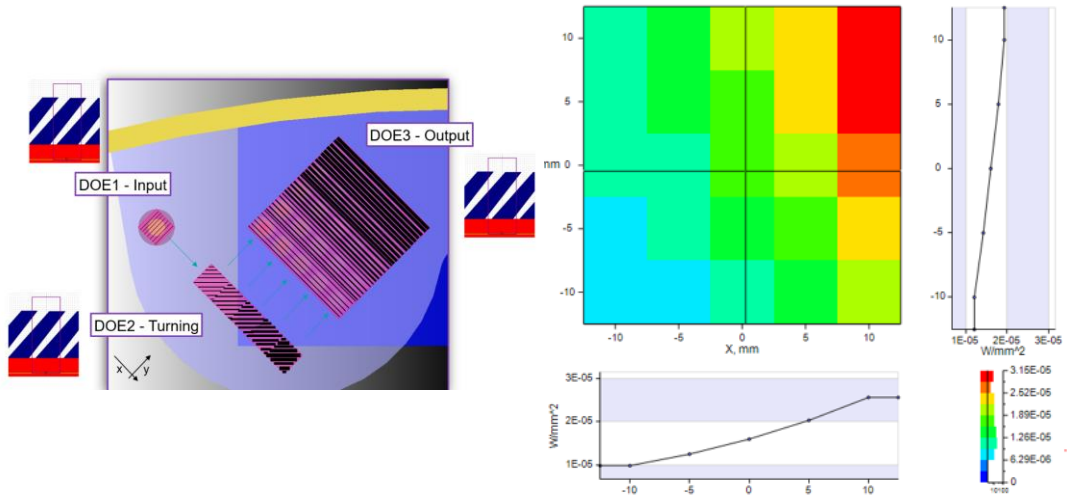
Workflow

1 **2** **3** **4**

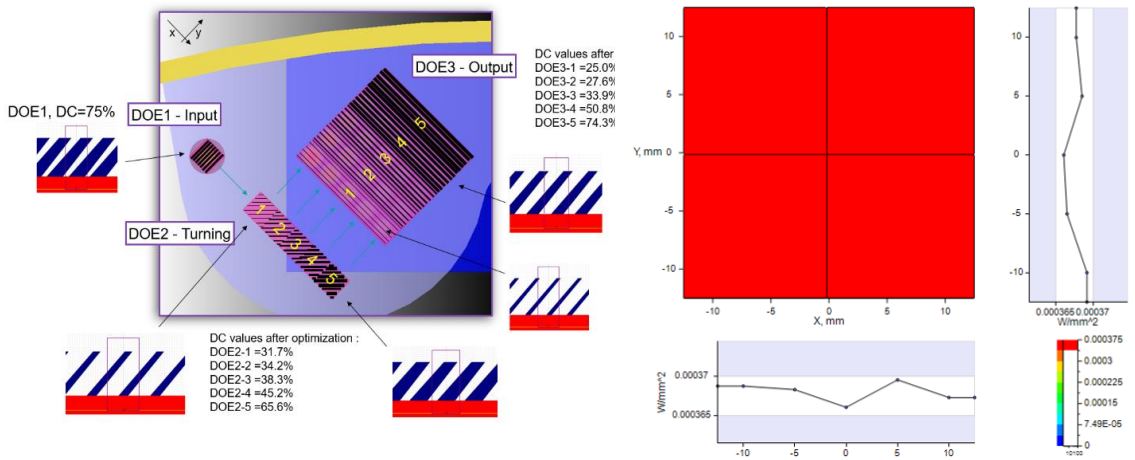
LightTools Design Optimization

Duty Cycle Variation





Illuminance uniformity map



Illuminance uniformity map

Before Optimization

Uniform DC (25 % FF)
Efficiency: 1.7%

After Optimization

Variable DC (20-70% FF)
Efficiency: 23.5%

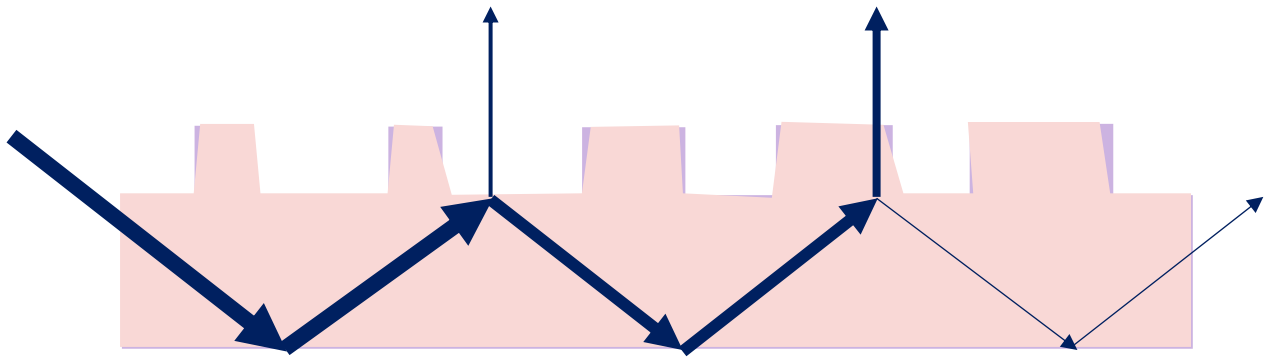
Efficiency: light on the eye box vs incident light

Agenda

1. OSG Synopsys Tools for Optical Design and Simulation
2. Micro-Optics Design and System Simulation
3. AR/VR Photonic Devices
4. **Manfacturing Impact and Optical Virtual Fab**

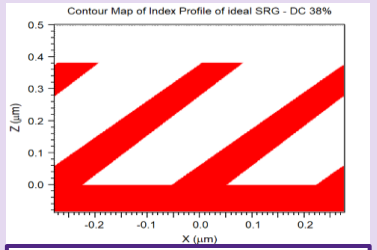
SRG After Manufacturing

Manufacturing artifacts may dramatically impact device performance

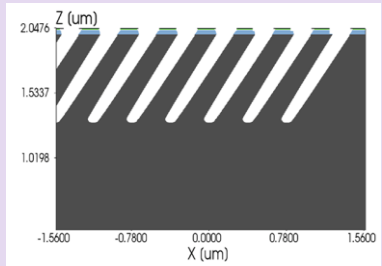


- Manufacturing produces a device that is not ideal (as the designer drew it)
  - Sidewall angles
  - Over etching
  - Rounding corners and at trench bottom
- These artifacts may result in:
  - Eye box uniformity degradation
  - Intensity loss
  - Blurred images
  - Failed devices

Manufacturing Aware Design Flow Targets First Print Correct Design



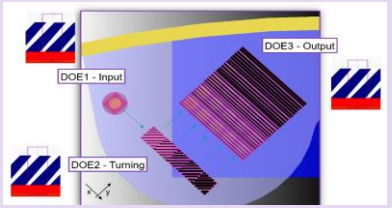
Nominal SRG Design
RSoft
DiffractMOD RCWA



Manufacturing prediction

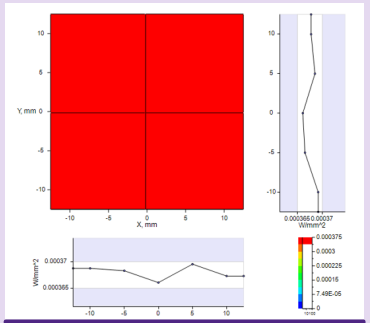
- OPC
- Lithography
- Etch

Manufacturing aware SRG Library
RSoft
DiffractMOD RCWA



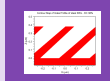
Manufacturing Aware Design

Optimize design using manufacturing aware SRGs
LightTools



Validation

Simulates optical device output

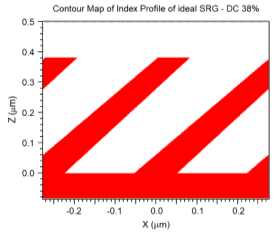
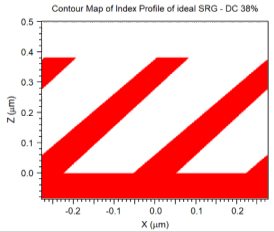
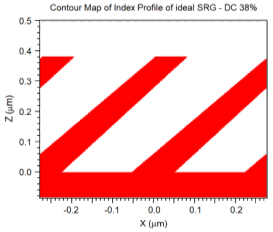
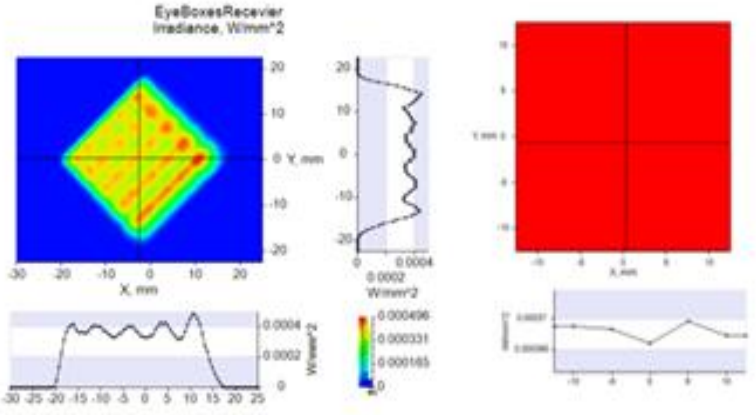
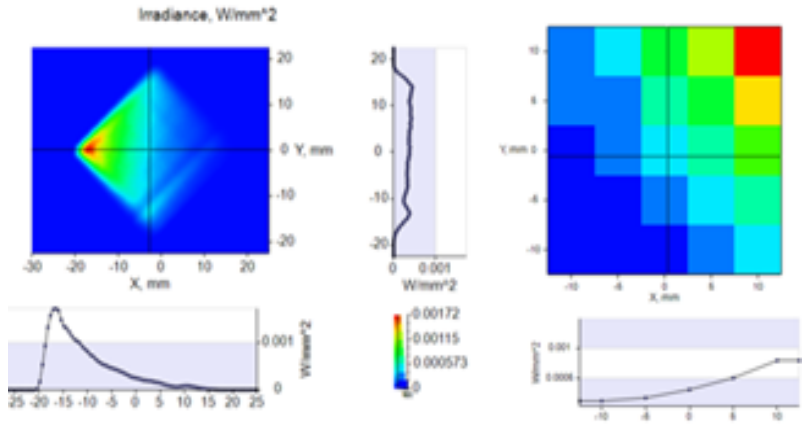
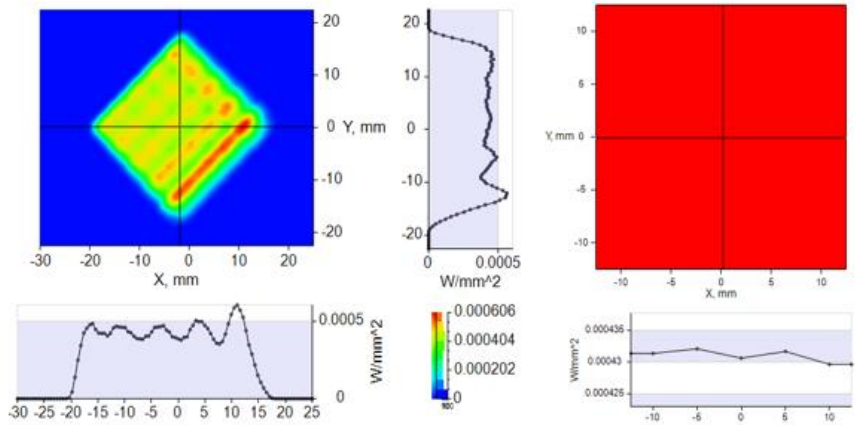


A design team develops SRG characteristics (Pitch, DC range, size, wavelengths, etc.)

SRGs are simulated through manufacturing

The simulated SRGs are used to design the desired DOE

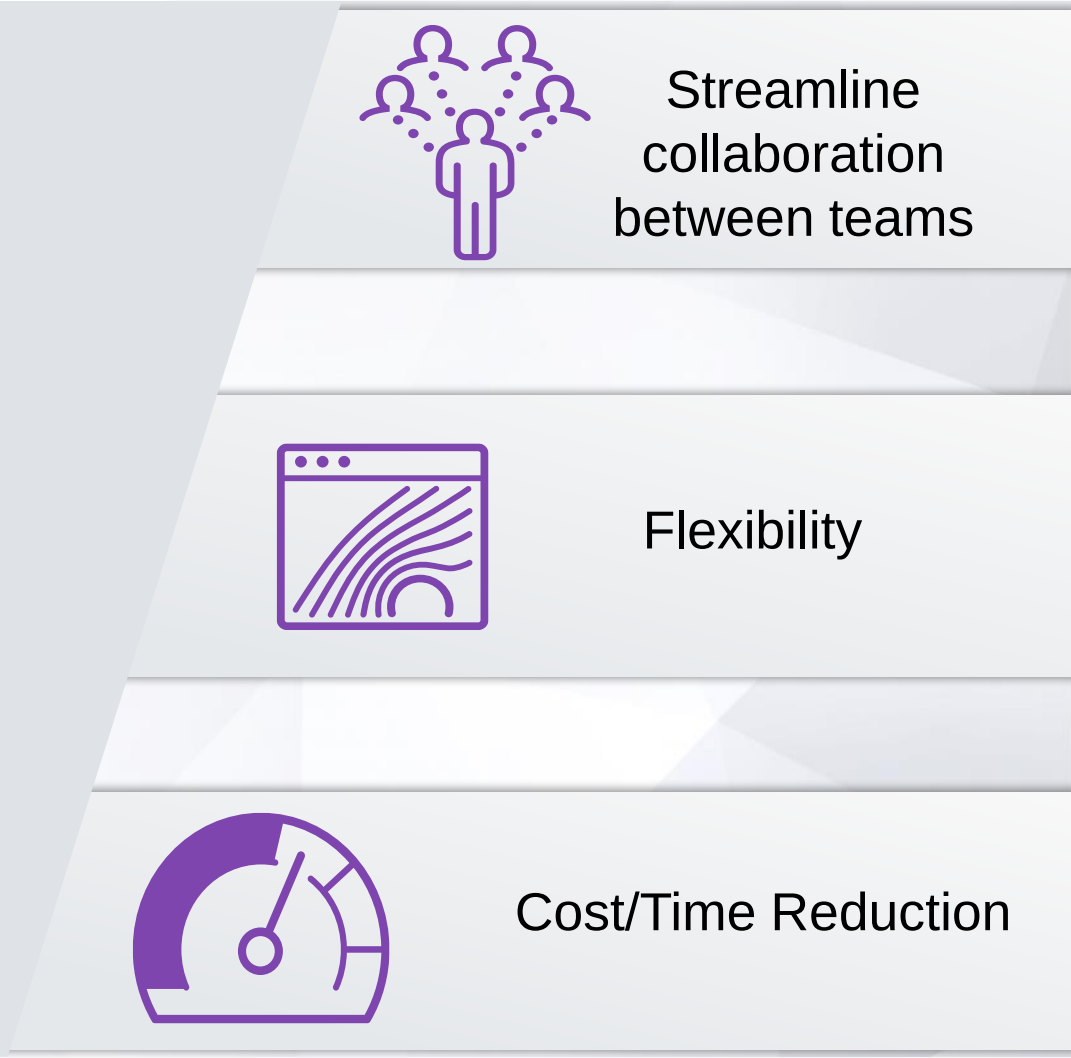
Optimizing the Design: Applying Manufacturing Simulation

Grating profile used in design:	 Ideal	 Ideal	 Realistic
Grating profile as-manufactured:	 Ideal	 Realistic	 Realistic
	 Efficiency: 23.5%	 Efficiency: 17%	 Efficiency: 27.4%

Illuminance uniformity on eye box

Conclusion

- Streamline collaboration between teams to provide useful and comprehensive flows
- Flexibility and interoperability between tools for a better system design simulation
- Cost and time reduction:
  1. Innovative algorithm
  2. Cluster computation
  3. Hardware acceleration
  4. Optical Virtual Fab



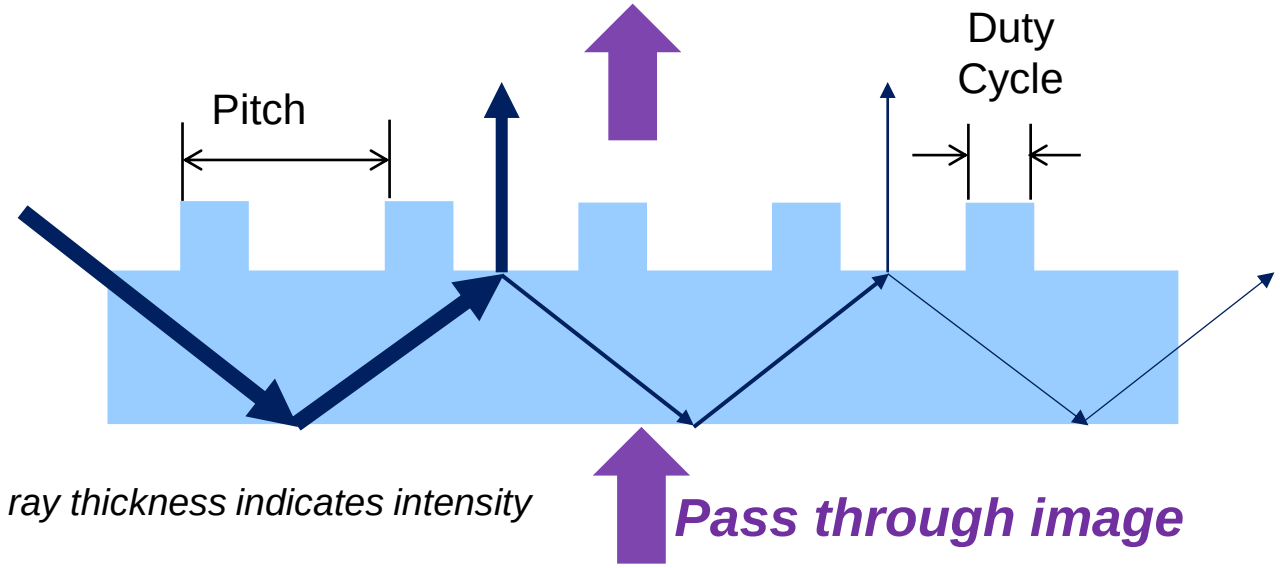
Thank you

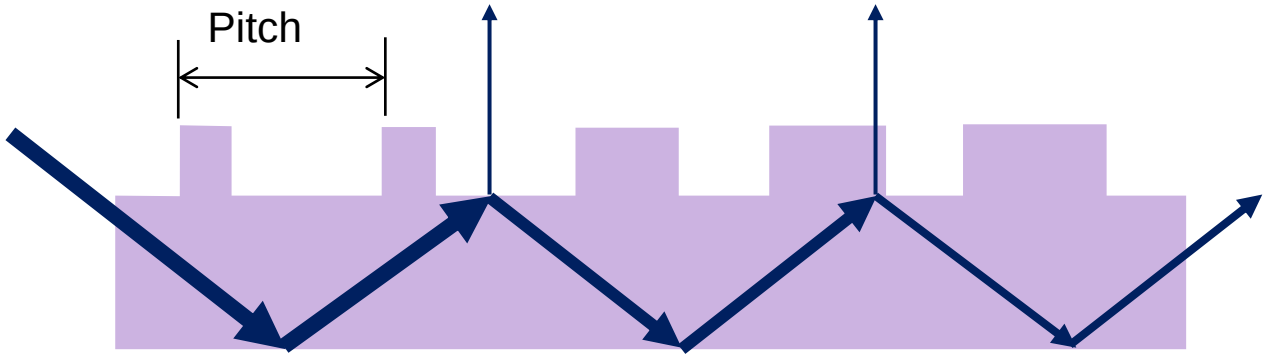

CODE V – OPTICAL DESIGN
LIGHTTOOLS – ILLUMINATION DESIGN
RSOFT – PHOTONIC DESIGN
LUCIDSHAPE – AUTOMOTIVE SIMULATIONS
IMSYM – VIRTUAL PROTOTYPING


SYNOPSYS®

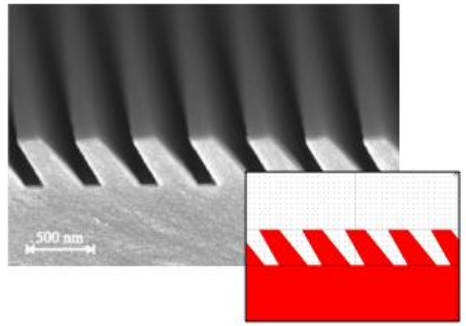
Surface Relief Grating Waveguide

An AR/VR strategy to combine environmental and graphical images



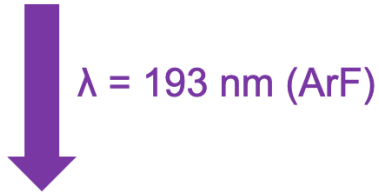


- SRGs are periodic structures of constant **Pitch**
- Pitch governs the wavelength(s) of light manipulated by the SRG
- The **Duty Cycle (DC)** governs reflected images
- **Filling Factor (FF)** = DC/Pitch
- DC is varied to balance output intensity
- Slanted gratings are more efficiently directing light than 90° gratings

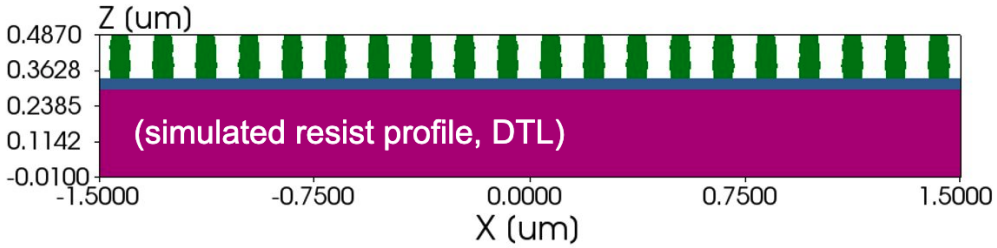


Modeling SRG Manufacturing

Stack and Process



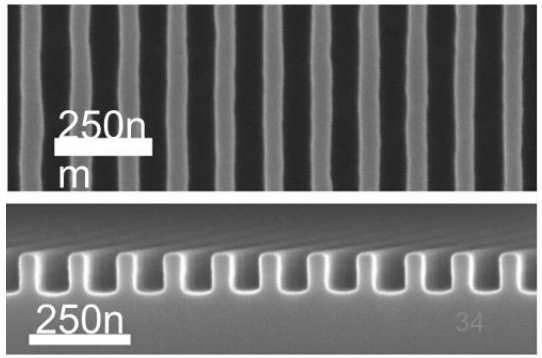
λ = 193 nm (ArF)

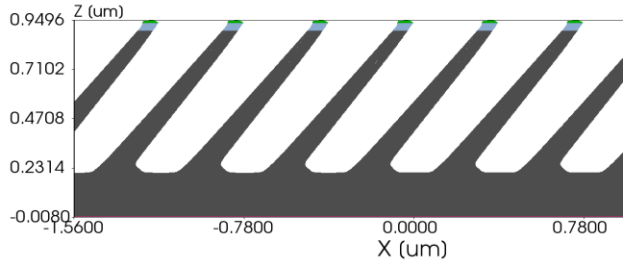


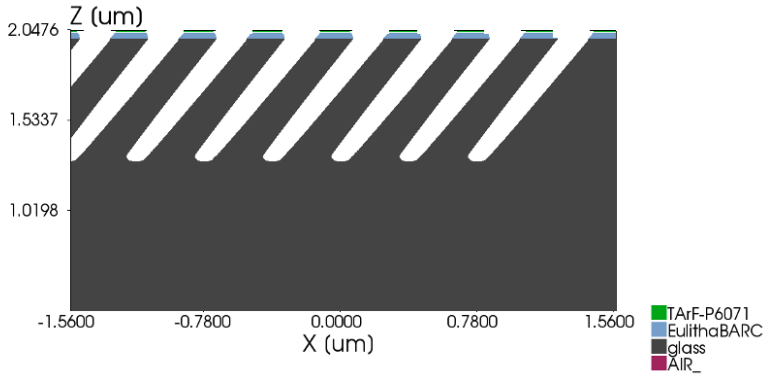
DUV Resist: 150 nm,
n=1.67, k=0.015

BARC: 37 nm,
n=1.67, k=0.3

SiO2: 300 nm
n=1.563, k=0







- 193 nm Displacement Talbot lithography imaged SRG patterns
- RIE etch simulation to transfer pattern into SiO_2 parameters
- In collaboration with Eulitha

WOOLEY, Kelsey, CHALONY, Maryvonne, DAWES, Andrew MC, et al. Simulating use of displacement Talbot lithography for high volume AR waveguide manufacturing. In : DTCO and Computational Patterning III. SPIE, 2024. p. 308-318.