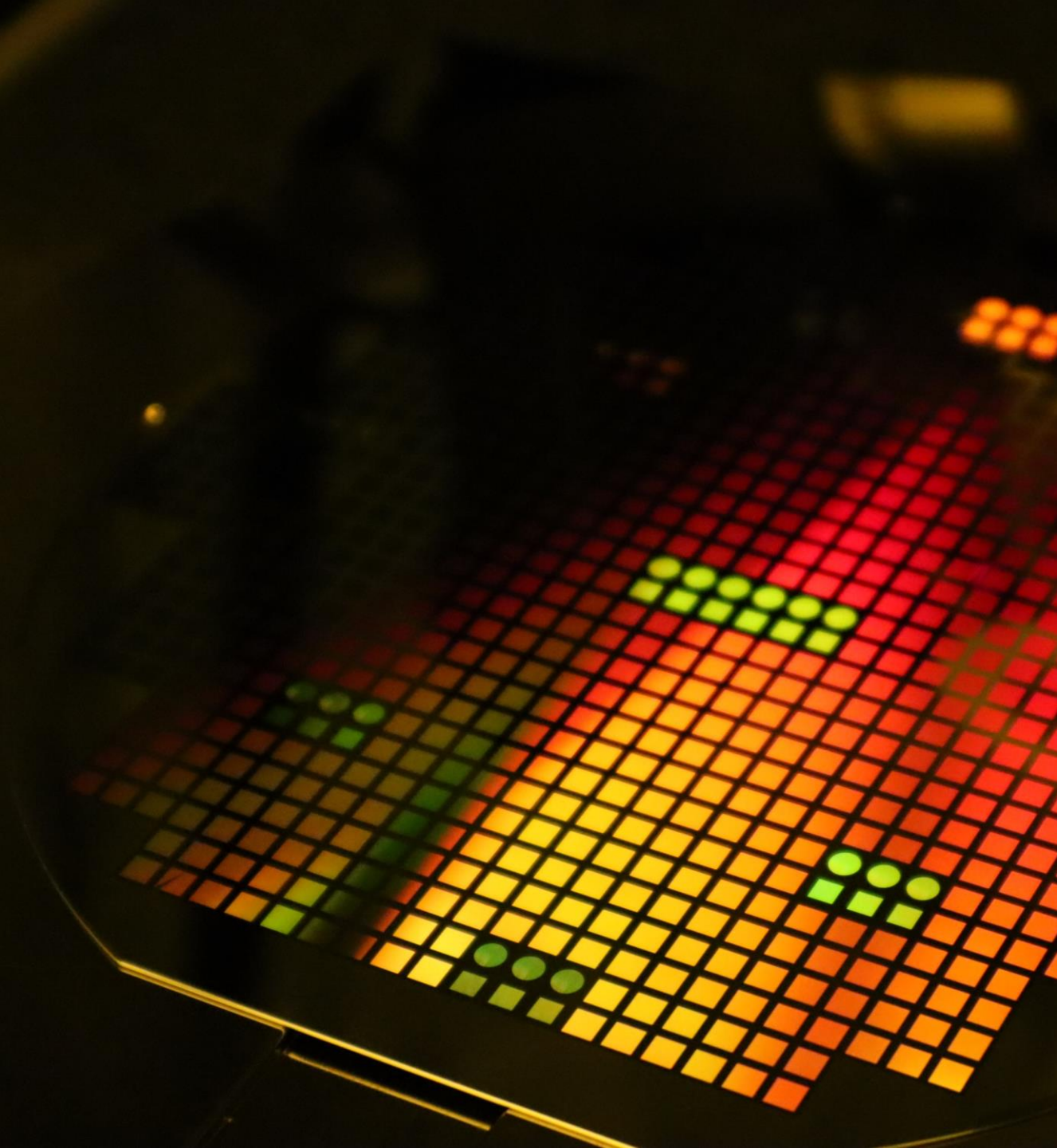


# Diffraction Optical Elements integration on VCSEL for ToF applications

*EPIC OTM on VCSEL technology and applications*  
*13.06.2022*

Ludovic Marigo

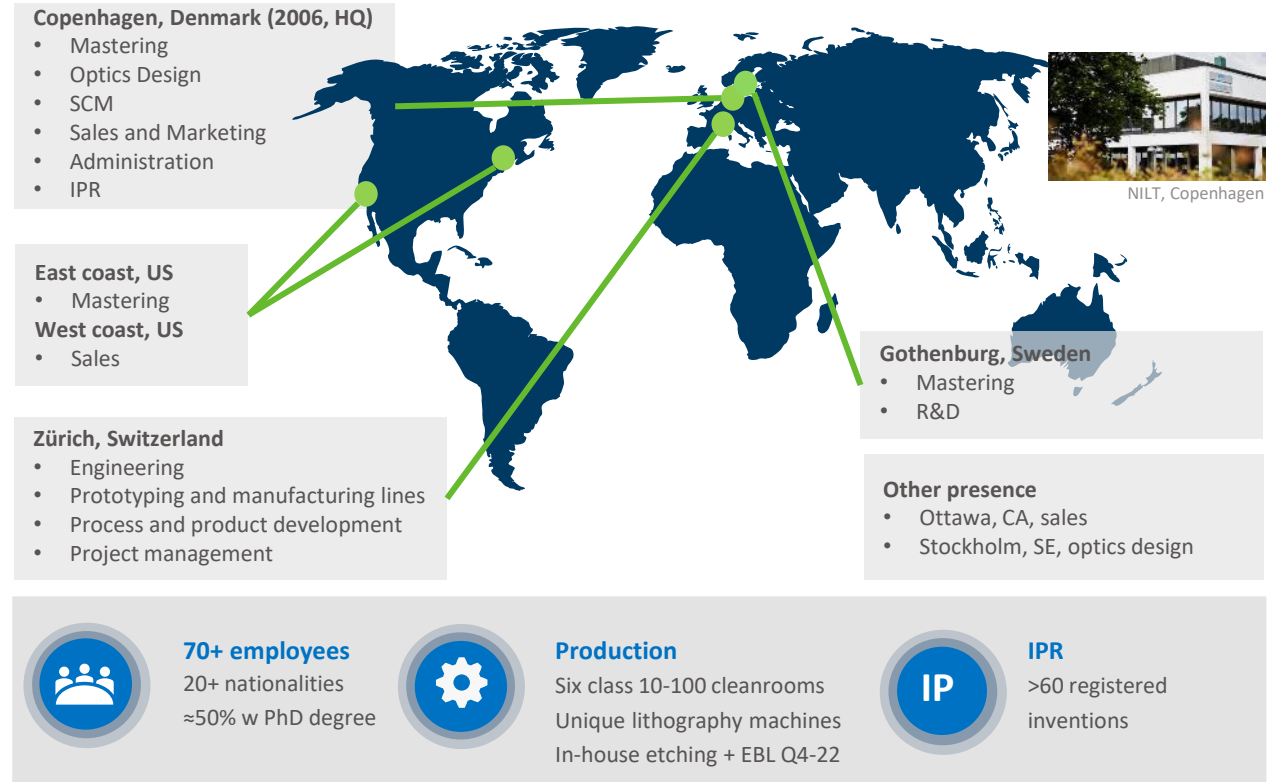


## 1. Manufacturing optical elements, components and modules

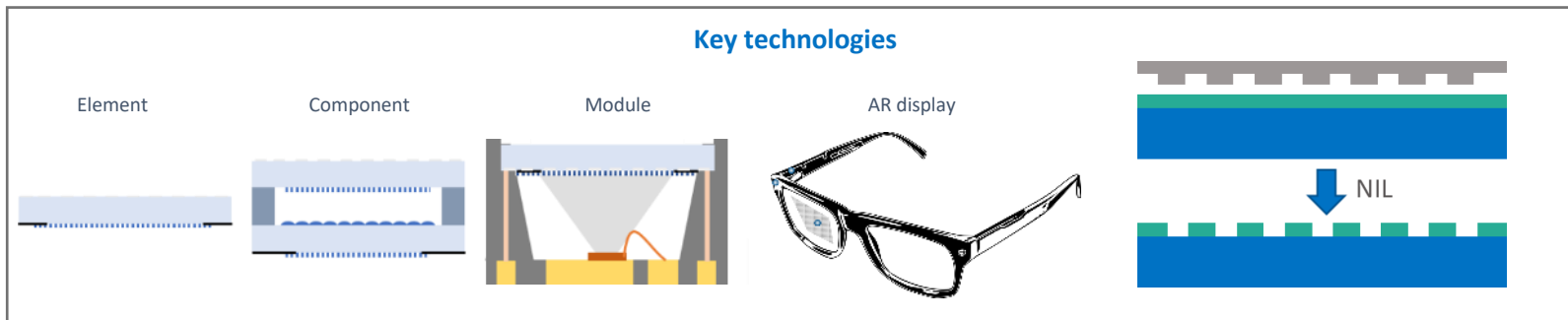
- Optical elements, **Rx and Tx**: diffusers, fanouts, collimators, focusing/imaging lenses; and building integrated functionalities
- Optical components and modules
- **Key technologies: DOE, MOE, gratings, MLA...**

## 2. Mastering technologies for diffractive waveguides

- **Masters (and working stamps) for AR/MR displays** to make diffractive planar waveguides

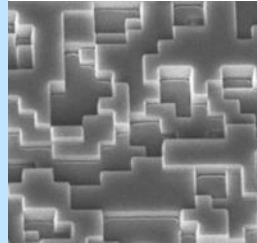


NILT, Copenhagen



# Products | Elements/components and masters for AR

## Diffractive Optical Elements (DOEs)



- Smartphone, automotive, industrial, medical, etc.
- Stacked and multi-element components
- Combined flood/patterned light module, incl collimation, for NIR/SWIR applications

### Diffuser

High efficiency, extremely low zero order  
FOI >70° available, FOI >100° under development

### Fanout

Dot uniformity >90%. Efficiency >94% demonstrated  
FOI >70° available, FOI >100° under development

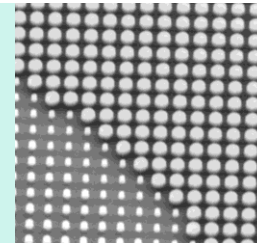
### Collimator

Collimation efficiency >80%. Diffraction limited spot size

### Focusing Lens:

Focusing efficiency >80% Diffraction limited spot size

## Meta Optical Elements (MOEs)



- Smartphone, automotive, industrial, medical, etc.
- Completely flat, thin imaging lenses: low F#, high RI, high FOV and concentricity in NIR & SWIR
- Polarization control

### One Metasurface lens (1M) camera module

Efficiency >80%, FOV >100°, F# <1.2  
Prototyping results available  
Efficient in NIR & SWIR, up to 94% MOE lens demonstrated

### Two Metasurface lens (2M)

Design and proto results available

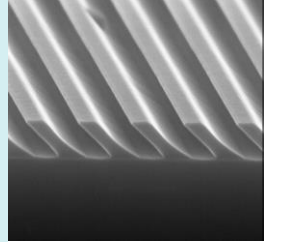
### Hybrid Lenses (1M3P, 2M2P,...)

Reduce Z-height and complexity of lens and system

### Emitter optics

Diffusers and fan-out, high FOI, polarization control

## Masters for Displays (AR/MR)



- Input-, expander-, and output gratings for waveguides in AR/MR and auto HUDs
- All grating types can be combined, in any relative placement and orientation

### Slanted Gratings

Flat trench bottom. Tunable tapering  
Roughness RMS <2 nm

### Large Area Gratings

>12 cm<sup>2</sup>, better than 20 pm pitch accuracy  
11 nm global positioning accuracy  
Non-periodic gratings are possible  
Pixelated gratings are possible

### Blazed/Binary Gratings

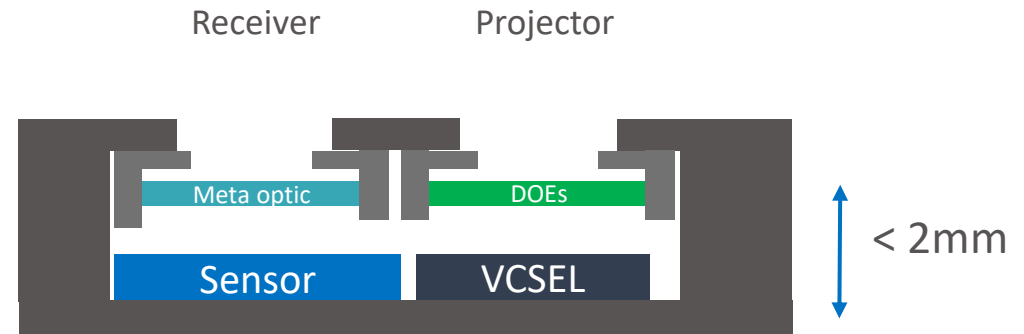
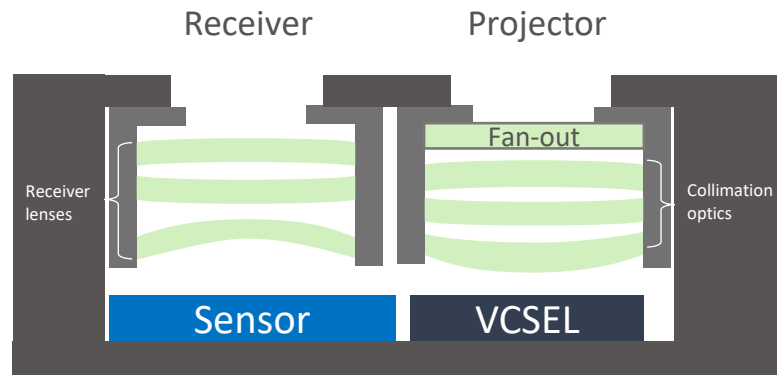
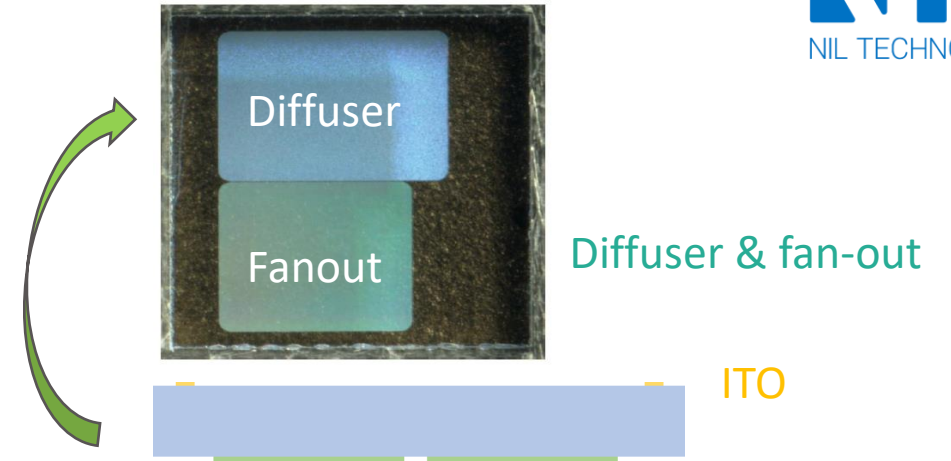
Down to 200 nm periods  
Small anti-blaze  
Roughness RMS <2 nm

# Products | Solution and advantages

- Compact solution for Diffractive Optical Elements (DOE) single-sided element, two-sided elements or combined/stacked



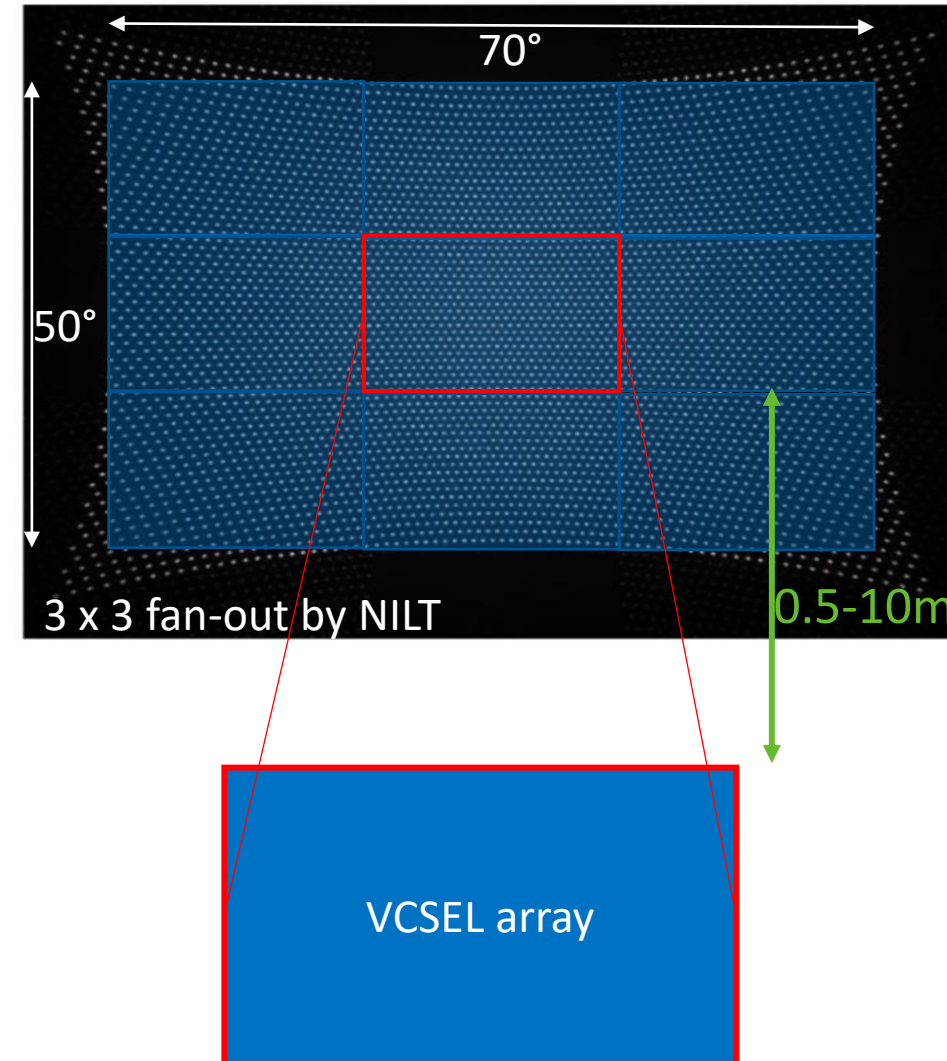
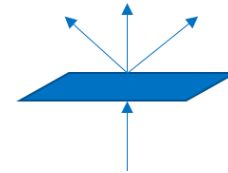
- Deep understanding of the alignment requirements
- Several elements can be integrated on one surface
- Overall system and assembly complexity can be significantly reduced
- Flat optics elements have the same aspect ratio than VCSEL → same pick and place tooling can be used



Note that, contrary to diffuser standalone, collimator associated with diffuser or Fanout requires special alignment tolerances

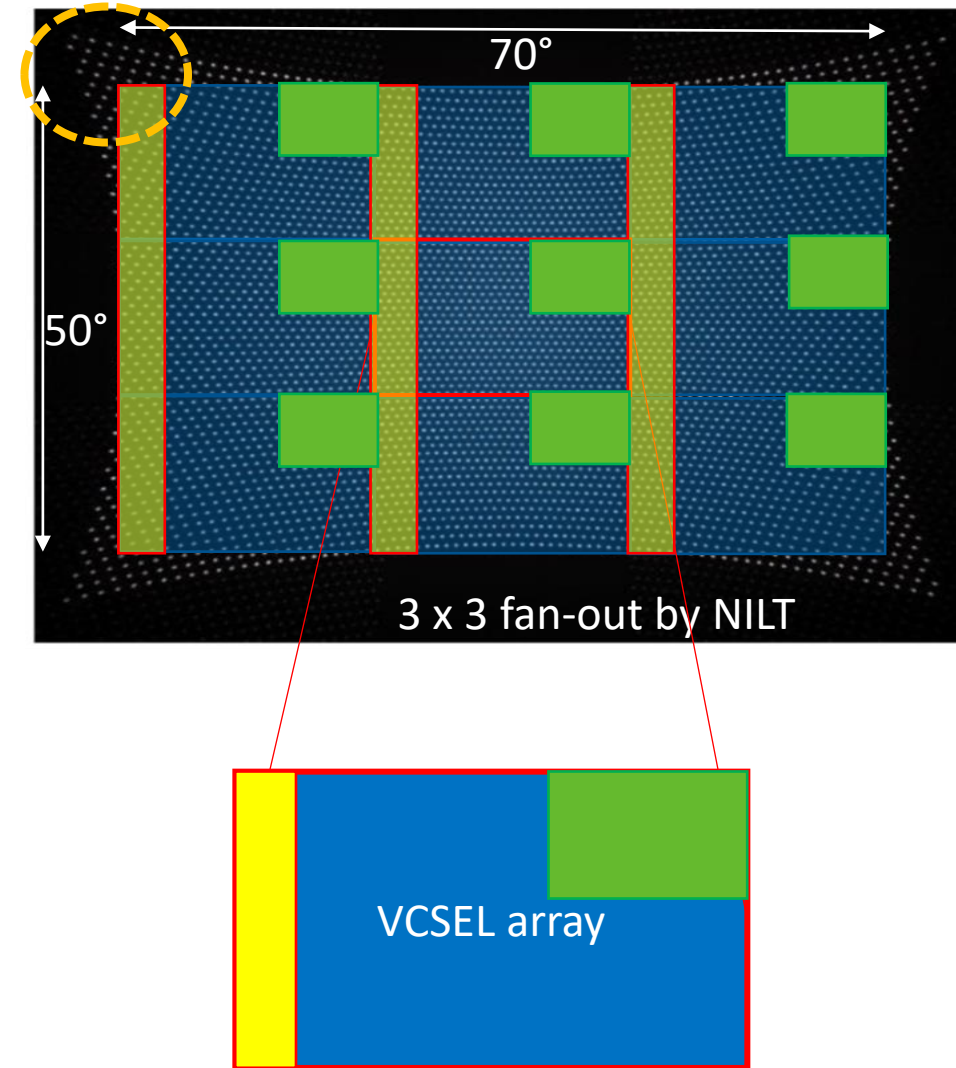
# Spot illumination | Uniform dot projected pattern

- Fanout splits each emitter dot from the VCSEL array into 3x3 or 5x3 or another dot configuration
- Fanout are used for depth measurement
  - dToF (ns-regime): SJ and MJ VCSEL
  - iToF (ms-regime): thanks to MJ VCSEL → longer range less complicated driver and module suitable for consumers applications such as AR/VR
- Overall demonstrated performances
  - FOI > 70° - Under development > 100°
  - Total efficiency > 94%
  - Uniformity error (↔ intensity difference between the different tiles) < 10%
  - Contrast ratio > 35 dB
  - Spot intensity in tiles can be tuned according to customer needs



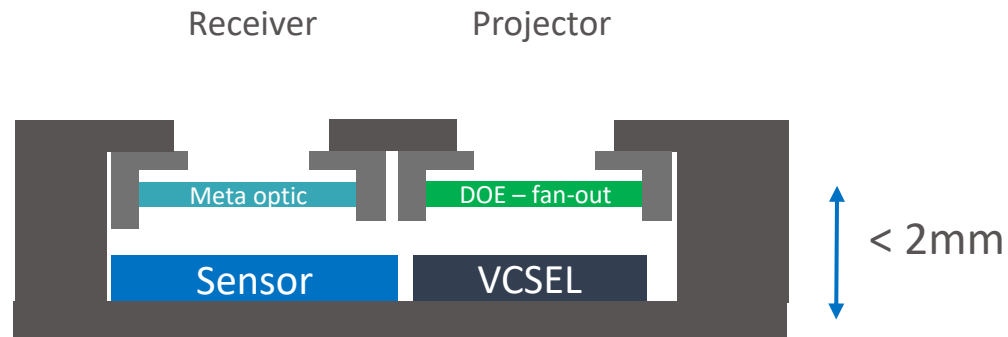
# Spot illumination | Selected area for LiDAR

- For LiDAR application:  
rotating mirror/MEMS → Addressable VCSEL arrays
- Combination with Spot illumination:
  - Vertical lines can be spaced by  $> 23^\circ$  and thus be individually distinguished by the sensor
  - Square area can also be used
- To be kept in mind:
  - **Distortion** at the corners to be considered when designing the entire system



# Conclusion

- NIL Technology is a vertically integrated company for optical design, mastering, replication, optical characterization and reliability of DOE and MOE
- Spot illumination can be designed according to customer needs to achieve compact module solutions
- Close collaboration needed to define the optimum set of elements: VCSEL – Collimator – Diffuser or Fanout





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