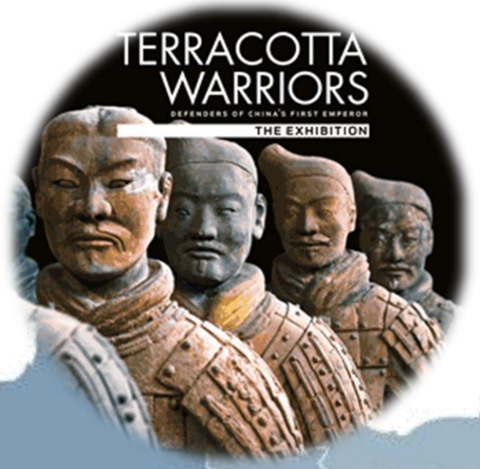
Beam shaping micro-optics made of glass for 3D sensing in the automotive industry

Dirk Hauschild, Jennifer Zhang, Dr. Daniel Braam

EPIC Meeting about Wafer Level Optics

7-8 November, Neuchatel, Switzerland

OVERVIEW


TERRACOTTA
WARRIORS
DEFENDERS OF CHINA'S FIRST EMPEROR
THE EXHIBITION

Xi'an


Dortmund

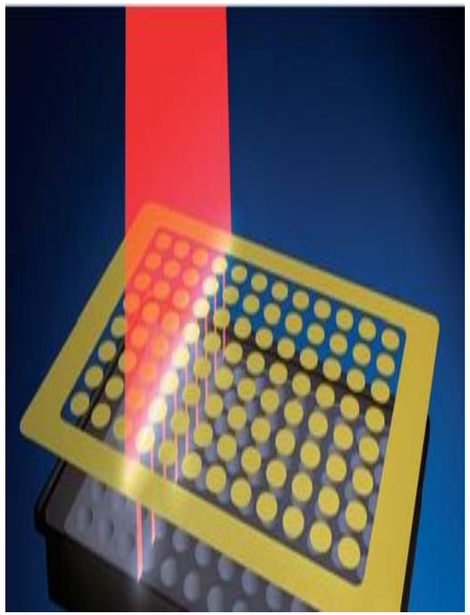

陕西省高功率半导体激光器产业园
Power Semiconductor Laser Industrial Park


LIMO

KEY FACTS & FIGURES

- Focuslight 12 years history; LIMO 27 years history
- R&D investment 17% (Xi'an operation center 21%, LIMO 11%)
- Around **570** employees (~310 from Xi'an operation center, 220 from LIMO,40 from Dongguan operation center)
- **789** patents (444 from Xi'an operation center, 345 from LIMO)
- **31,000** m^2 self-owned building (20,000 m^2 for Xi'an operation center and **11,000** m^2 for LIMO) → **4,900** m^2 clean room (2,900 m^2 for Xi'an operation center and 2,000 m^2 for LIMO)
- **ISO9001** certified + **ERP** implemented
- **IATF16949** certification in 2020 scheduled

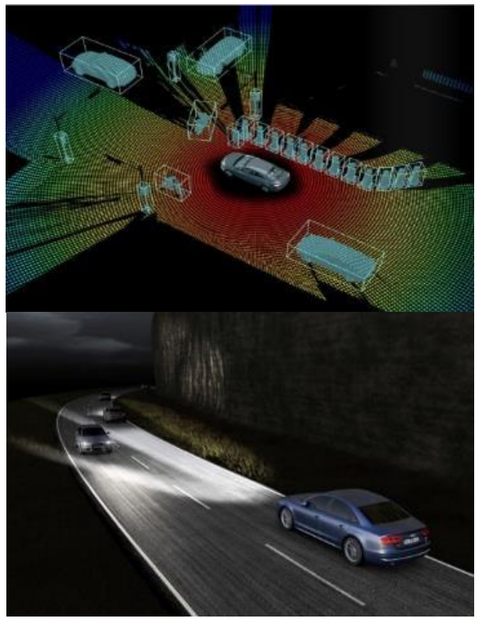
MARKETS



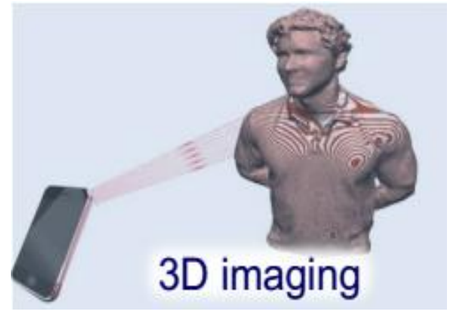
Advanced Manufacturing

Health

Research



Automotive



Information Technology

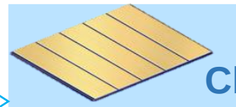
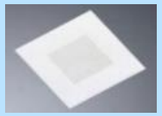
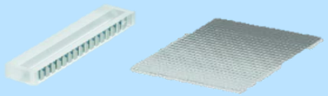
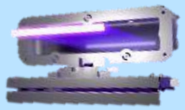
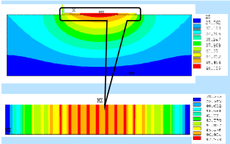
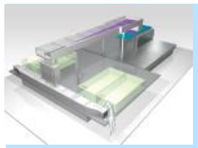
To be the world's leading diode laser and laser optics manufacturer through innovation and enhancement of customer value with quality products and application solutions

VALUE PROPOSITION

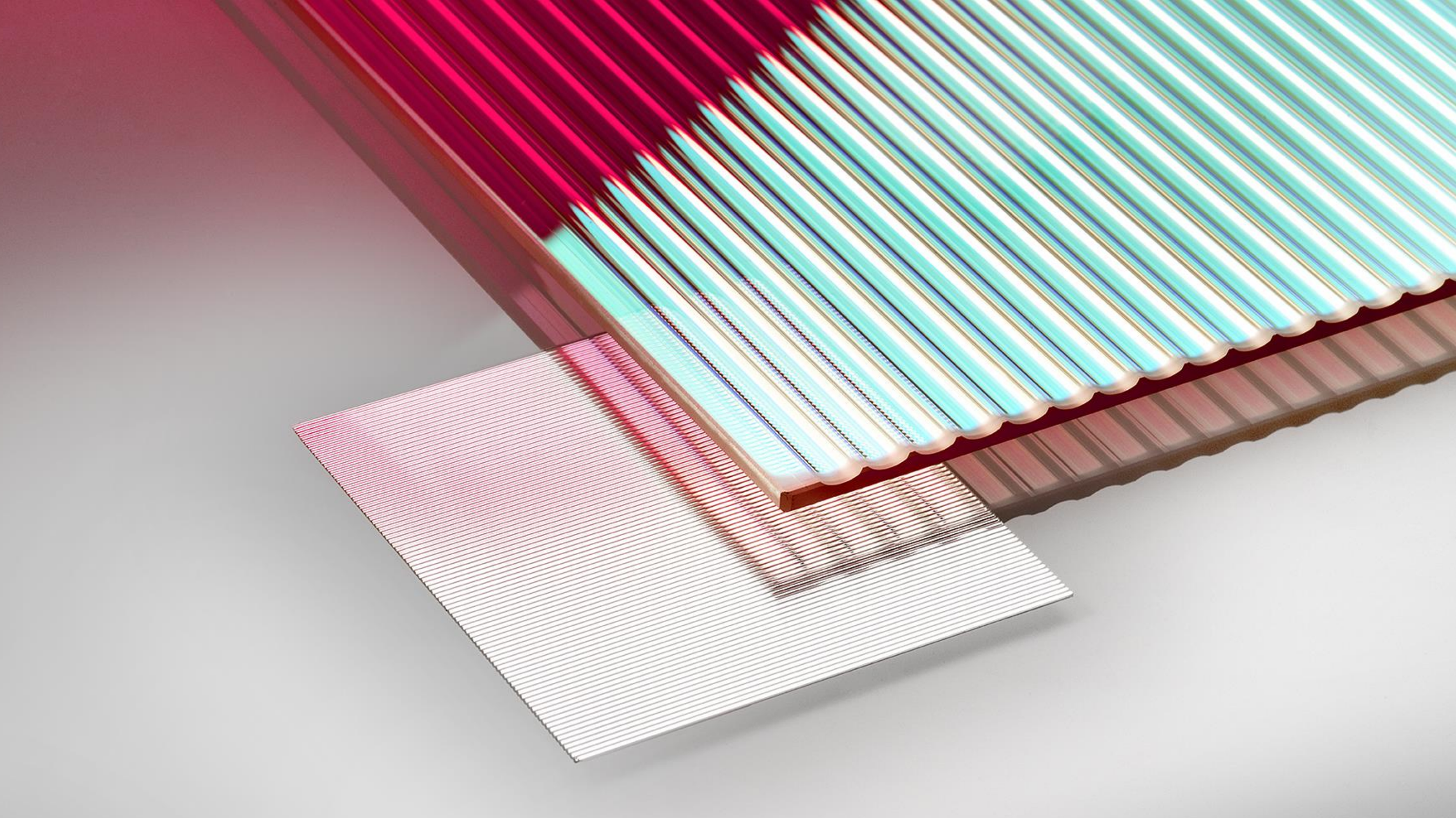
FOCUSLIGHT Never stop exploring | LIMO A Focuslight Company

Full Value Chain

Total Solution & Service

Raw Materials	 Chips(Strategic collaboration with Suppliers)	+  Packaging Materials	+  Optics Substrate
Components & Devices	 Light Sources	+  Optical Components	+  Fiber coupled Modules
Modules/Subsystems & application systems	 Laser Subsystems	+  Optical Subsystem	+  Integrated Modules
Solution, Support & Service	 Application Centers in US, Europe & Asia	+  Technical Support	+  Field Service Centers in US, Europe & Asia

Industry Leader
Strong Financial Backing
Healthy Stable Company, Invest in the Future



CONTENTS

FOCUSLIGHT

- **INTRODUCTION**
- **MOTIVATION**
- **3D LIGHT SHAPING**
- **EXAMPLES**

INTRODUCTION

Light speed sensors see the problem before it is visible for us!

- All what we now about nature we learned from photon-material interaction
- To use well controlled photons in time, space and energy is the basis for accurate 3D measurements like LIDAR
- How to design a superior 3D sensor:
  - *Synchronize the field of illumination and field of detection in space and time*
  - *Keep the laser power on a safe level for the environment and the distance measurement*
  - *Keep the performance constant at all environmental conditions*
  - *No moving parts and keep it simple*

CONTENTS

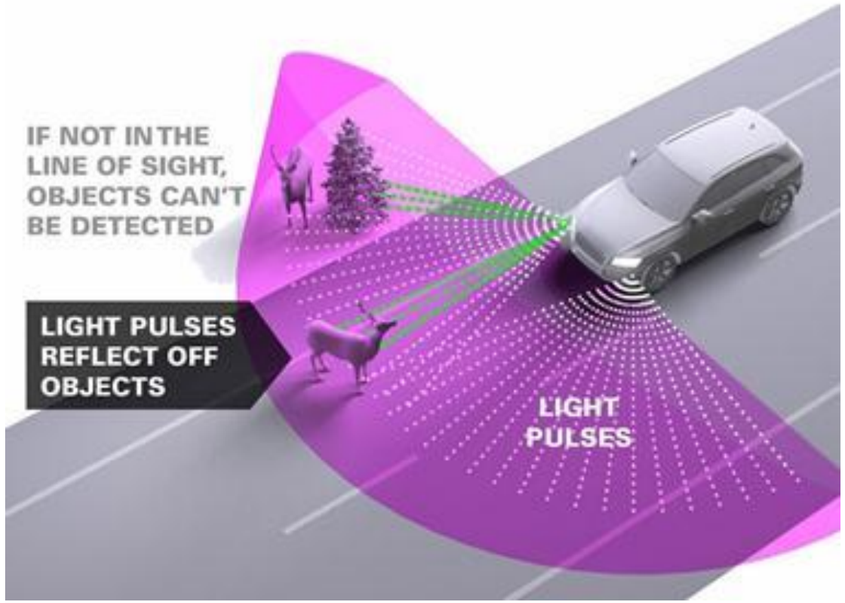
FOCUSLIGHT

- INTRODUCTION
- **MOTIVATION**
- 3D LIGHT SHAPING
- EXAMPLES

MOTIVATION

3D sensing with LIDAR can reduce 95% of all accidents!

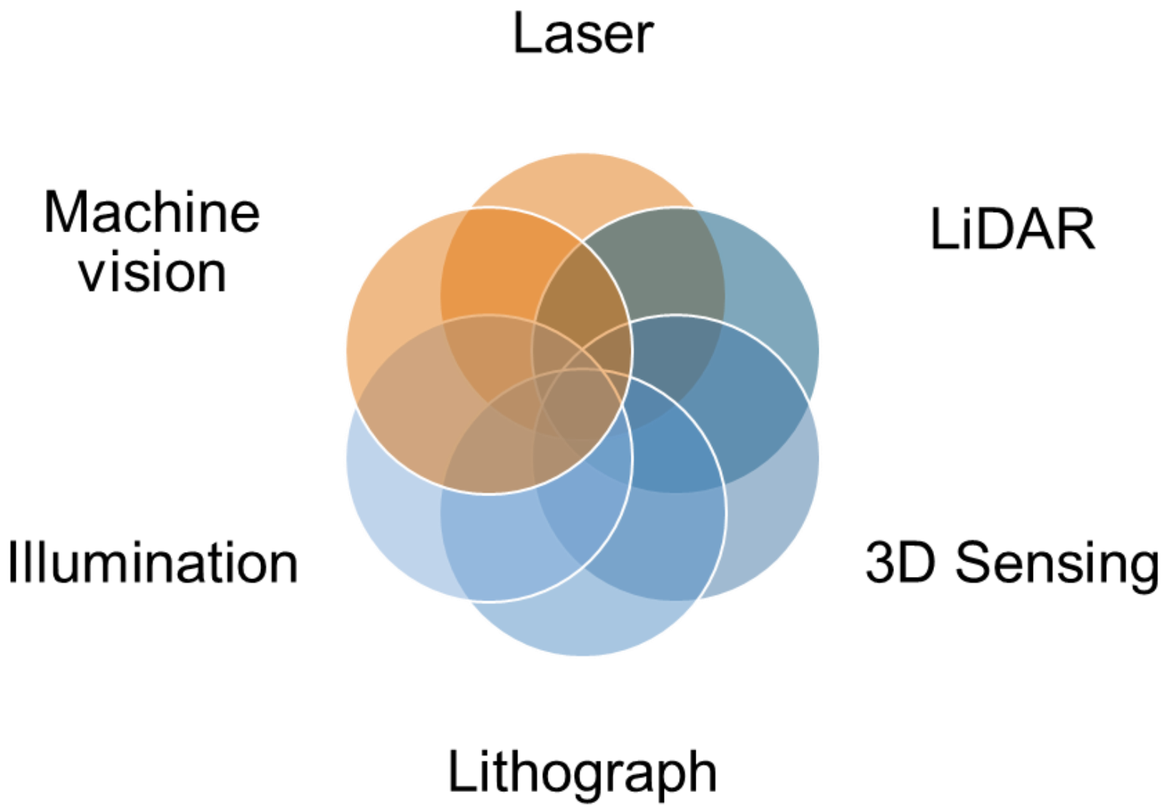
- To keep this target alive the LIDAR sensors should detect 100% of the objects that they were designed for and maybe more!
- 360° detection needs a team work of lasers and optics
- Intelligent use of photon concentrations in vertical and horizontal directions is needed to get the right signal back into the detector
- Safe operation at all speed levels



MOTIVATION

Why micro-optics made of glass?

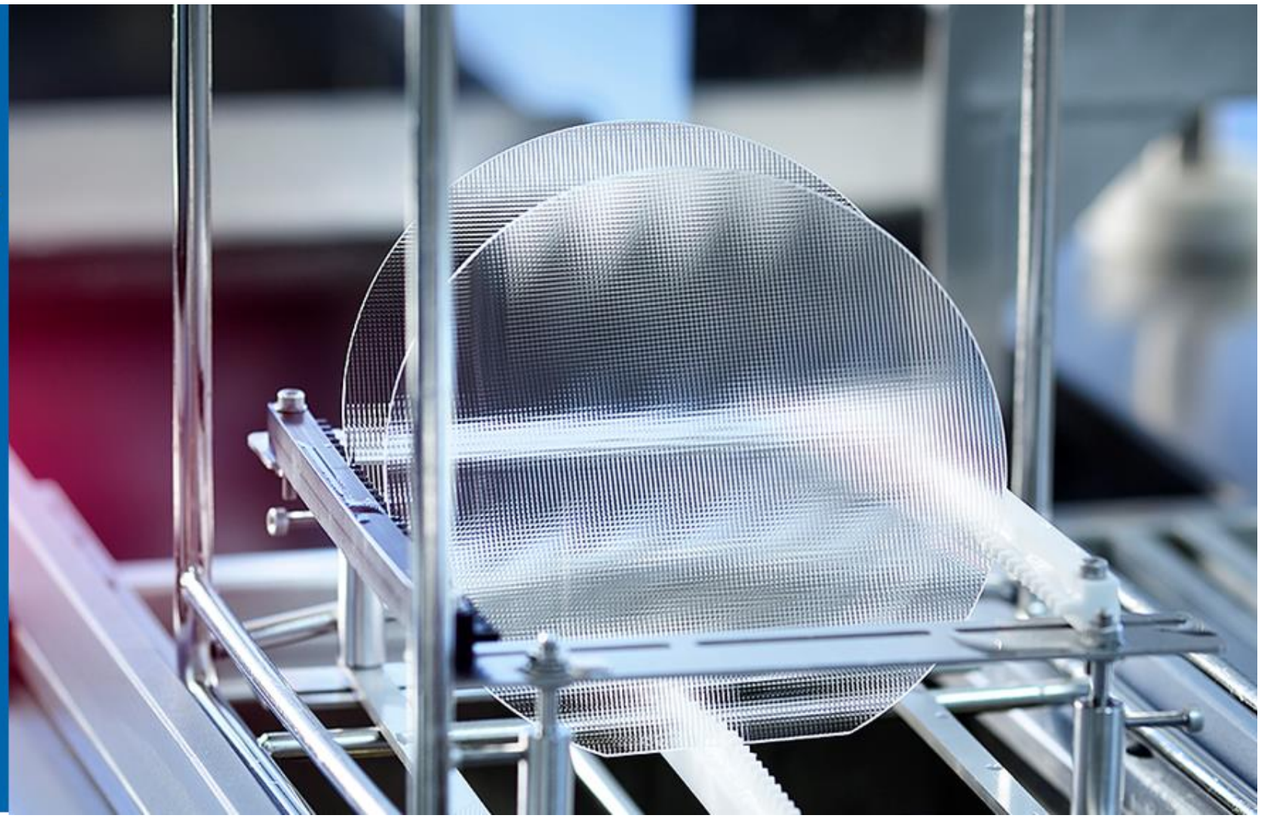
- Constant performance
- Maximum lifetime
- No degradation
- High laser induced damage threshold
- Minimum energy loss
- No “hot spot”, eye safety
- Large angle of incident
- Large FOV
- Insensitive alignment
- Outperforming productivity
- Material 100% recyclable



MOTIVATION

Flexible combination of material parameter and surface shapes

- Any glass materials / 2D freeform FA / SA collimators, beam transformation system (BTS), Homogenization/Diffuser
- Spot to line / spot to area, Gaussian-to-top-hat, multi-spot
- (Micro-) optical assemblies
- Wafer level up to 300mm x 300mm



CONTENTS

FOCUSLIGHT

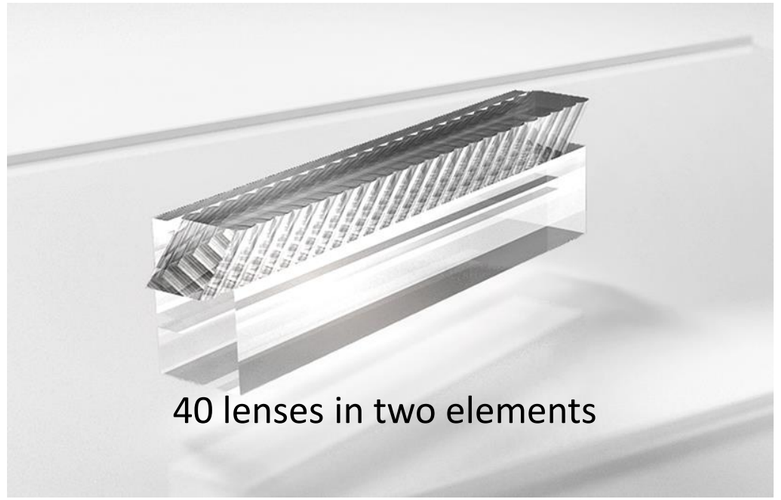
- INTRODUCTION
- MOTIVATION
- **3D LIGHT SHAPING**
- EXAMPLES

3D LIGHT SHAPING

Micro-optics are the key components for precision 3D sensing

What optical features are needed?

- Make use of 100% of the laser source power:
  - high numerical aperture to collect all the laser light
  - anamorphic features to control x- and y-direction individually
  - High long-term stability = glass is needed!
- Simplified design:
  - Less optical components
  - Higher level of functionality (optical and mechanical)



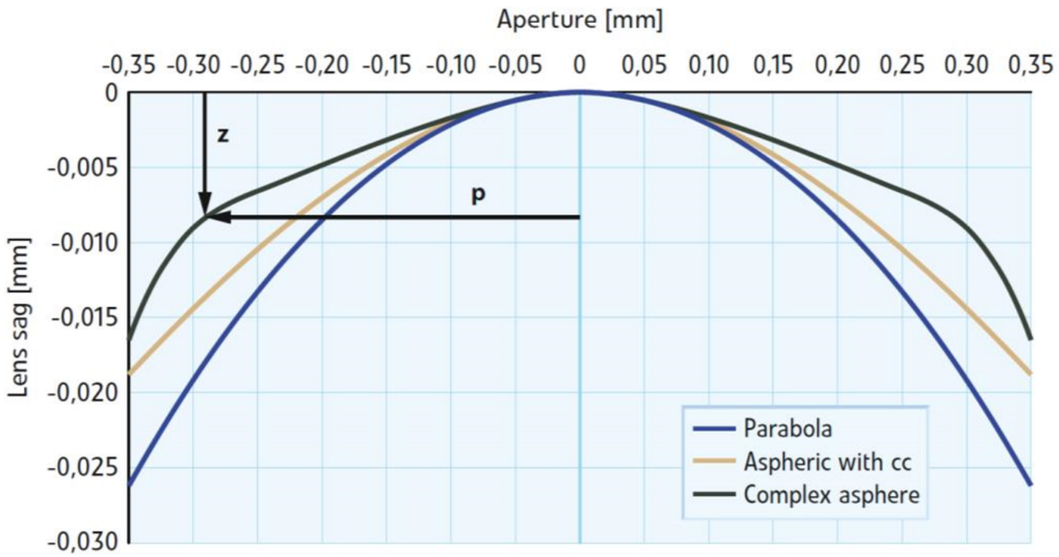
3D LIGHT SHAPING

How to designs and produces the right optical components for LIDAR?

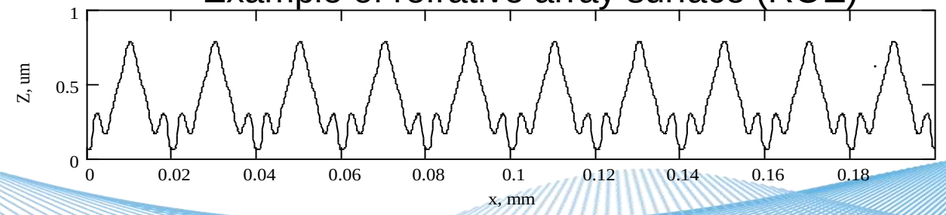
- Free-form cylindrical lenses and arrays with numerical aperture up to NA=0,9
- Optical refractive structures that combine large NA and homogeneous light distribution
- Simulation and measurement of system performance

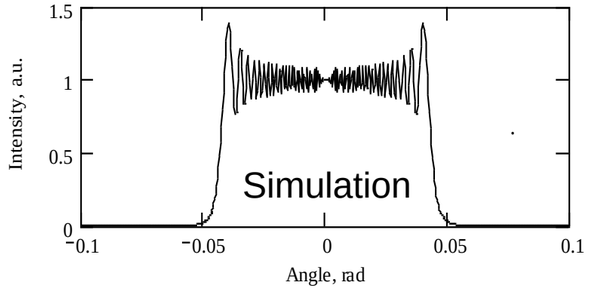
Lens Shape Formula:

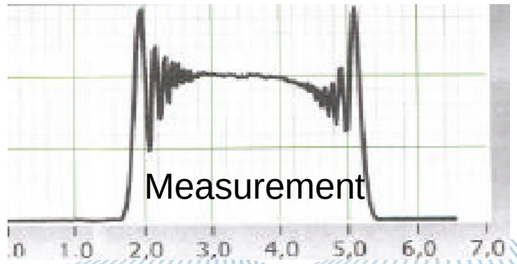
$$z = \frac{cv \cdot p^2}{1+\sqrt{1-cv^2(cc+1)p^2}} + \sum_{i=1}^{\infty} AS_i p^i$$



Example of refrative array surface (ROE)



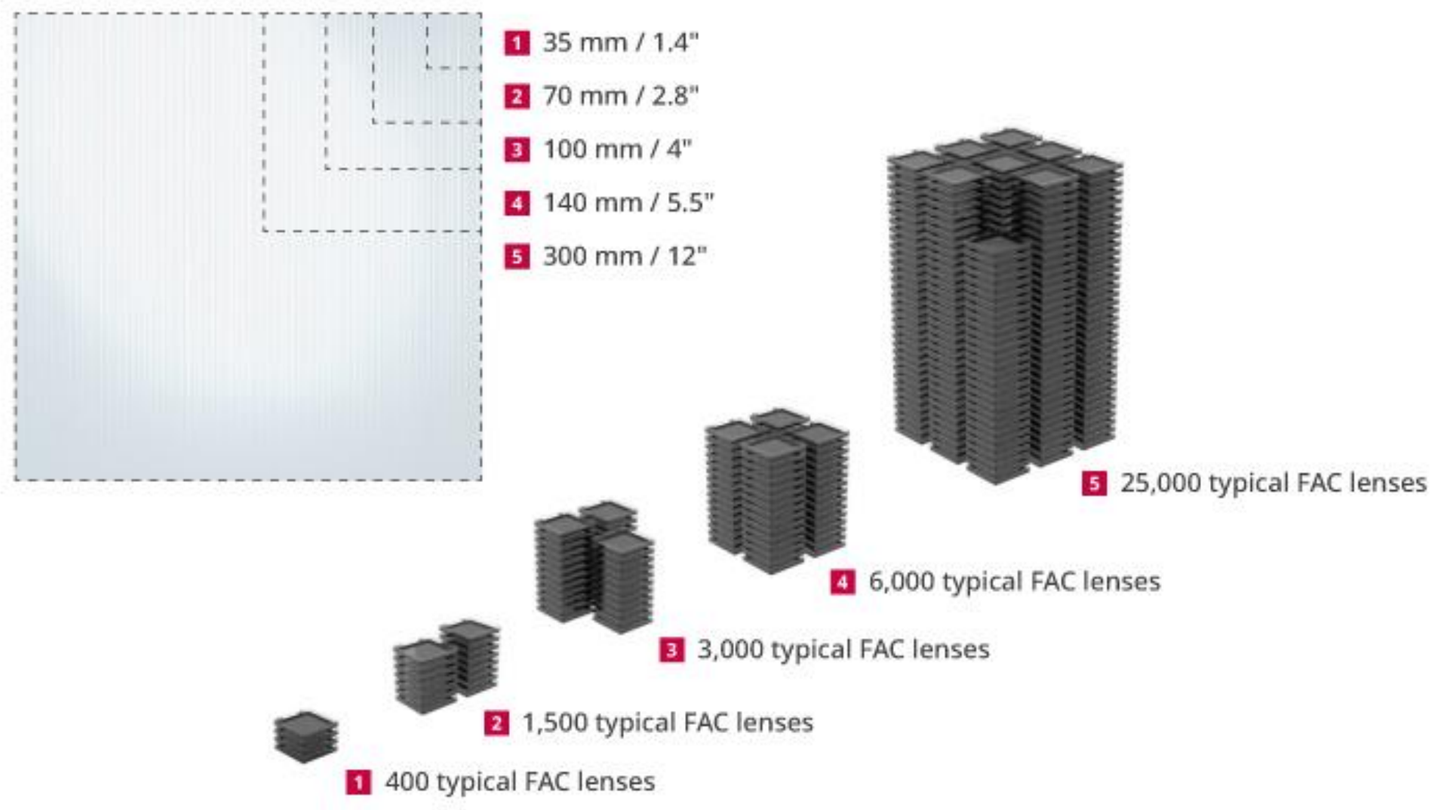




3D LIGHT SHAPING

Scaling production using wafer level micro-optics

- 12’’ Wafer level production technology with scalable productivity above 100 mio. pcs per client per year
- Handling & testing of millions of parts

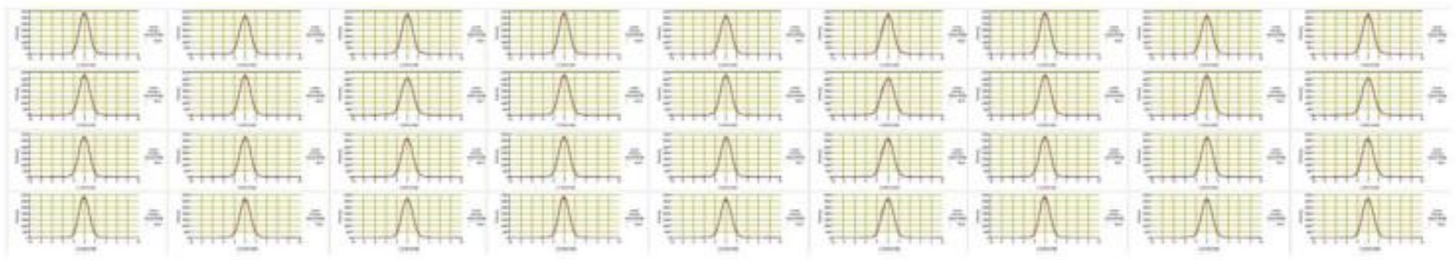


3D LIGHT SHAPING

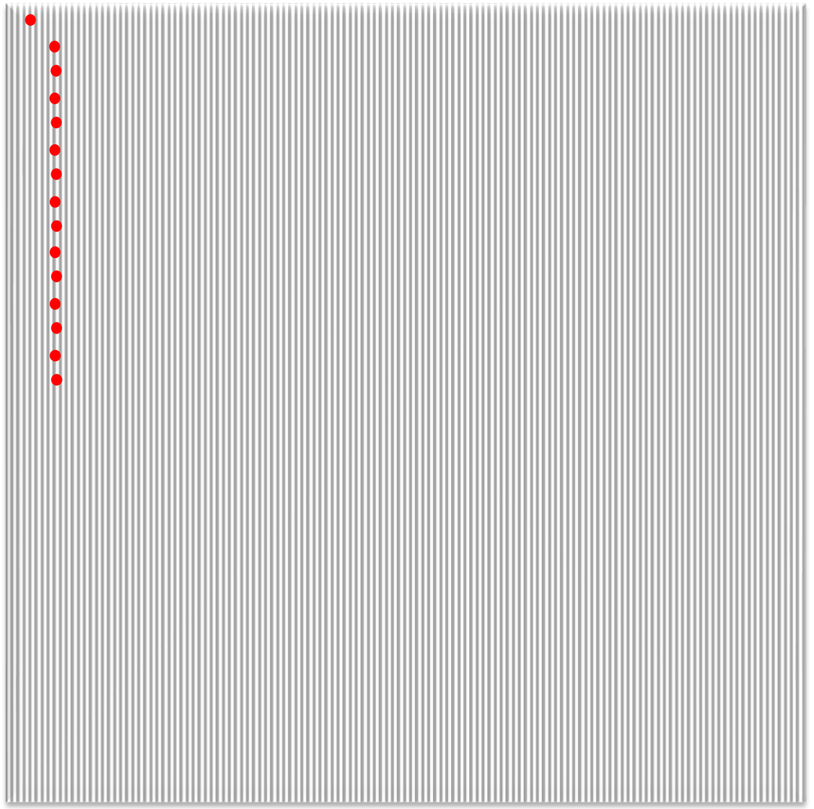
Scaling production using wafer level micro-optics

Quality and performance test on wafer basis!

- fast and reliable 2D quality mapping of lenses
- surface shape analysis and performance simulation
- optical performance tests



performance mapping in FAC production



3D LIGHT SHAPING

Scaling production using wafer level micro-optics

State of the art:

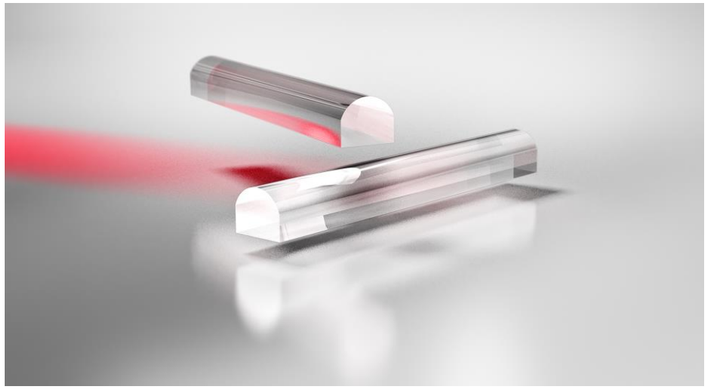
- 300mm x 300mm wafer

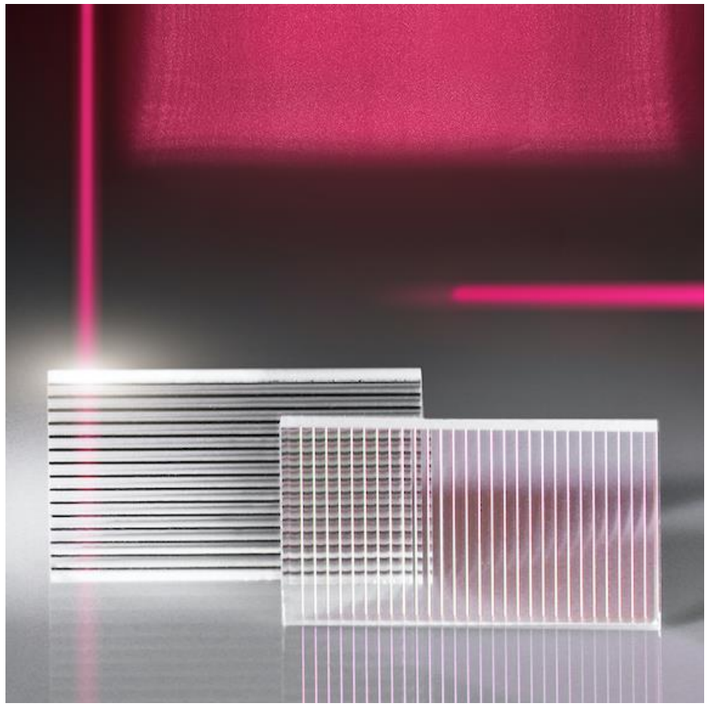
- Refractive and diffractive optics on both surfaces

3D LIGHT SHAPING

Optical functions needed for laser beam shaping:

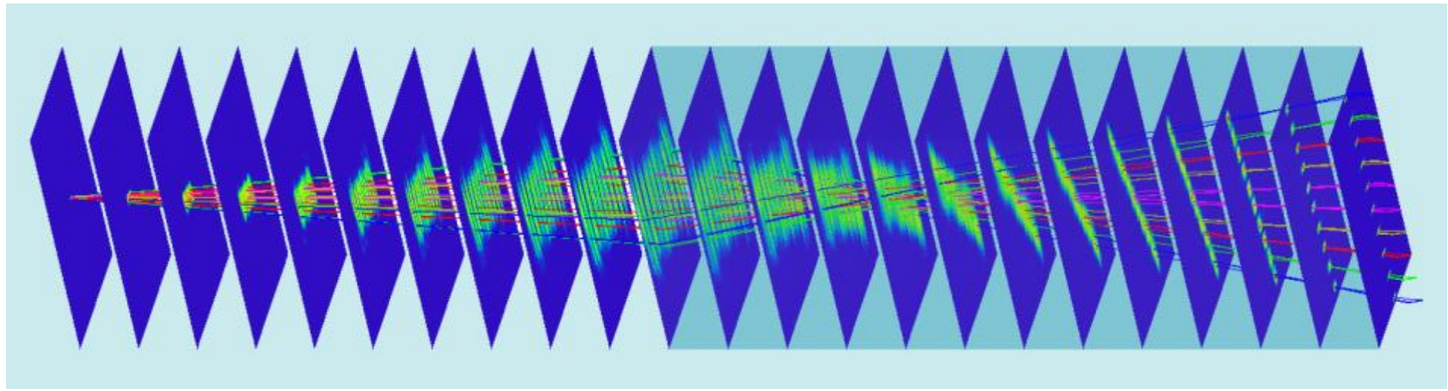
Source	Optics
Edge emitter	Fast & slow axis collimators
Stack emitters	Homogenizer/Diffuser
VCSEL	Diffuser up to >120° FWHM

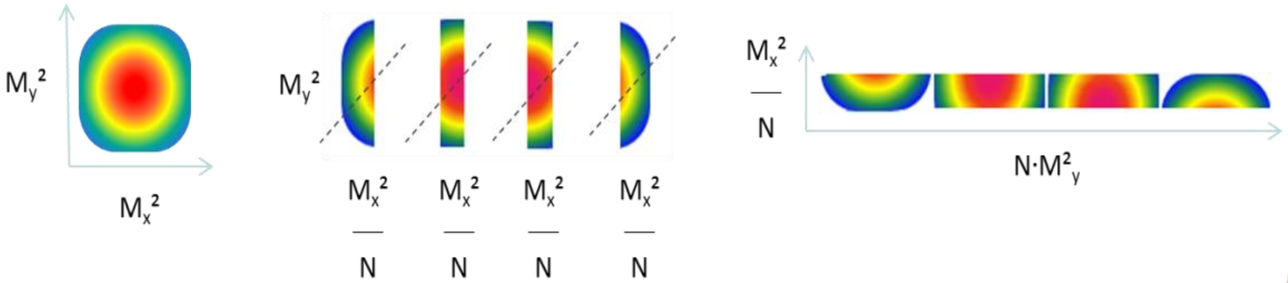


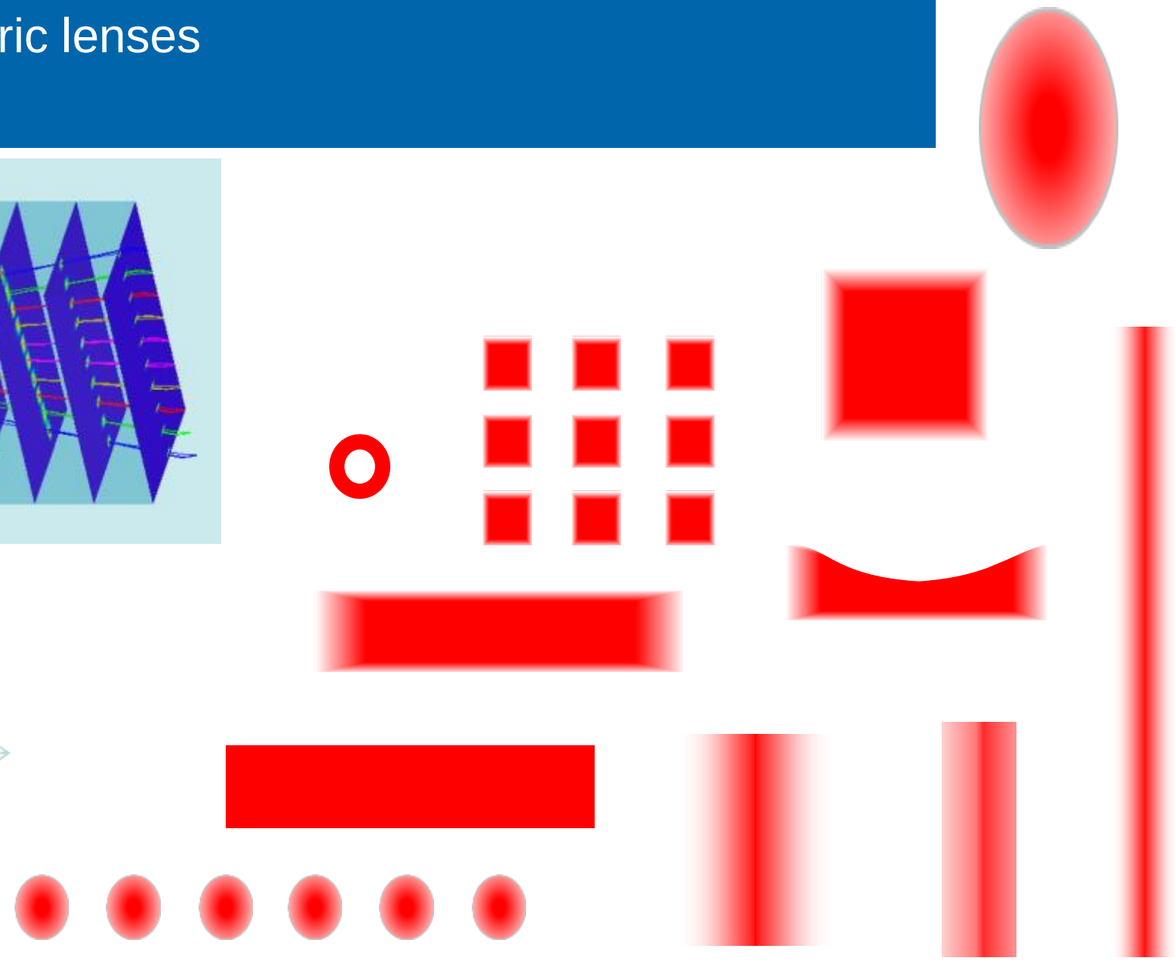


Simulation of refractive AND diffractive functions!

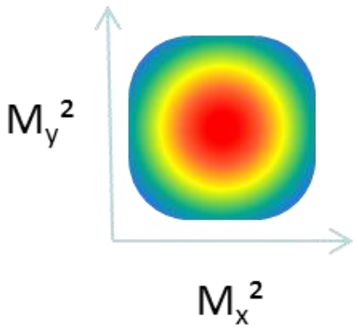
- Anamorphic shaping of laser light: spot to line / spot to area / Gaussian-to-top-hat / multi-spot
- Asymmetric emitters exclude using rotational symmetric lenses
- Laser illumination with precise beam profiles

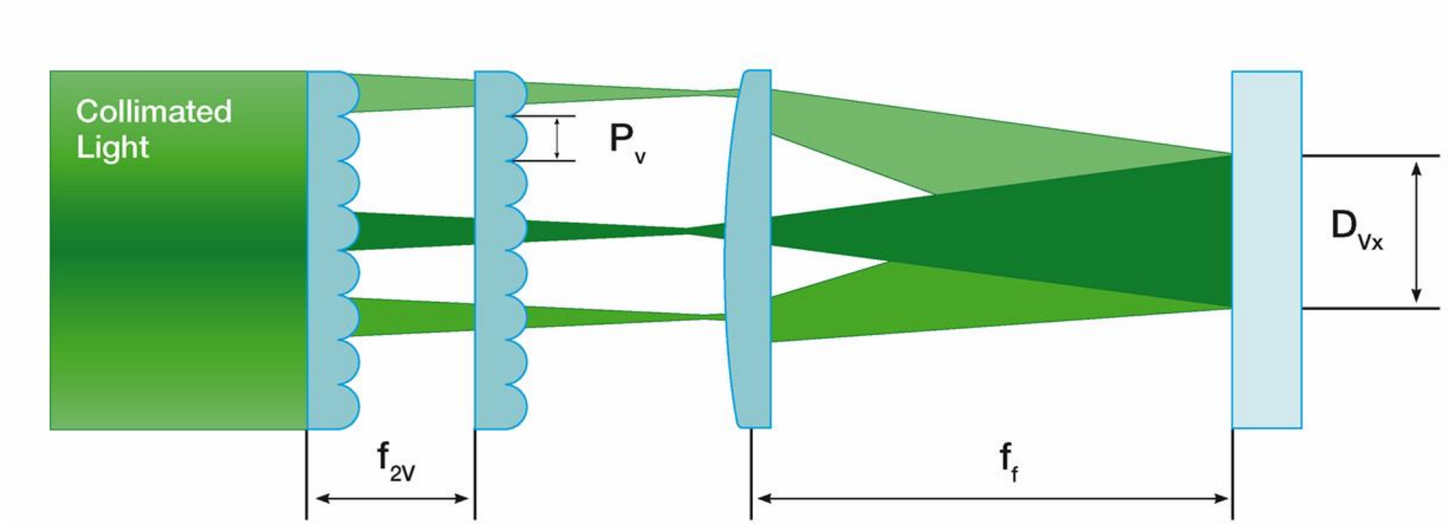


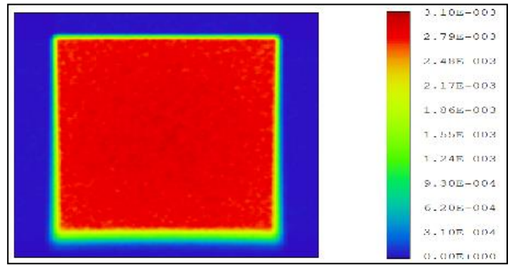




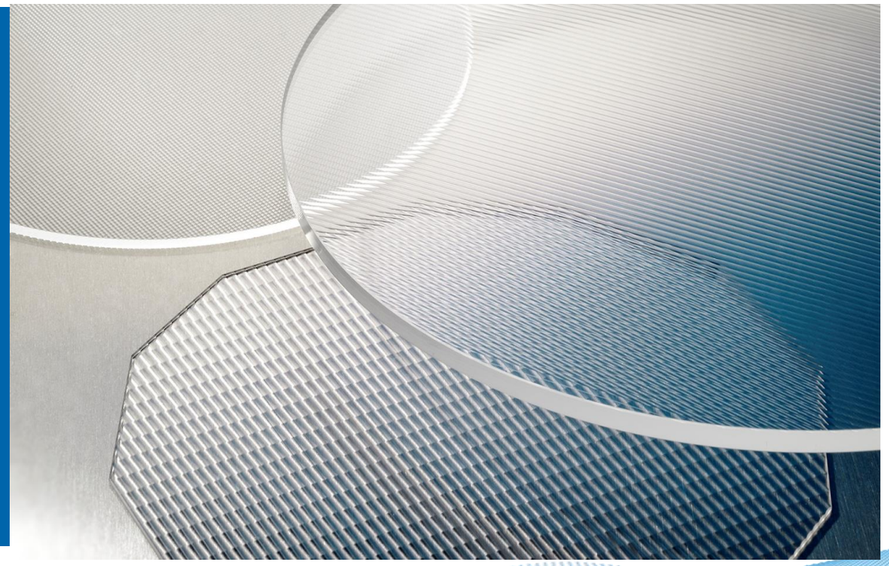
Homogenizer/Diffuser





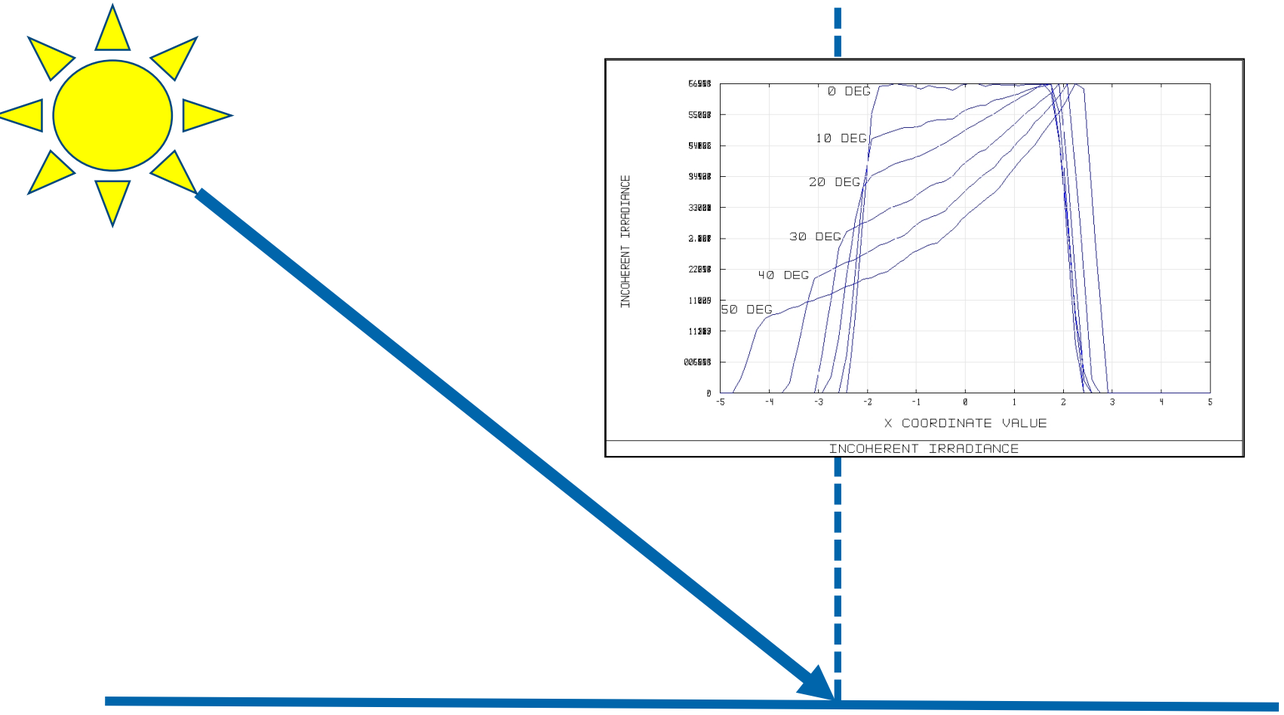


- ***Refractive Optical Element (ROE)*** to shape/pattern laser beam
- Bring photon to the desired place and shape the intensity profile
- NO “hot spot” (zero order effect) ***=> eye safety***
- High energy efficiency >90% ***=> minimal energy loss***
- Glass material feature: ***high laser induced damage threshold (LIDT) , no peeling off or delamination @ high temperature, small refractive index variation with temperature***



Off-Axis Homogenizer/Diffuser

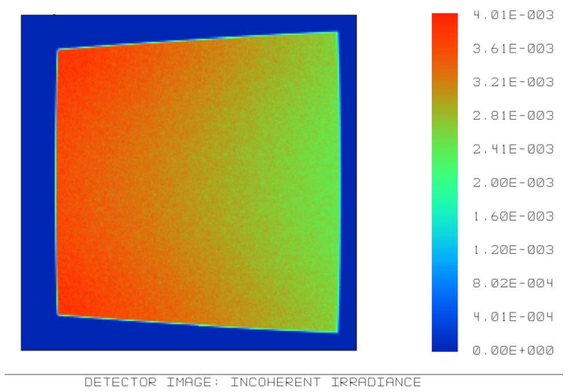
3D beam shaping needed to correct intensity variation because of a tilt angle between illumination source and object

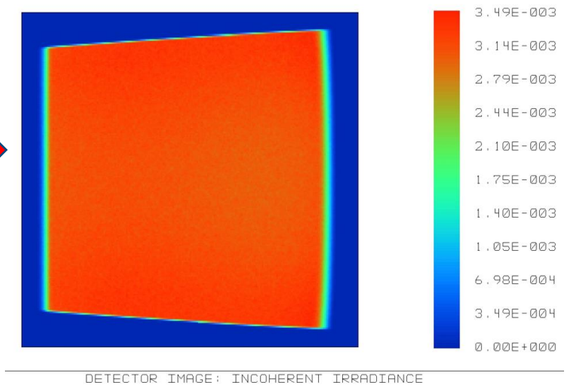


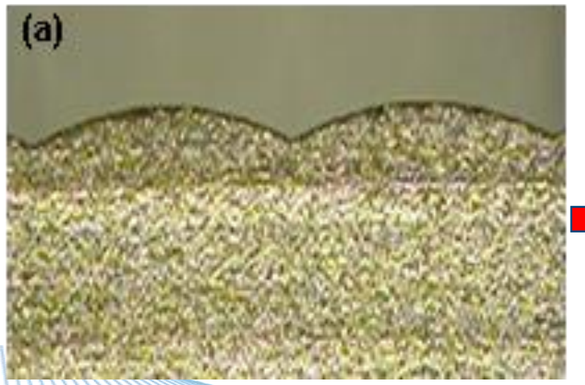
tilted illumination source like in a car

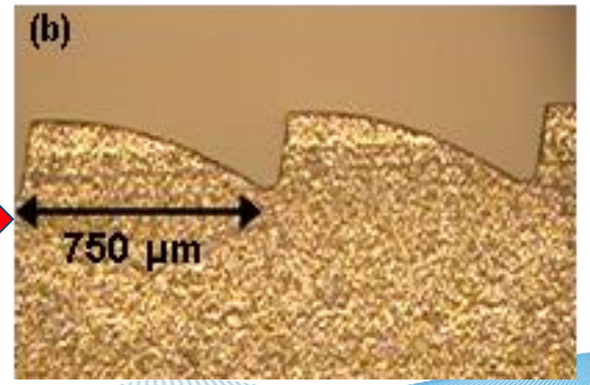
symmetric lenses

asymmetric lenses









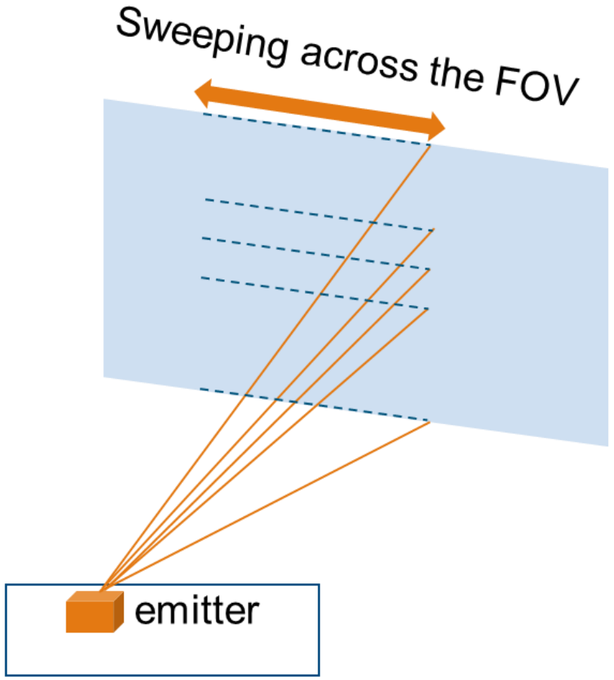
CONTENTS

FOCUSLIGHT

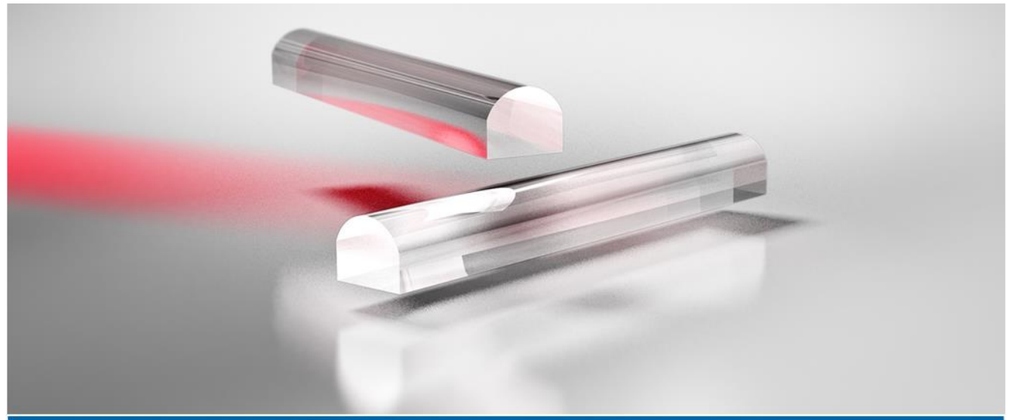
- INTRODUCTION
- MOTIVATION
- LIDAR LIGHT SHAPING
- **EXAMPLES**

EXAMPLES

FAC Lens



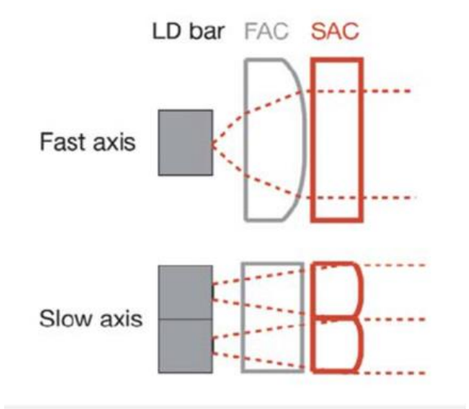
FAC lens is used to increase the angular accuracy and detection distance of scanning LiDAR.

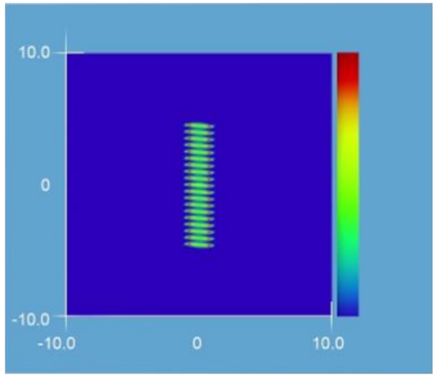


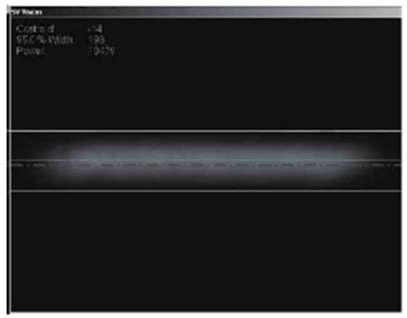
Typical FAC Lens Specs	
Effective focal length	0.16 ~ 1.5 mm
Remaining divergence	±3.6 ~ ±0.045 mrad
Transmission	>99%
Standard coating	790~990 nm
Power enclosure within the divergence angle	>85% , 92%

EXAMPLES

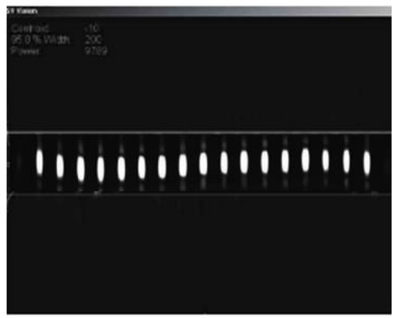
SAC Lens, SAC Array



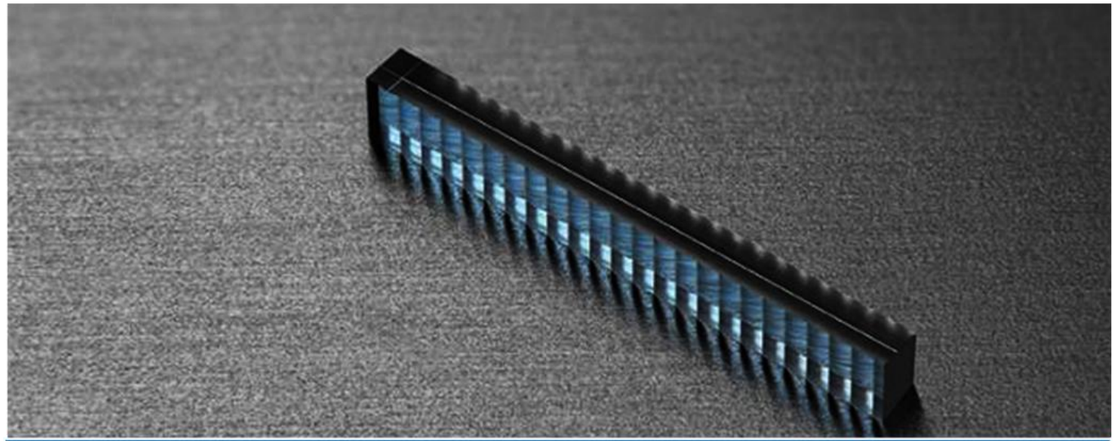




LD bar without SAC



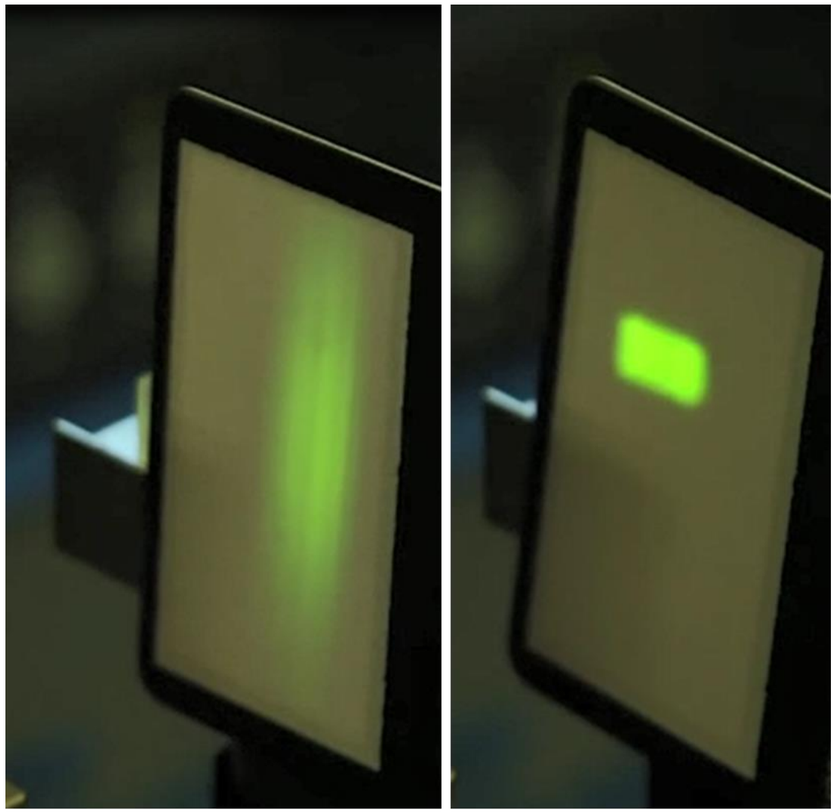
LD bar with SAC



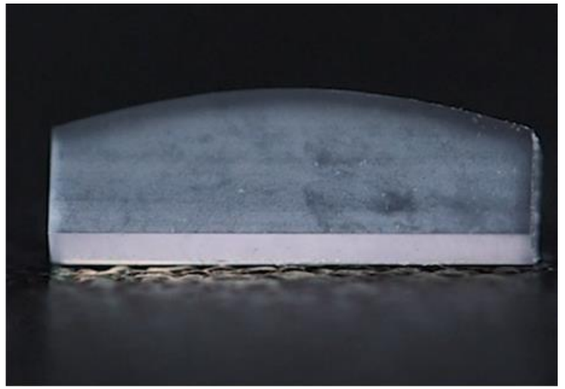
Typical FAC+SAC Lens Specs		
	fast axis	slow axis
Remaining divergence	±0.7 mrad	40mrad
	±1.1 mrad	40mrad
	±0.7 mrad	90mrad
	±1.1 mrad	100mrad

EXAMPLES

FAC+SAC Monolithic Module



Before and after
adding monolithic FAC-SAC lens

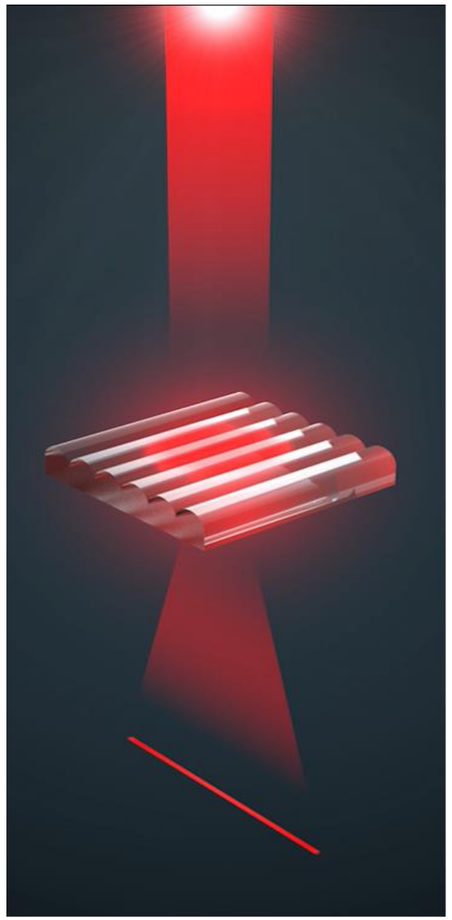


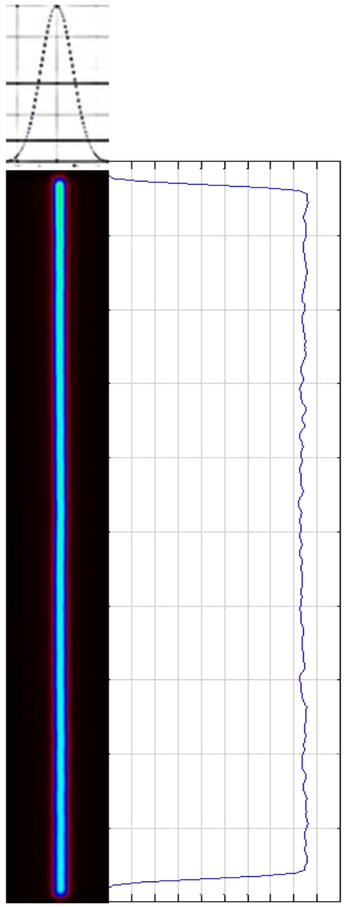
ONE lens for **Two** purposes:

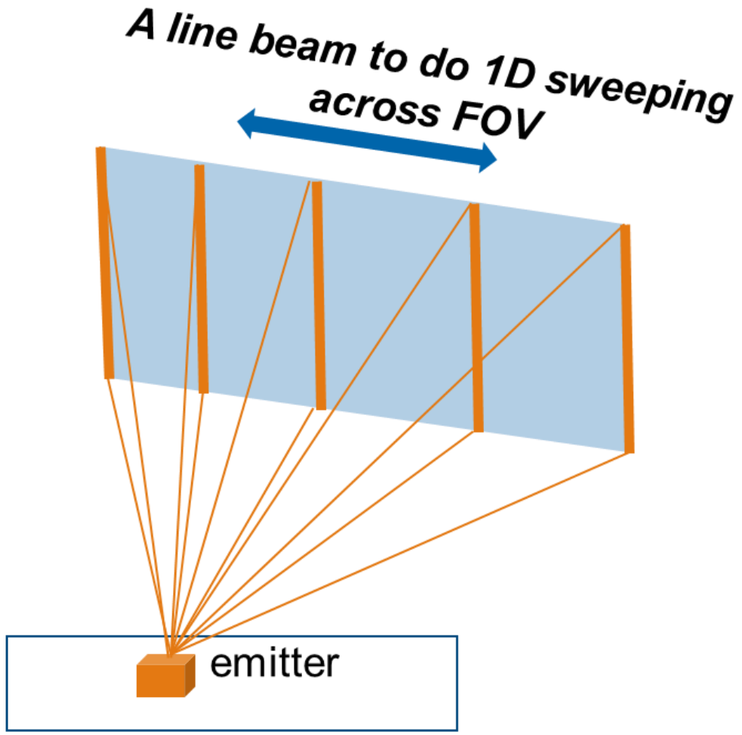
- Unique compact and cost-effective optical solution
- Both fast and slow axes are collimated or focused by one single lens
- Less component handling, easy alignment, and less surface reflection loss

EXAMPLES

Line Beam Generator



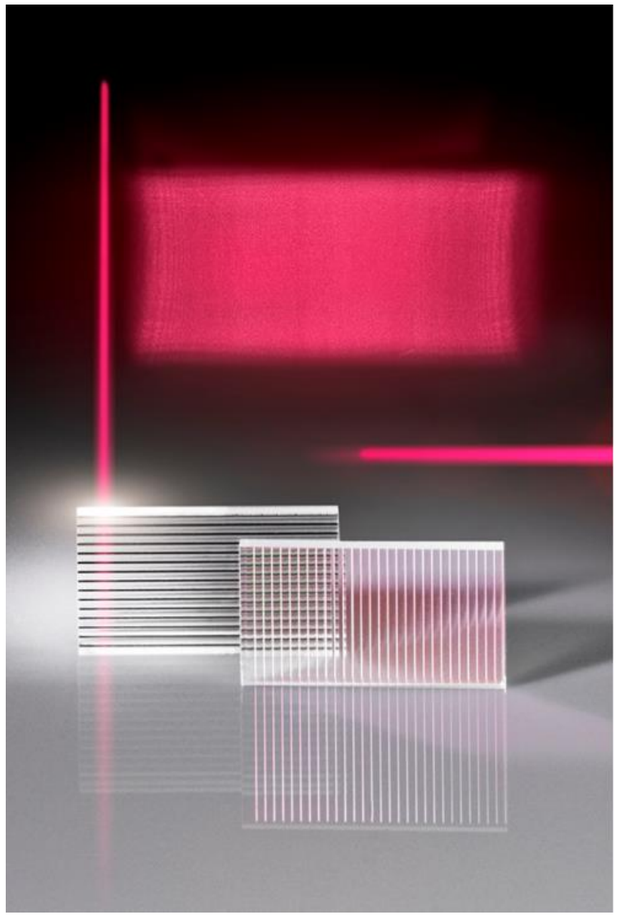




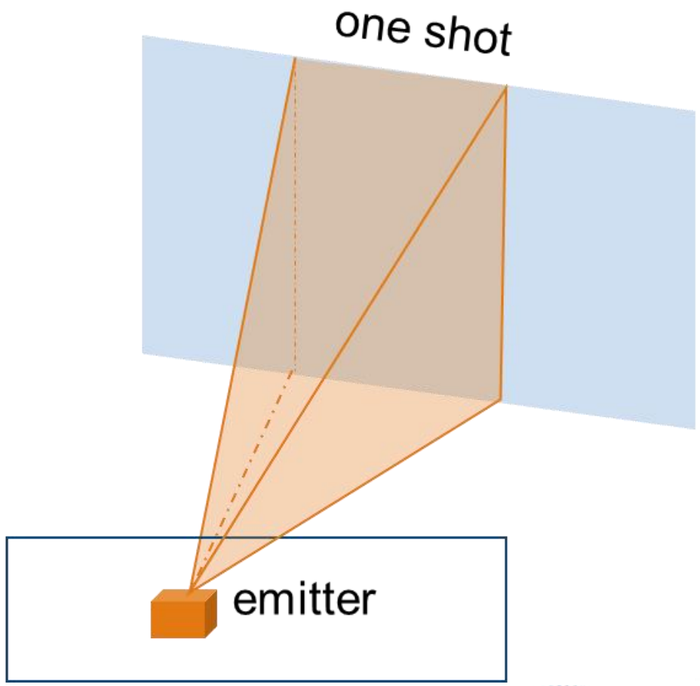
- Integrated high-grade micro-optics to generate line-shaped beams
- FOV is formed by line sweeping of **single** light source => less complexity comparing to multiple dots sweeping from multiple light sources

EXAMPLES

Large Angle Diffuser



Building a LiDAR or ToF- What is important for your **usability**, **quality** and **safety**?

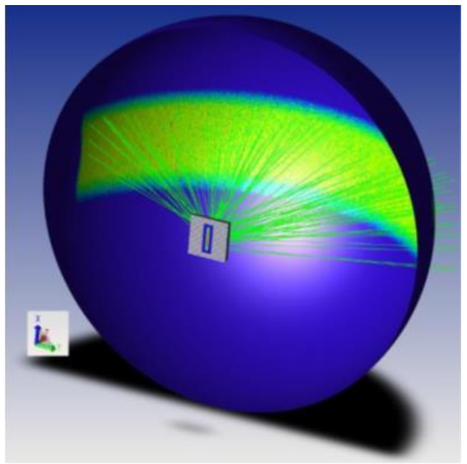


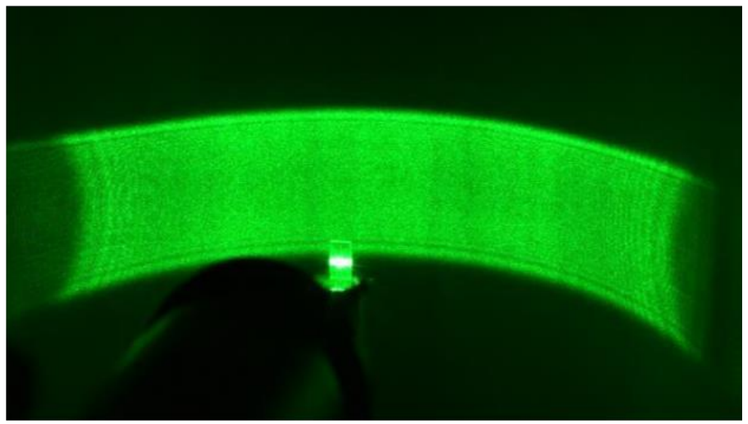
Requirements	LIMO /Glass	Other /Polymer
Line Shape (for scanning)	✓	✓
Rectangular Shape (for flash)	✓	✓
Sharp Slopes	✓	✗
No Zero Order	✓	✗
No Hot Spots	✓	●
High Damage Threshold	✓	●
Repeatability	✓	✓
Transmission Efficiency	✓	●
Angles >100°	✓	●
No Degradation under UV	✓	✗

EXAMPLES

Large Angle Diffuser

- Applicable to various LiDAR light source: **EEL, VCSEL, DPSSL**
- Sharp angular intensity distribution
- Glass material, stable performance in wide temperature range (-40℃~150℃)
- Long-term reliability & automotive standard
- Higher laser induced damage threshold (LIDT): >1J/cm^2 (>5 J/cm^2 for FS)
- High uniformity: as high as 90%
- ROE instead of DOE, NO zero-order effect, eye safety
- Arbitrary combinations of angles, typical LiDAR FOV:
  90°~125° (horizontal) ; 5°~45° (vertical)





Good match of simulation and reality

SUMMARY

- Micro-optics made of glass enable safe laser beam shaping for LIDAR
- Freeform cylindrical lenses can control illumination in x- and y-direction
- Multifunctional micro-optics simplify the system design
- Large angle Diffuser can illuminate 360° view with 4 light sources
- Wafer level micro-optics made of glass can do more than polymer optics

THANK YOU

FOCUSLIGHT
Never stop exploring
LIMO
A Focuslight Company

This presentation was presented at EPIC Meeting on Wafer Level Optics 2019

HOSTED BY

SÜSS MicroOptics

DINNER SPONSOR

SWISS PHOTONICS

GOLD SPONSOR

PIXAPP Photonic Packaging Pilot Line

SILVER SPONSORS

LAMBDAS

Technobis group

BRONZE SPONSORS

NIL TECHNOLOGY

DELO INDUSTRIAL ADHESIVES

MIRPHAB ENABLING CHEMICAL SENSING

NTS OPTEL

PASSION

OptoSigma

EU initiatives funded by
www.photonics21.org

PHOTONICS21 PHOTONICS PUBLIC PRIVATE PARTNERSHIP