The path towards mass manufacturing of optical waveguide combiners via large-area nanoimprinting

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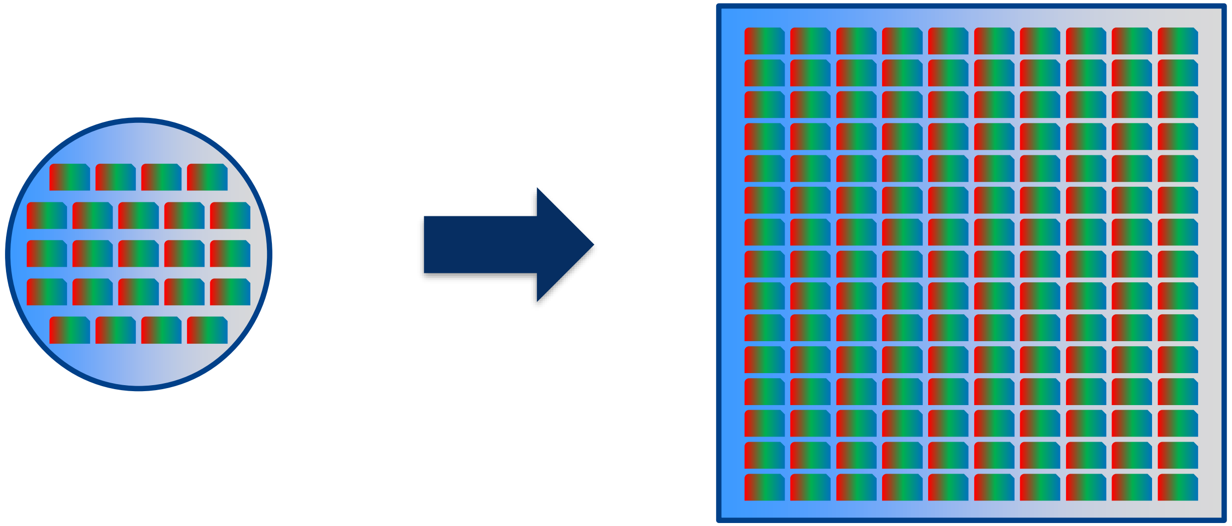
Agenda

Beyond Wafer-scale

- Cost is king if AR Glasses want to be the ‘next big thing’
- Goal - Show a path beyond wafer-scale for AR Waveguide Optics Mass Manufacturing is viable
- Showcasing - a ‘basic’ proof-of-concept & entire value chain that can produce AR waveguide optics in high-volume
- Design for Manufacturability & Affordability - Same design & manufacturing rules don’t apply!
- Master up-scaling needed to help lower the barrier of entry - Keep master costs low & tile-up many on a ‘working stamp”

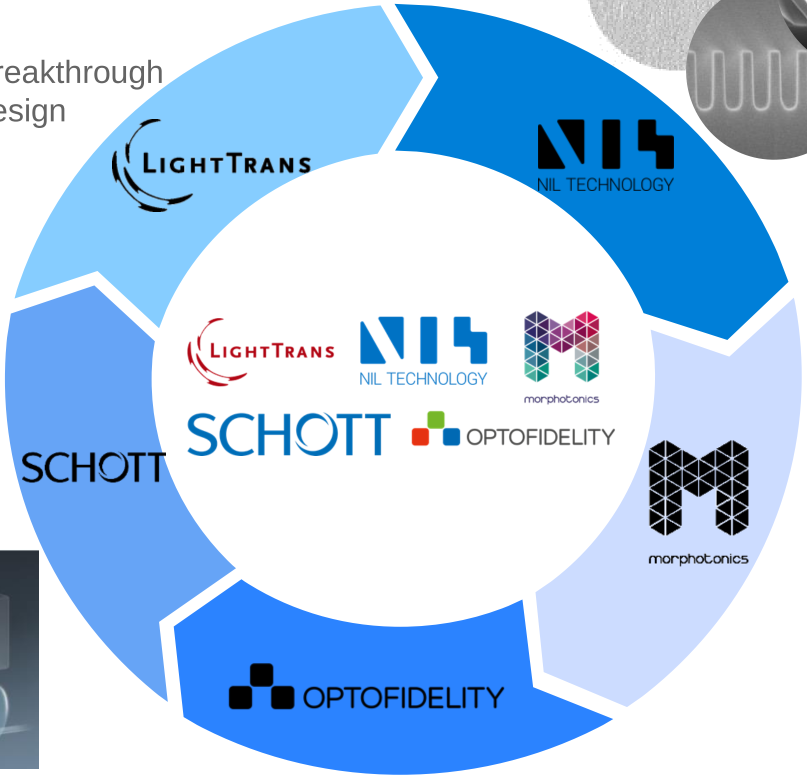


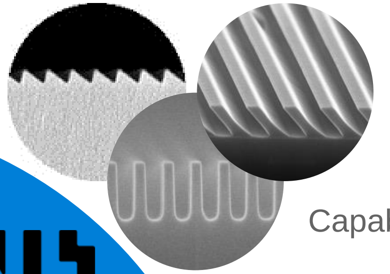
Complete Value Chain of Pioneers

New Standards in Fast Physical Optics with Design Software VirtualLab Fusion

VirtualLab Fusion operates with a breakthrough technology for optical modeling & design beyond ray tracing

A powerful platform for innovative developments: LiDAR, AR/MR/VR Glasses, Laser Systems, Gratings, etc.





Large Area High-Precision Gratings

Accuracy in grating periodicity across large areas

Capable of designing & delivering non-periodic gratings

Leaders of Large-Area Nanoimprinting

World’s largest-area, commercially available, fully integrated nanoimprinting machine

Cost-effective mass manufacturing of nano/micron structures via large-area nanoimprinting

Pioneering – responsibly – together

Founder Otto Schott is considered the inventor of optical glass and became the pioneer of an entire industry.

Always opening up new markets and applications with a pioneering spirit and passion – for more than 130 years.

Enabling Smarter Future

Global market leader in automated optical metrology & characterization solutions for AR waveguides and displays throughout the entire product life-cycle from R&D to high volume manufacturing

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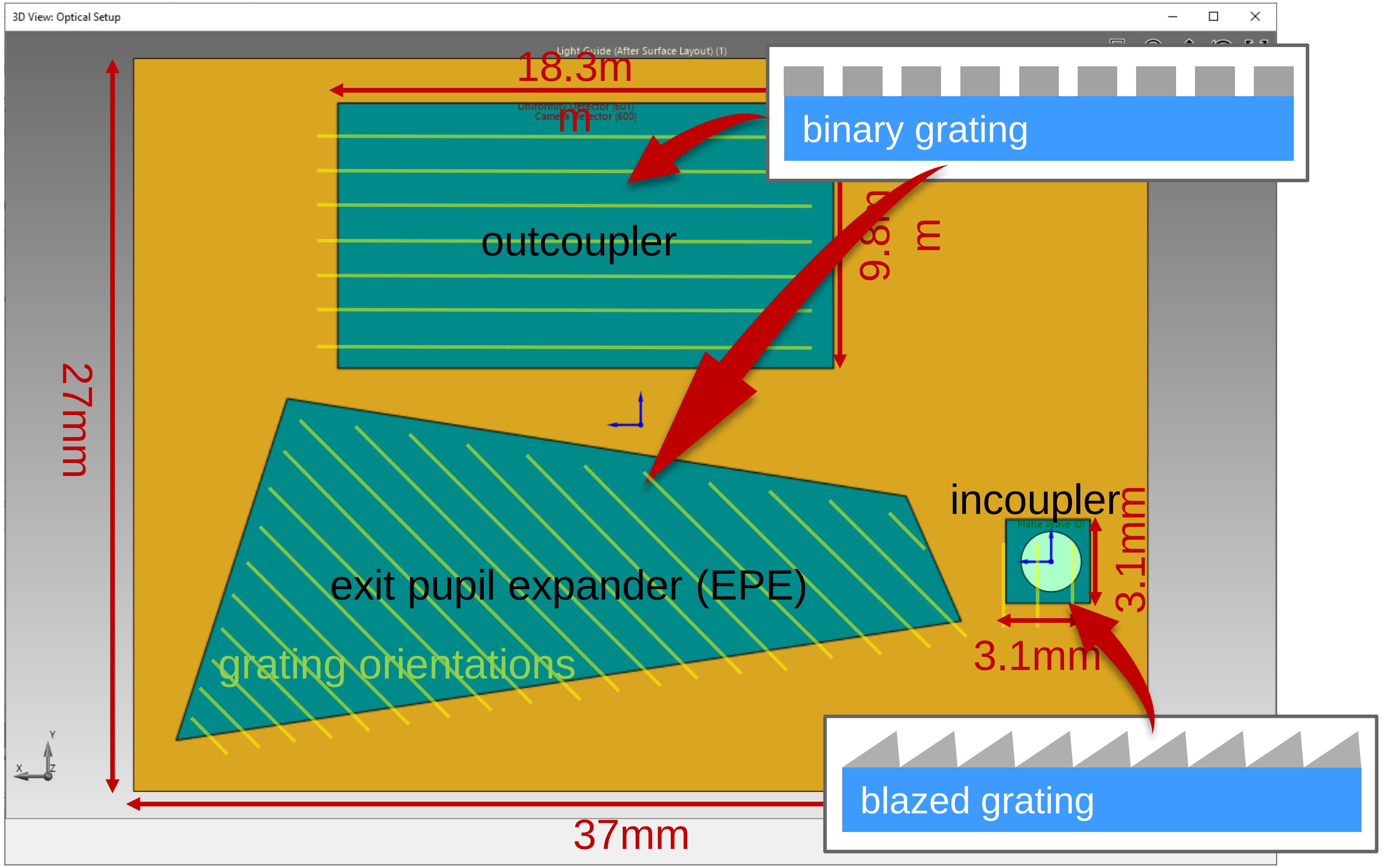
Design of Lightguide – Lateral Layout

Specifications:

- 532 nm wavelength
- 1D-1D pupil expansion
- FOV: 32°×18°
- Eyebox: 15 mm × 8 mm
- Substrate: Schott Realview 1.9
- 1D-periodic gratings
- Refractive index of resin: 1.9



Design of Lightguide – Grating Parameters

Incoupler:

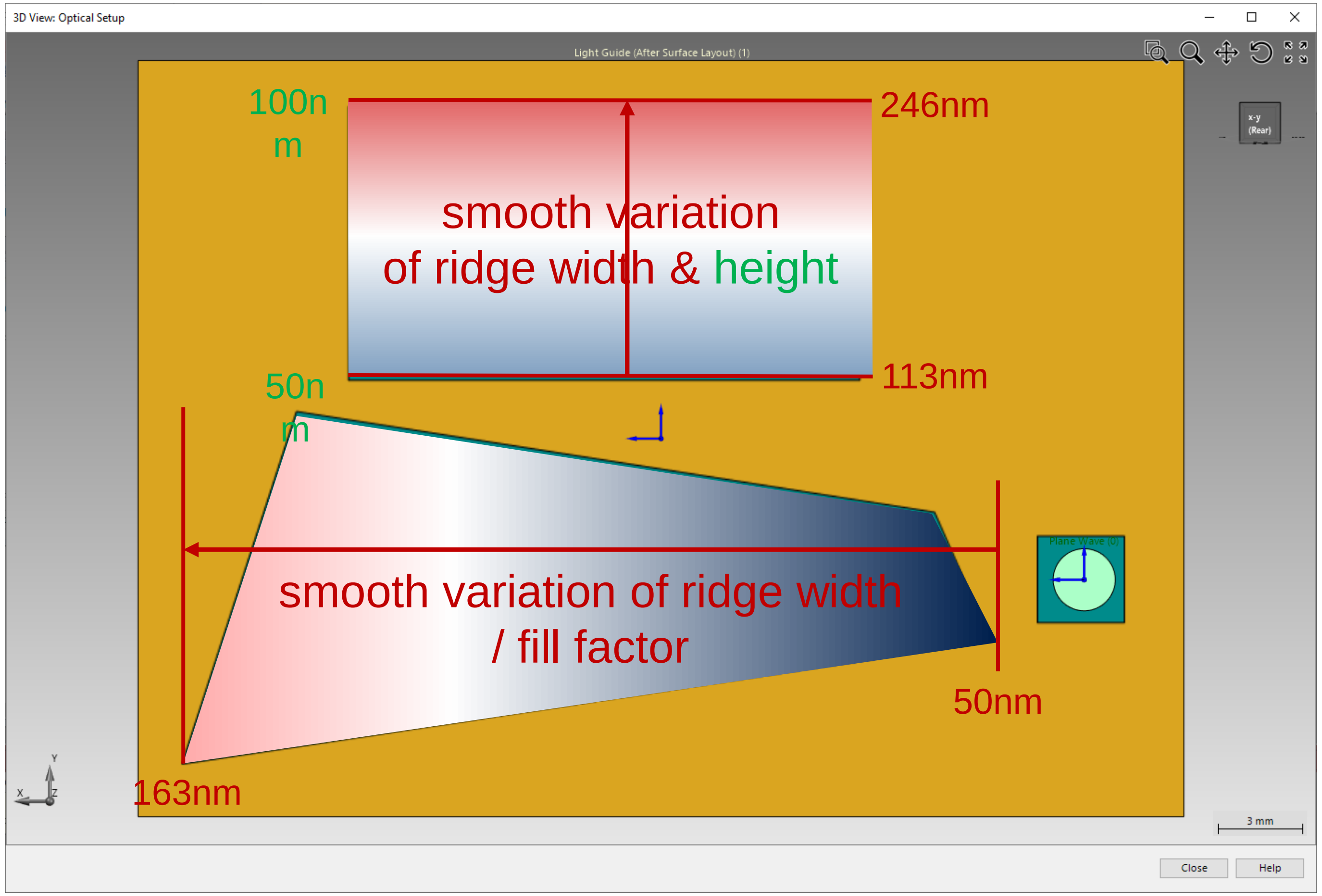
- Period: 415 nm
- Blaze angle: 29.9°

EPE:

- Period: 293.45 nm
- Width of ridge: 50–163 nm (smooth variation)
- Height: 50 nm (constant)

Outcoupler:

- Period: 415 nm
- Width of ridge: 113–246 nm (smooth variation)
- Height: 50–100 nm (smooth variation)



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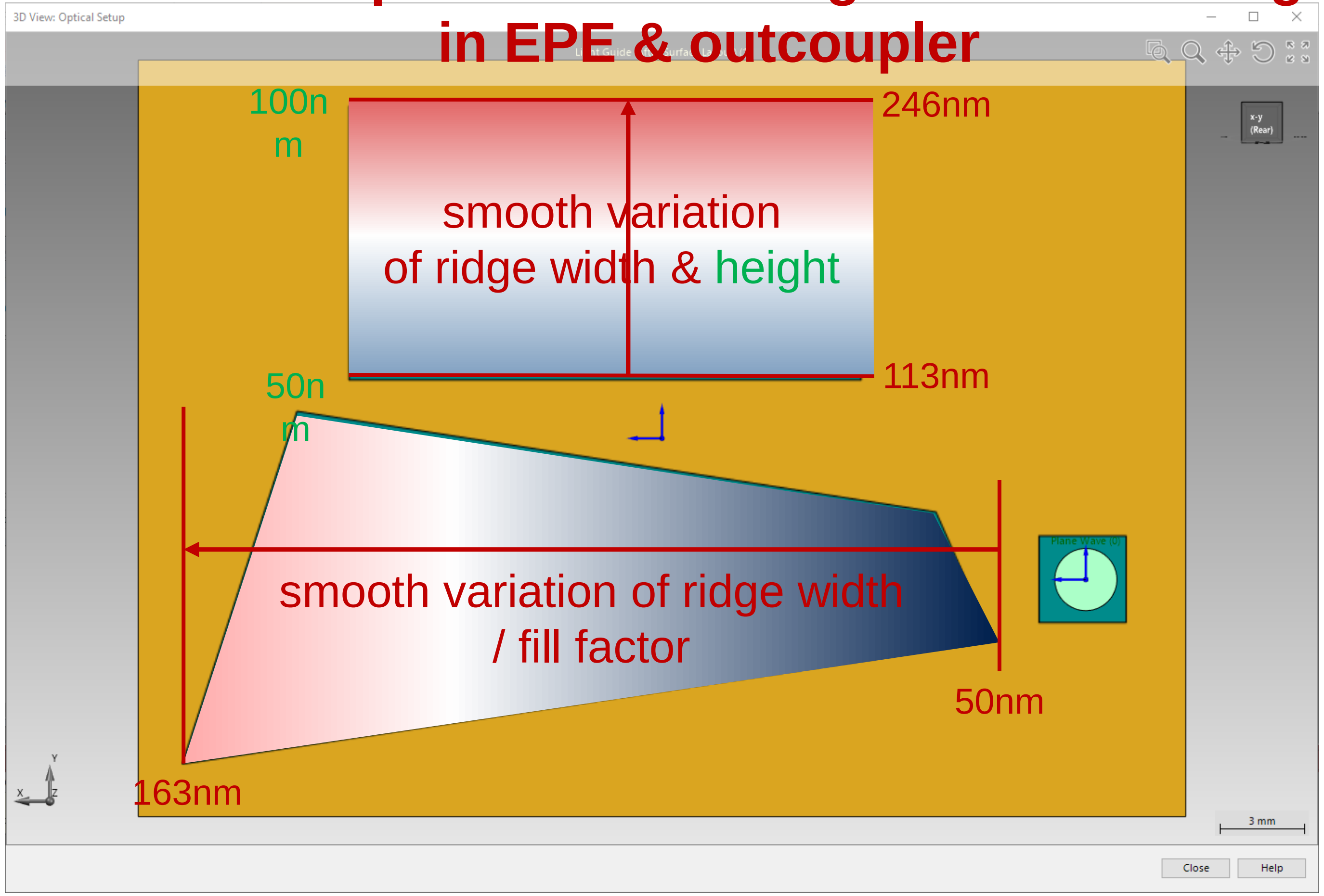
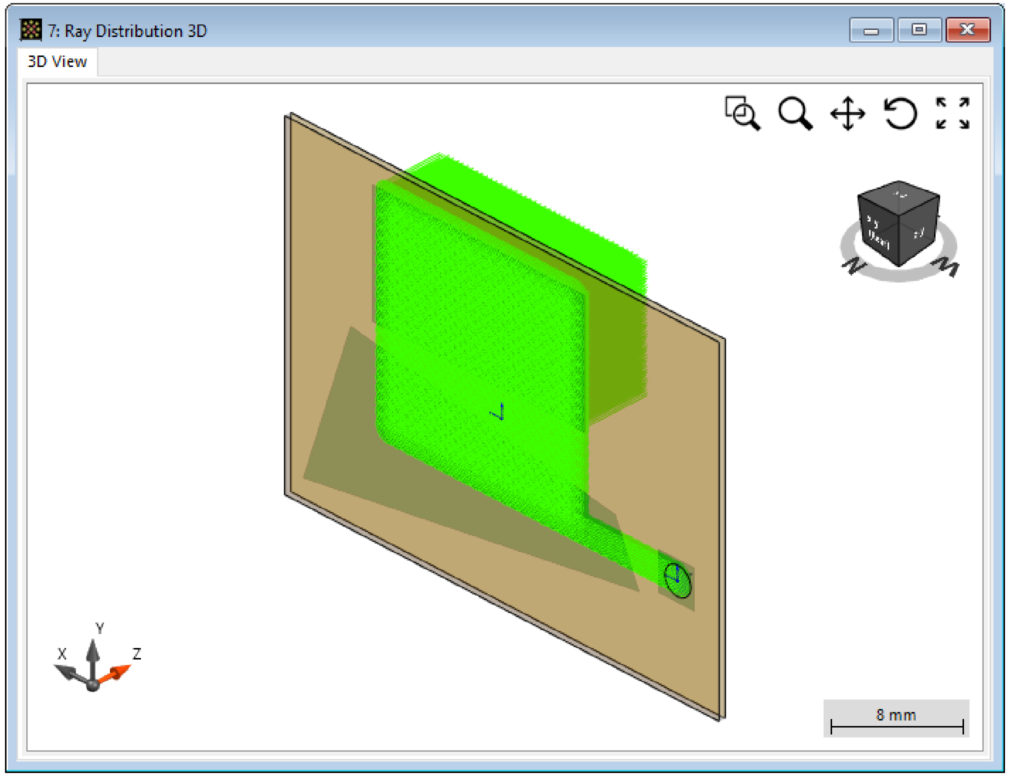
Parametric optimization of ridge width and heights in EPE & outcoupler



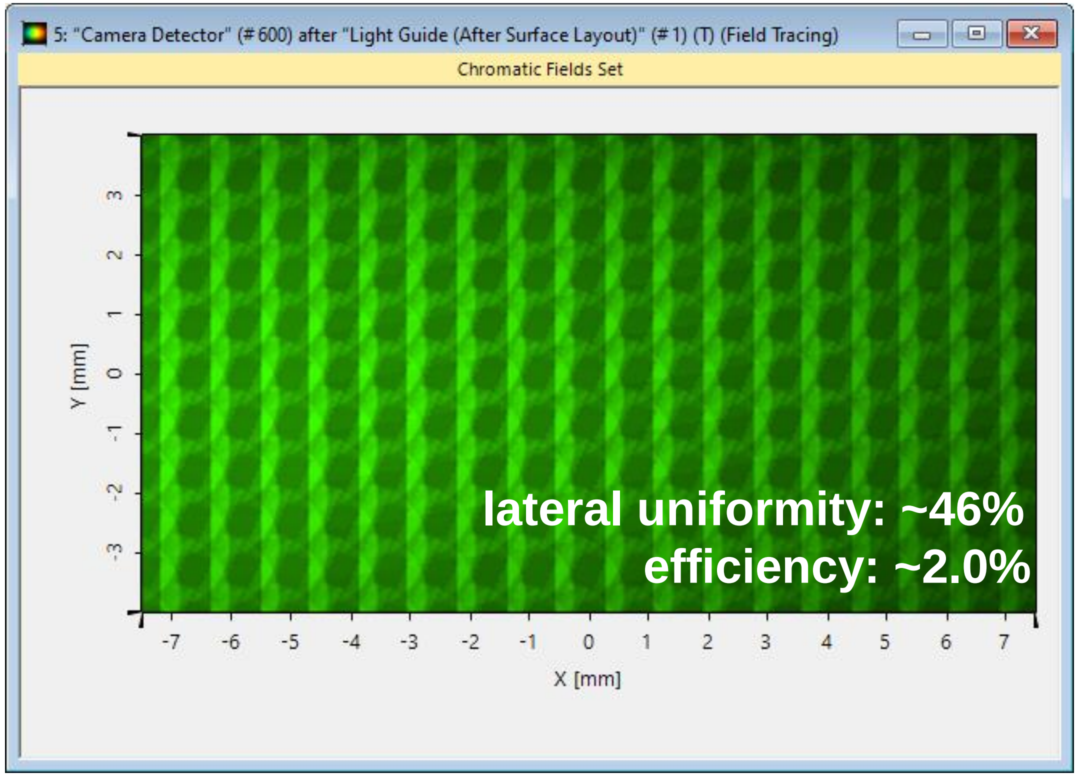
Result of optimized system

Result of ray tracing for central FOV mode



for illustration just light hitting the eyebox shown

Light distribution in eyebox for central FOV mode



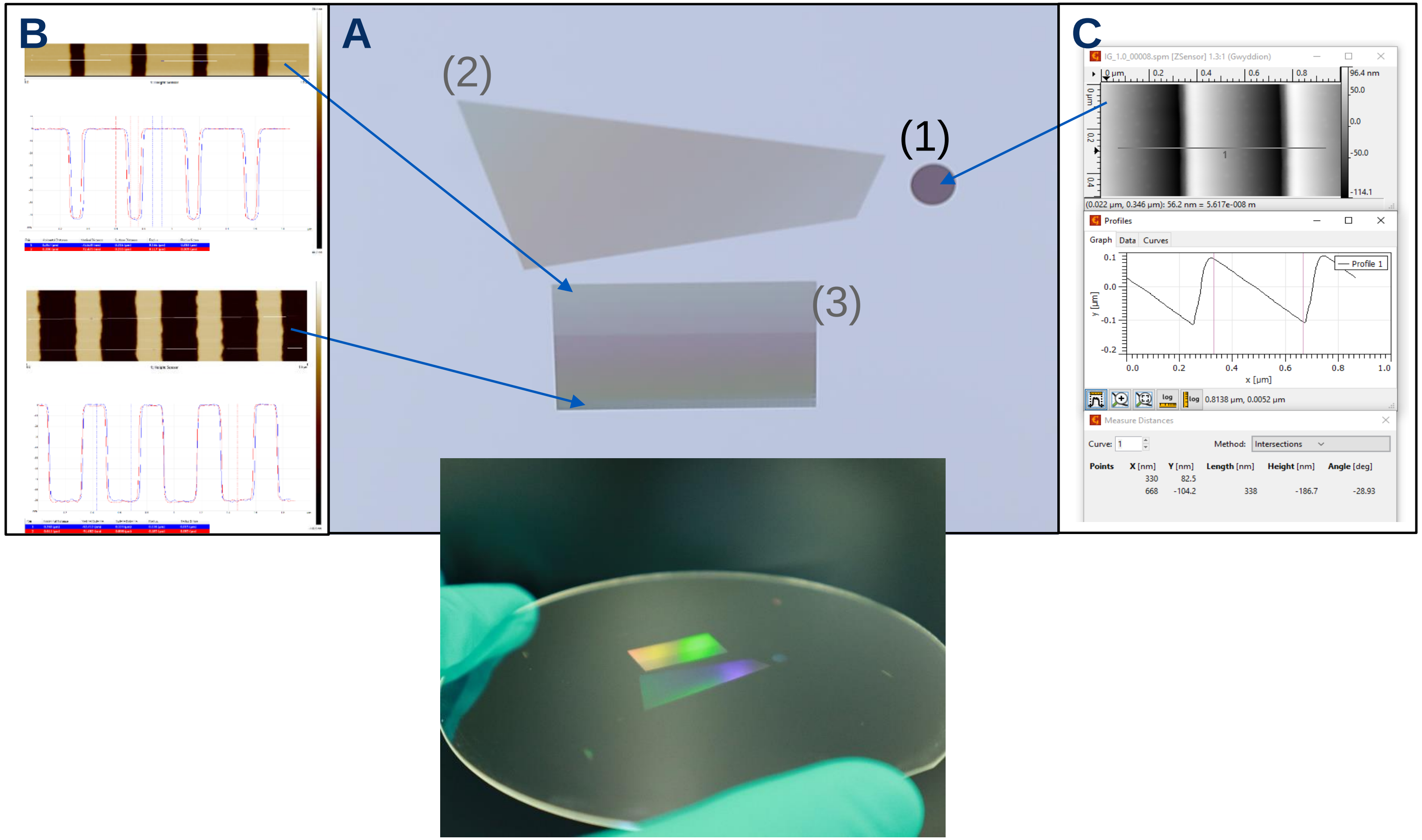
including polarization effects & rigorously calculated grating responses

Waveguide Optics Mastering

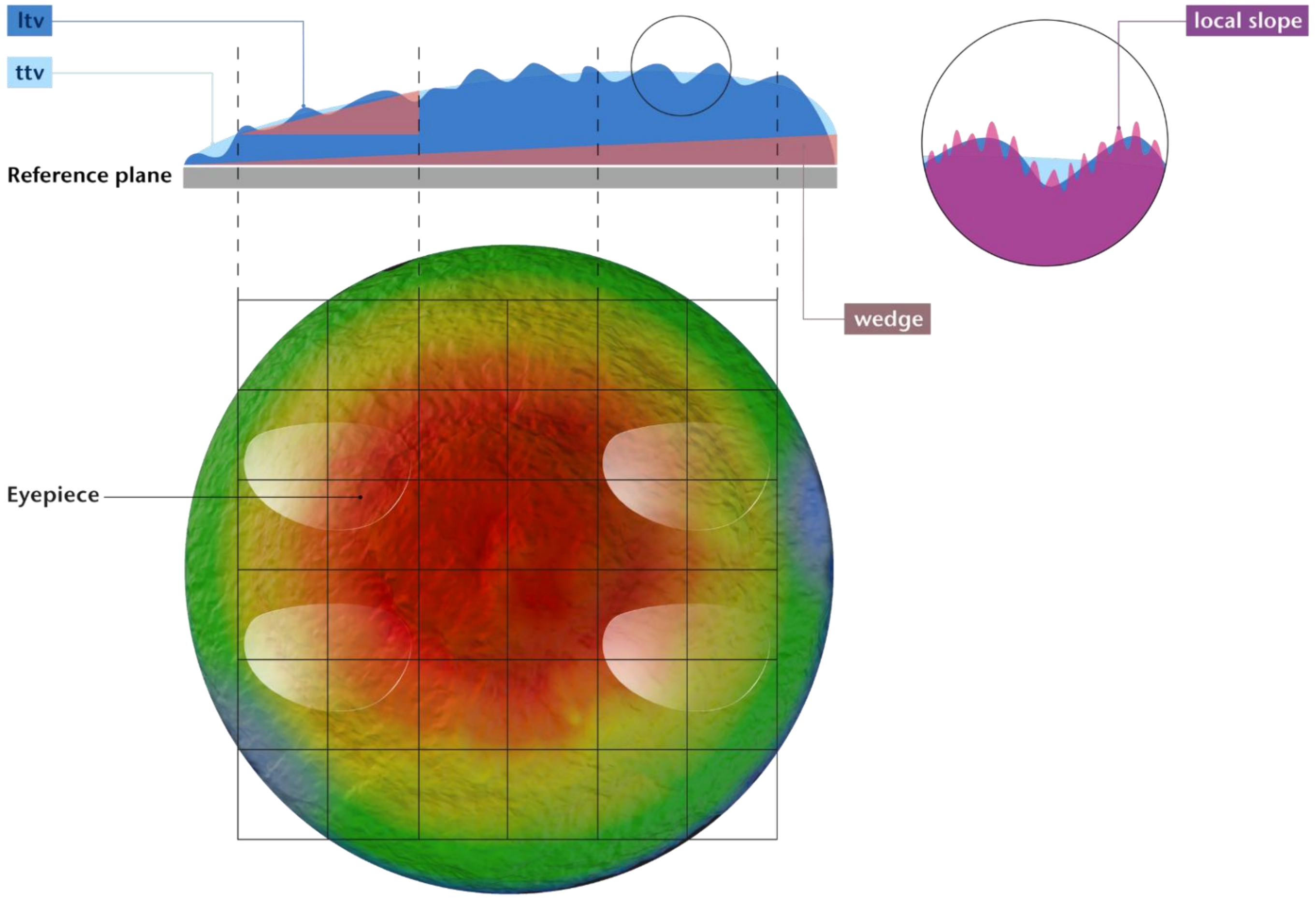
A: Complete AR master with blazed input grating (1), fill factor modulated expander grating (2) and depth and fill factor modulated output grating (3).

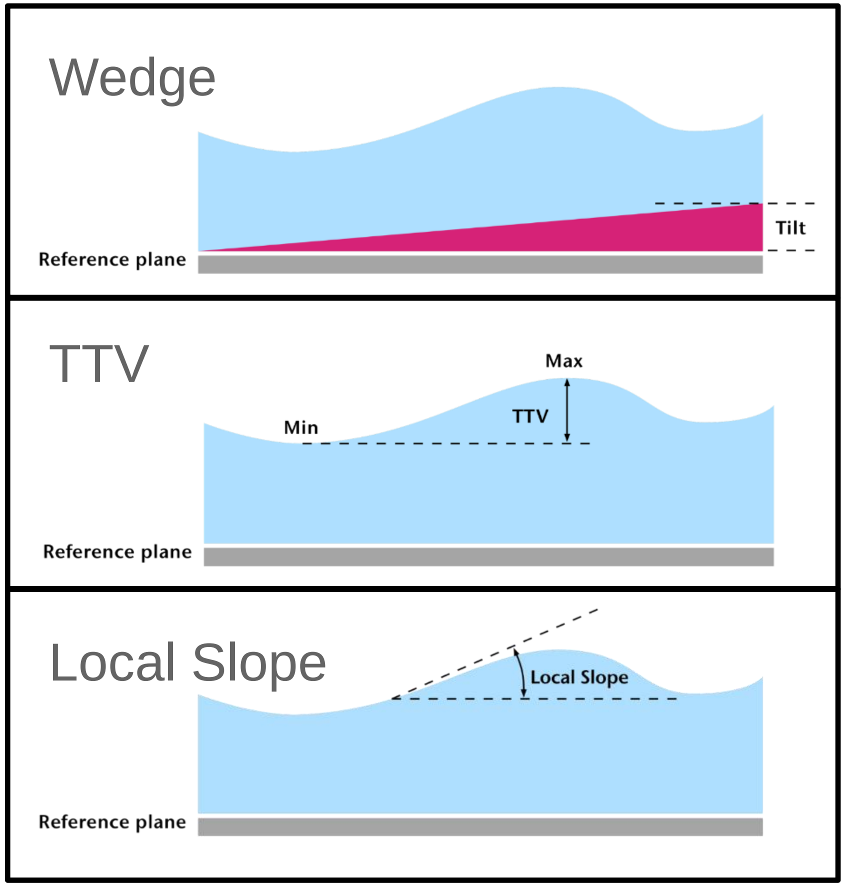
B: AFM scans of Output grating showing both fill factor modulation from 17% (top) to 56% (bottom) and depth modulation from 72 nm (top) to 92 nm (bottom).

C: AFM scan of blazed input grating showing the sharp profile with 29 degrees blaze angle.



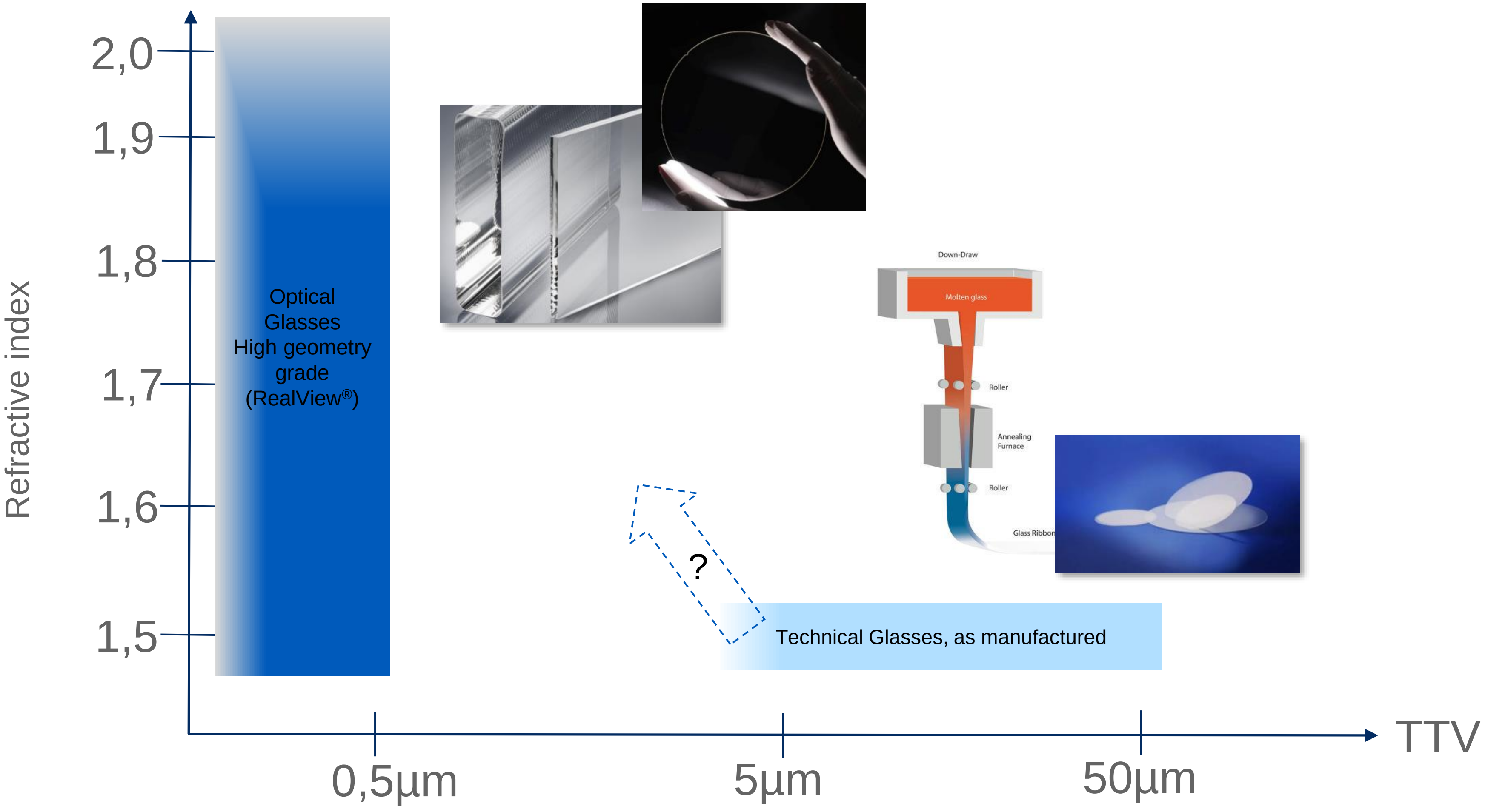
Surface topology directly impacts waveguide performance





RealView® technology continues to fuel AR industry

SCHOTT
glass made of ideas



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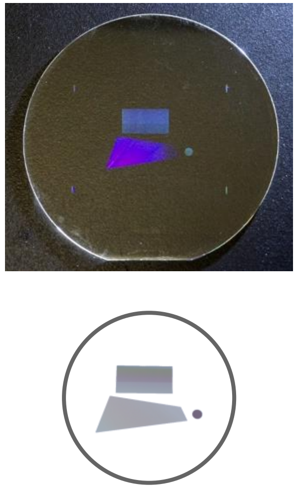
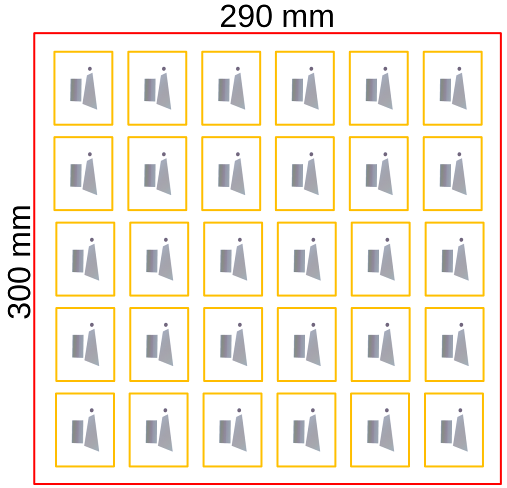
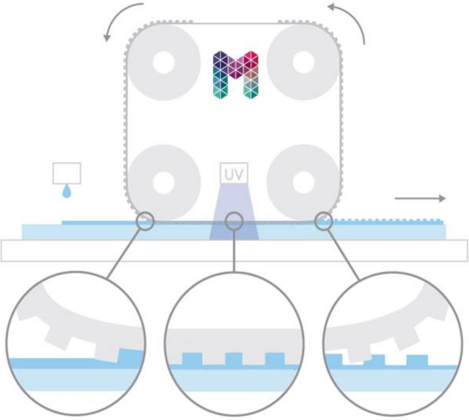
Manufacturing scaling advantage

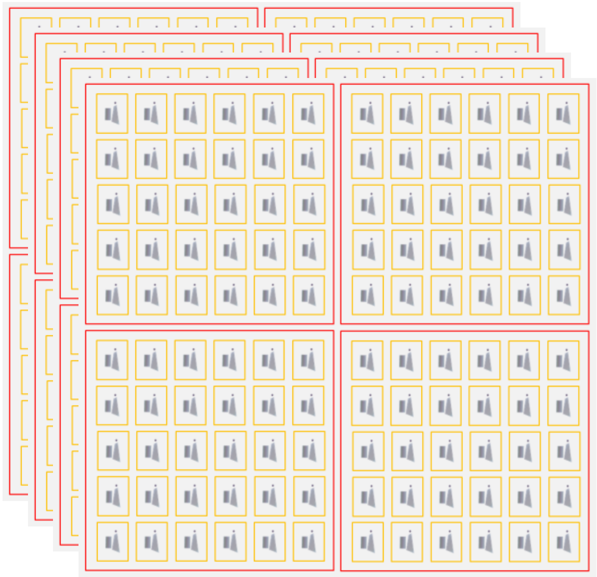
Single eyepiece Master → **Master Upscaling (Morphotonics proprietary)** → **Large Area R2P Nanoimprint Lithography (NIL)** → **Mass Production enabled**

Gen-3.5: 12 & 40 runs/hr | 1,440-4,800 eyepieces/hr
Gen-5: 12 & 40 runs/hr | 3,240-10,800 eyepieces/hr*







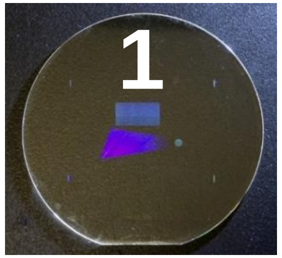


- Masters can be tedious & complex to originate, only a limited number of eyepieces can be made in wafer format
- Upscaling of masters is needed to increase throughput
- Roll-to-Plate (R2P) NIL can replicate multiple scaled-up masters on large substrates or smaller wafers grouped together

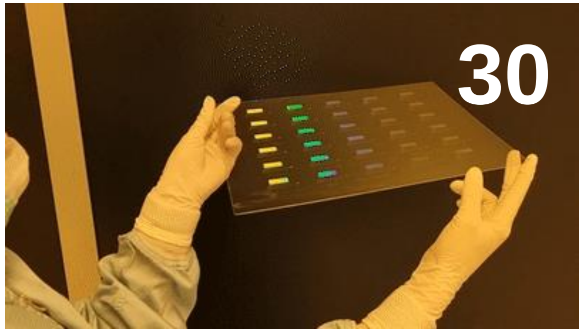
*Assuming 5 mins/run & 1.5 mins/run on Portis & Aurora equipment

Going beyond wafer-scale

Single eyepiece Master



Upscaled Submaster



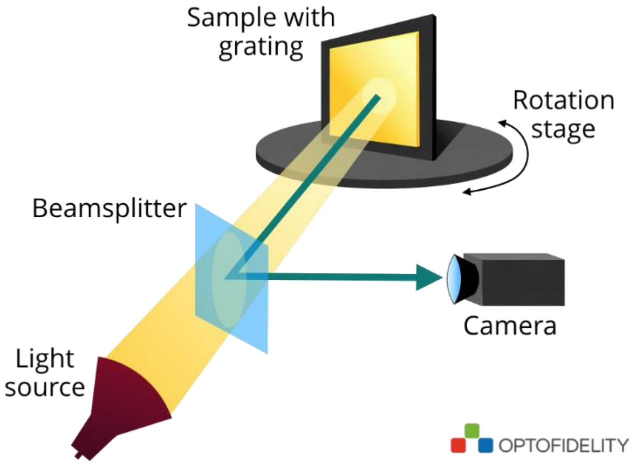
Gen-3.5 size Imprint

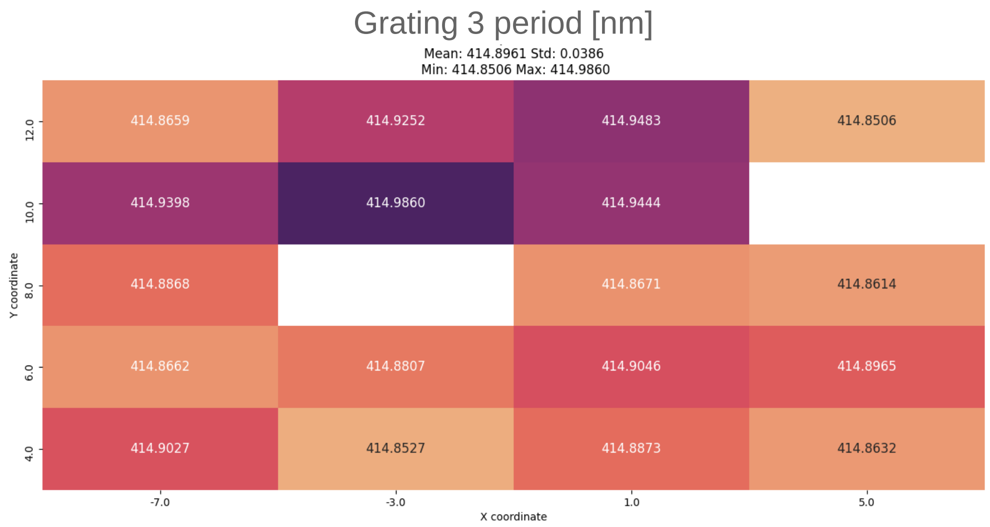
- From a single eye-piece to imprinting 30-up on 4 wafers per run (on Gen-3.5 carrier)
- Imprint using HDS (High Dimensionally Stable) stamp ensuring dimensional stability
- Imprinting in resin with 1.9RI on smaller 1.9RI wafers*
- Squared wafers have more than 25% surface area than circular wafers**
- Replication on round wafers is also possible by using a wafer-carrier

*1.9 RI resin (PixNIL-SFT1) co-developed with Pixelligent, resin formulation can also be further tuned in RI
**300mm circular wafer vs. 300mm squared wafer

Grating characterization

OPTOFIDELITY





Littrow diffractometer

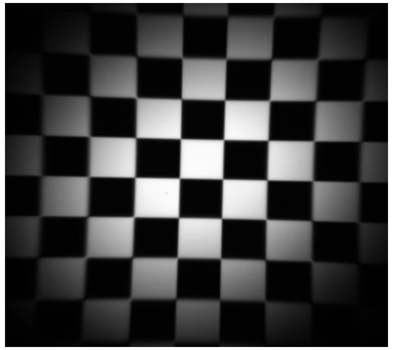
- Finds the Littrow angle, where light diffracts back to the laser from the grating
- Grating equation used to calculate the grating period
- Hardware: ultra-stable laser at 405 nm, very accurate rotation stages
- Relative grating line orientation can also be measured

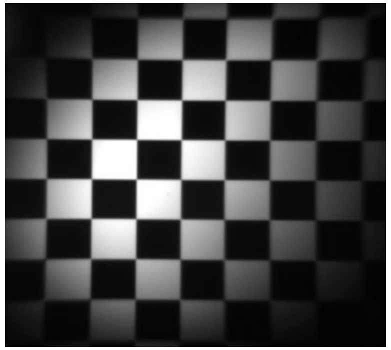
Results, (Sample 3-6)

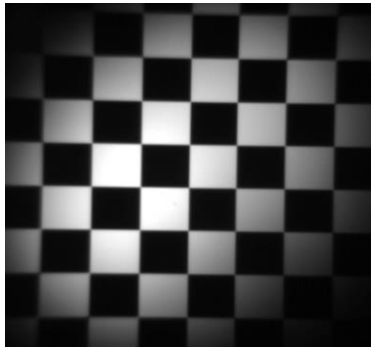
- Average period vs. nominal 415 nm
  - 414.98 nm, Grating 1
  - 414.88 nm, Grating 3 ± 40 pm (1 sigma)
- Relative orientation, Grating 1 vs. 3 (nominal 90 deg)
  - 89.99973 deg

Waveguide image quality measurements

User experience is characterized by the observed image quality from the eyebox of the waveguide


Reference


Sample 1


Sample 2

Measurement system

- Custom reticle projector to illuminate the input grating
  - Köhler illumination, 16 x 16 deg FOV
  - Green LED at 532 nm
- OptoEye wide field-of-view AR/VR camera
- Laboratory setup with manual positioning

Results of first measurements

- Overall, the waveguides work well, certainly for a first trial sample
- Reference measured without the waveguide
- Luminance uniformity is visually good
- Further measurement data will be included in manuscript & poster

Summary

There is a path for Augmented Reality Waveguide Optics Mass Manufacturing…

For a successful transition to high-volume manufacturing of AR waveguide optics:

- Robust design – mastering – replication proven, showing good waveguiding at first pass!
- Display-oriented large-area manufacturing mindset is possible
- An end-to-end supply chain & cooperation between different disciplines is key