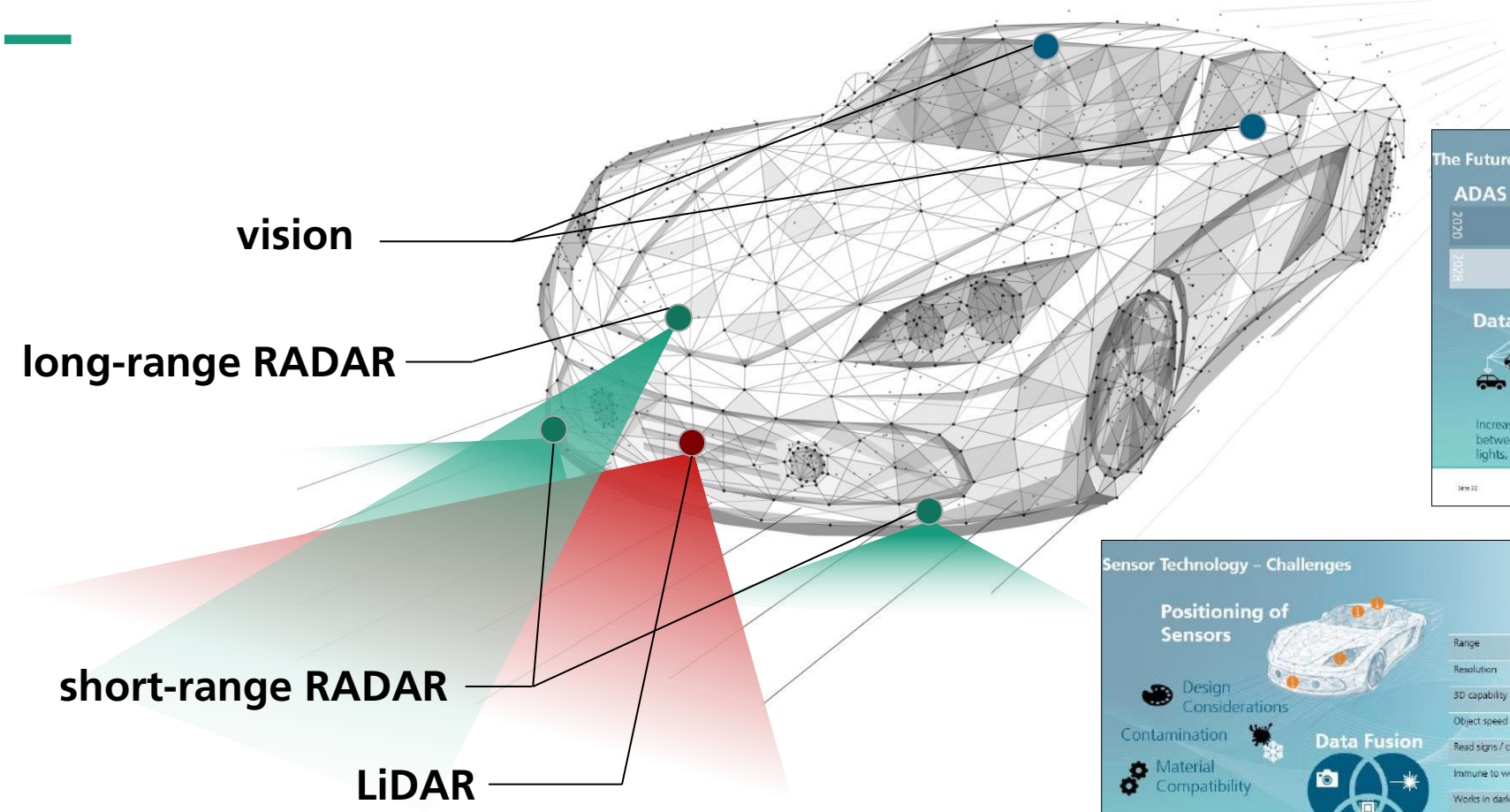
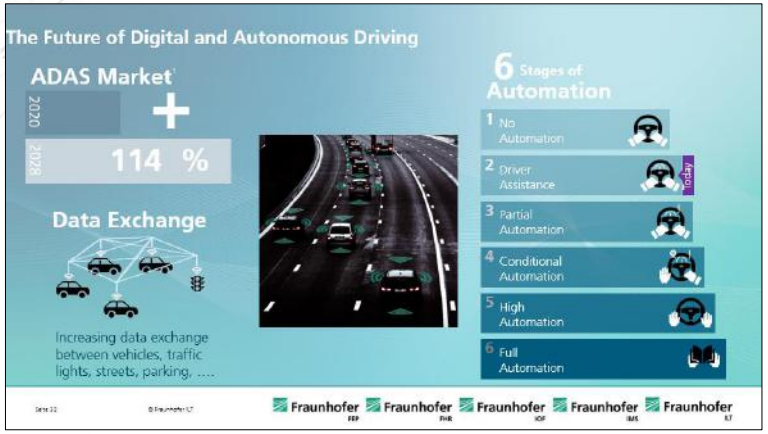
Coaxial RADAR, LiDAR and Light Integration in Smart Headlights

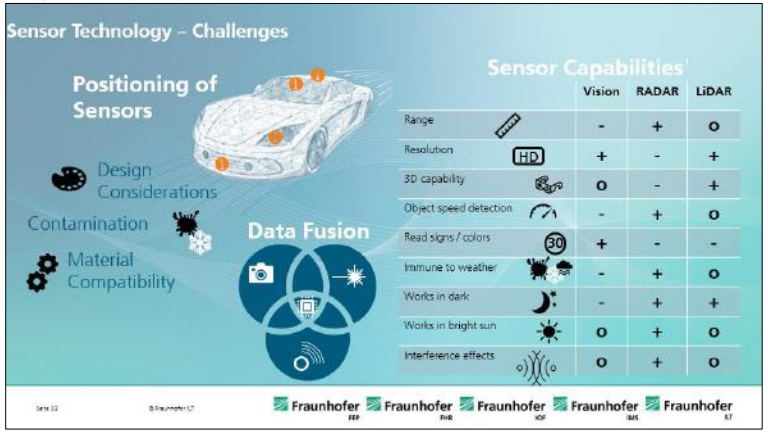
SMART HEADLIGHT

Fraunhofer FEP Fraunhofer FHR Fraunhofer IOF Fraunhofer IMS Fraunhofer ILT

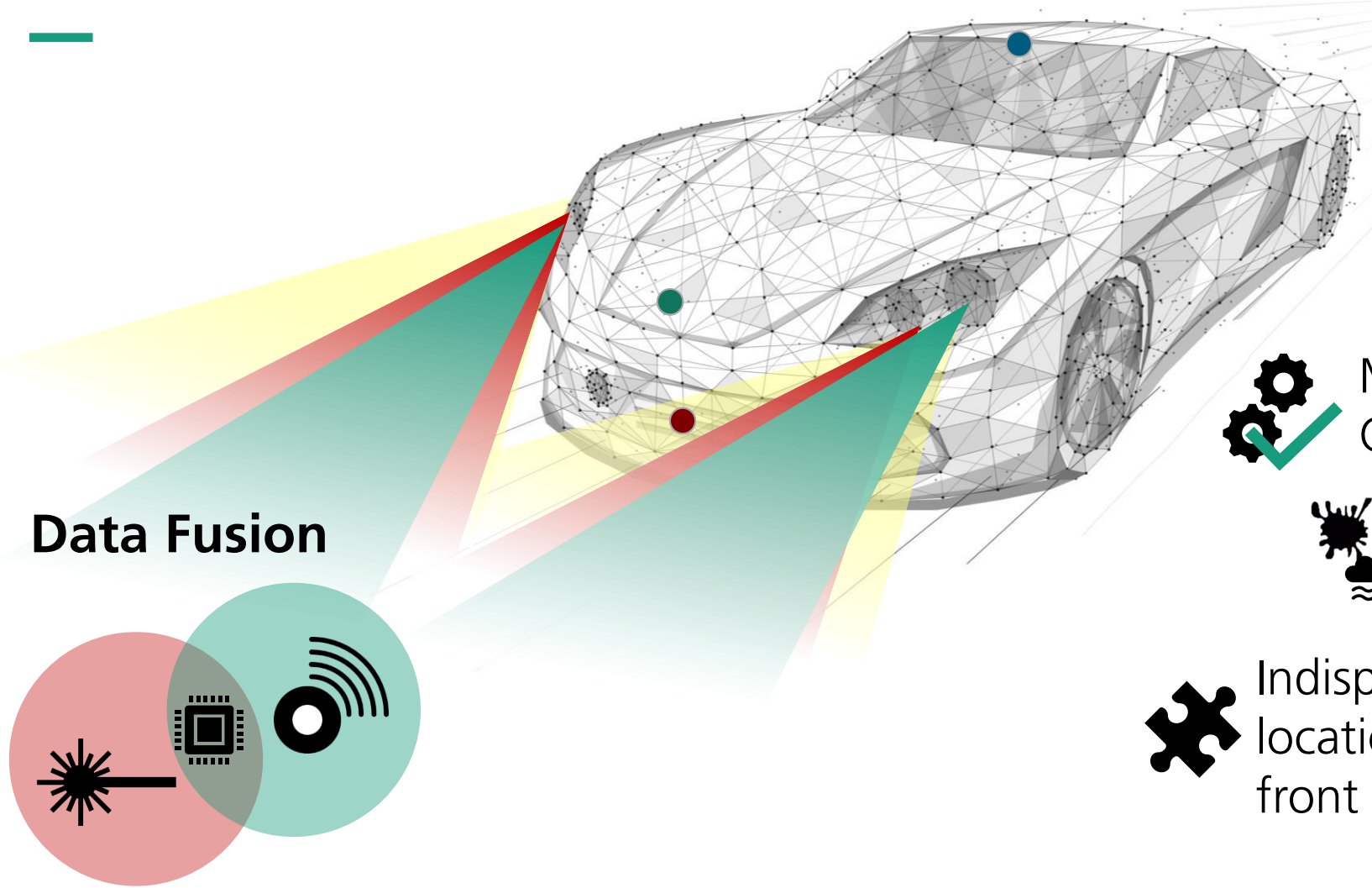
State of the Art







Our Solution: Coaxial RADAR, LiDAR & Light Integration in Smart Headlights



Data Fusion

Advantages

Freedom of Design

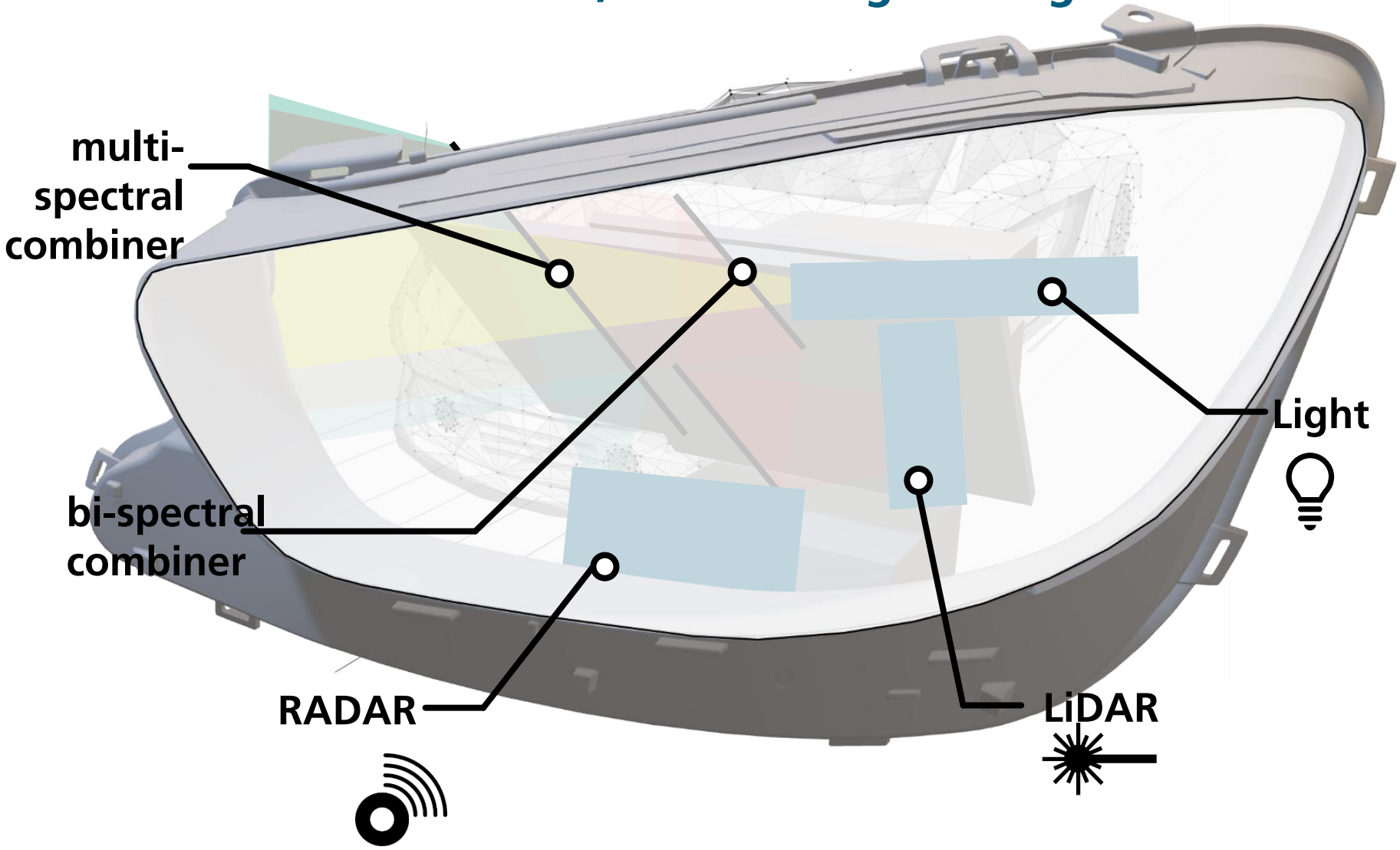
Opening up new sensor space

Material Compatibility

Clear line of sight – in all conditions

Indispensable sensor location at vehicle front corner

Our Solution: Coaxial RADAR, LiDAR & Light Integration in Smart Headlights



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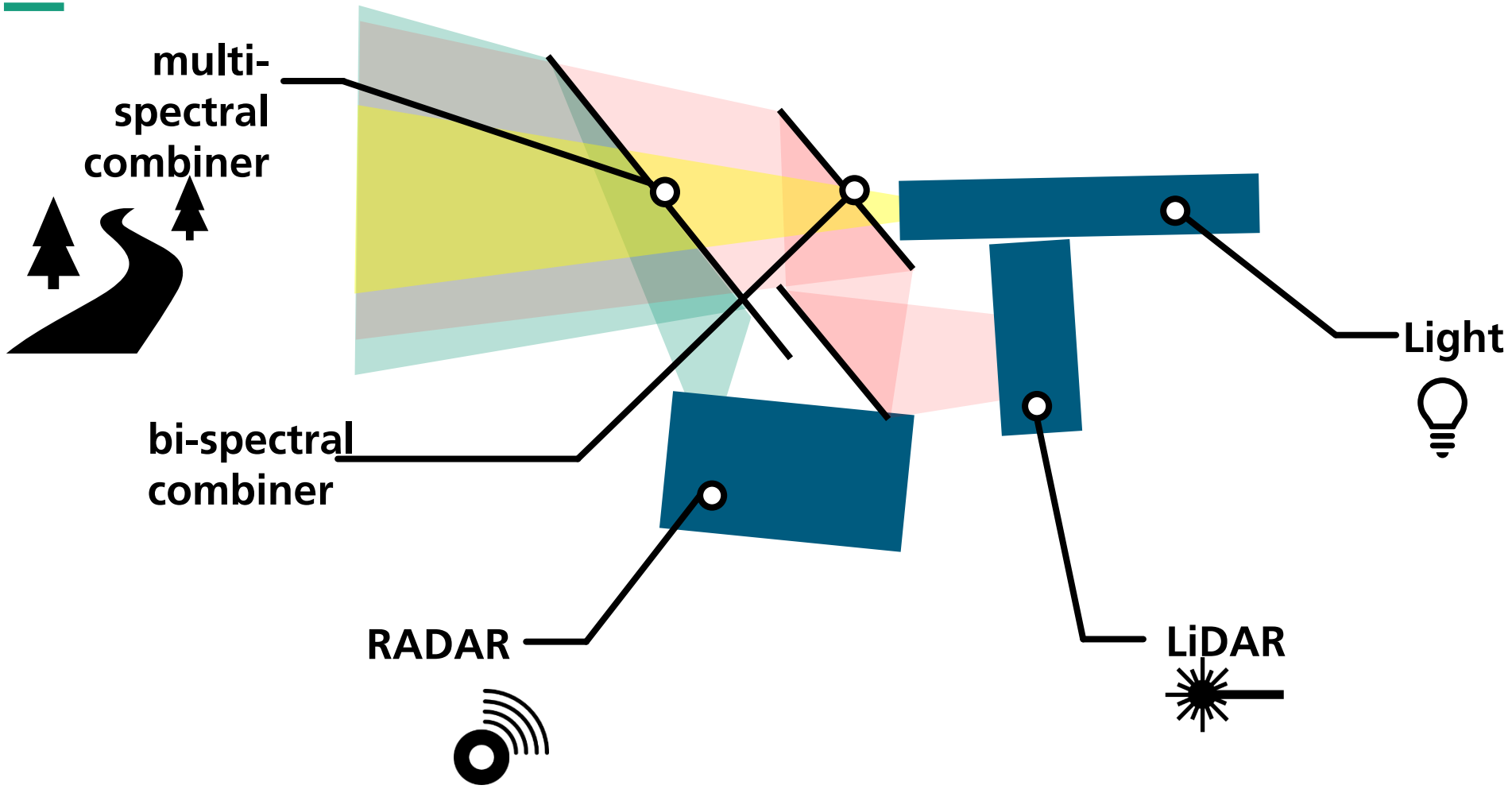
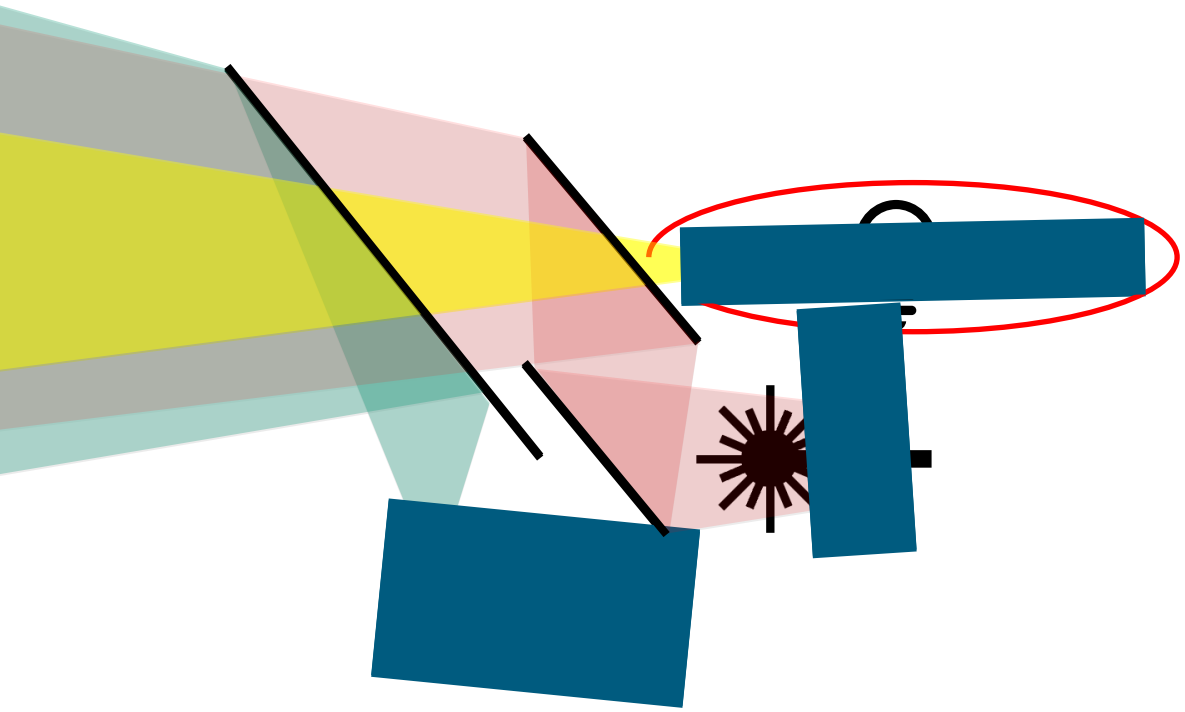


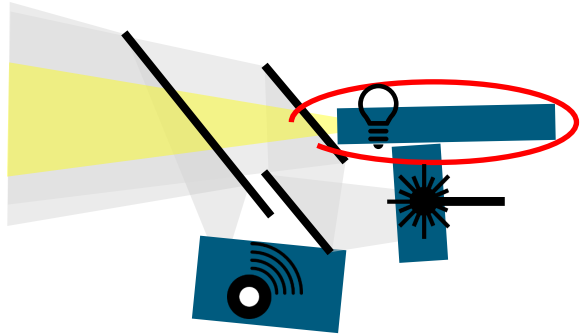
Fraunhofer ILT



Lighting – a Micro-Optical Approach

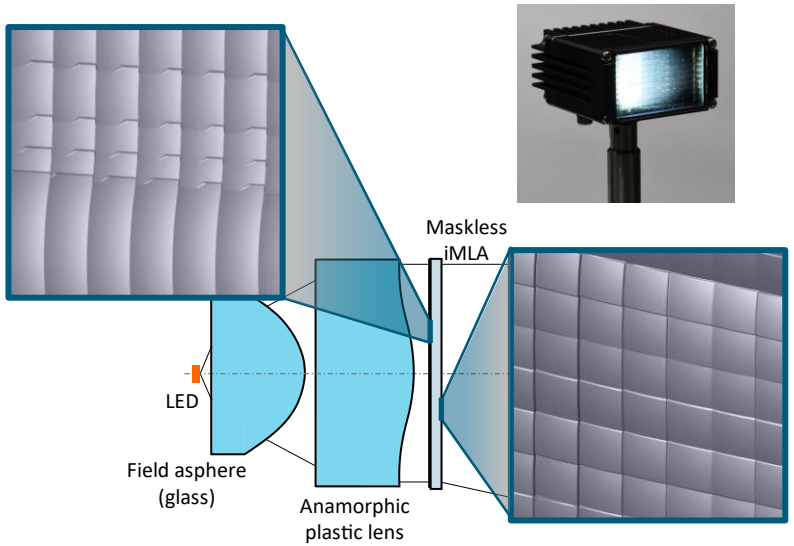
Lighting – a Micro-Optical Approach

Low Beam



Design

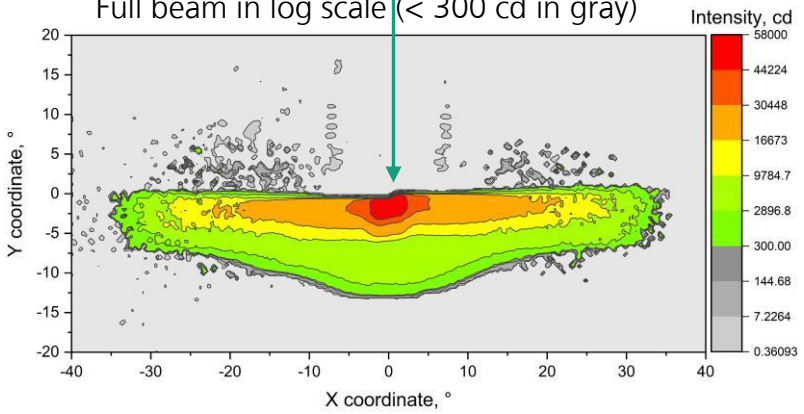
+ Completely **maskless** MLAs on both sides
+ Simpler collimator architecture possible
+ Size reduction → room for sensors



Simulation

- FOV ±35° horizontal (~625 cd); -12°…0° vertical
- Asymmetric and steep cut-off (in compliance with ECE standard)

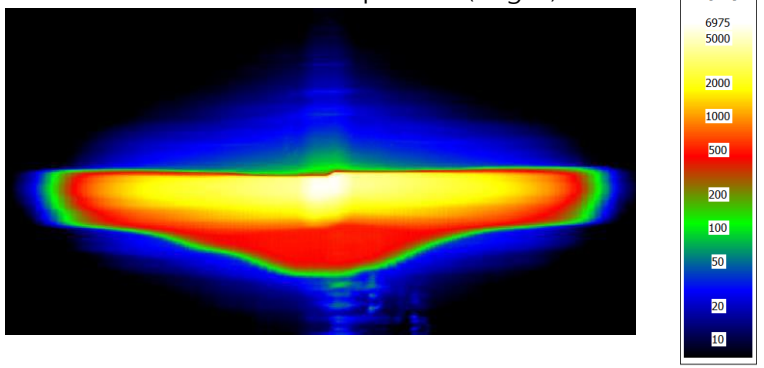
Full beam in log scale (< 300 cd in gray)



Measurement

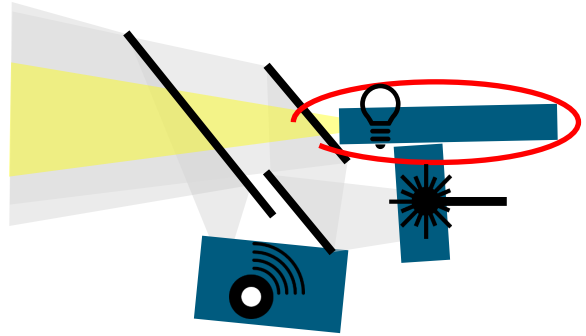
- Up to ~10.5 kcd / module → **42 kcd total**
- Sharp cut-off, no color
- **75 %** total transmission
- **91 %** MLA transmission (uncoated)

Luminance camera picture (Log 3)



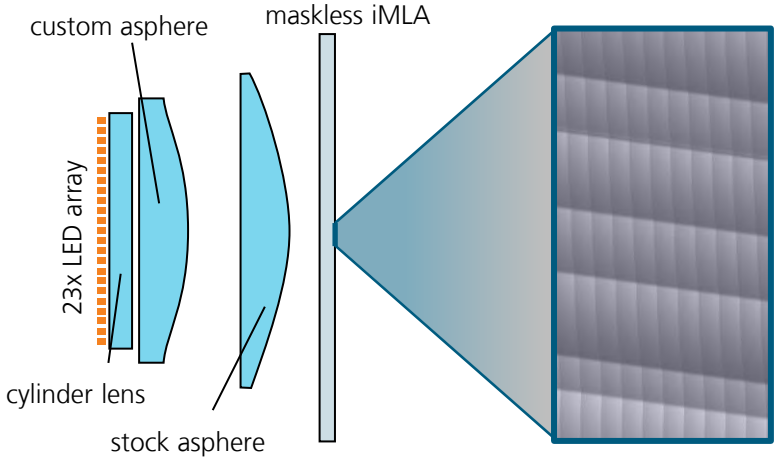
Lighting – a Micro-Optical Approach

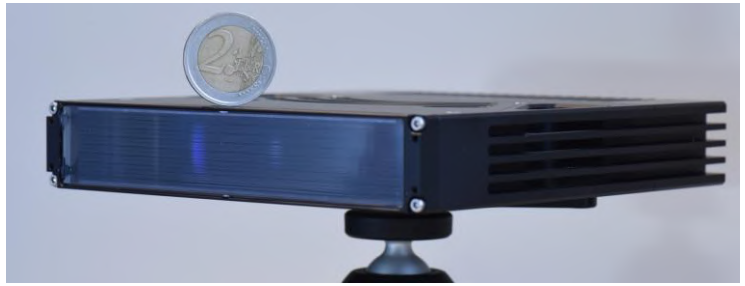
High Beam



Design

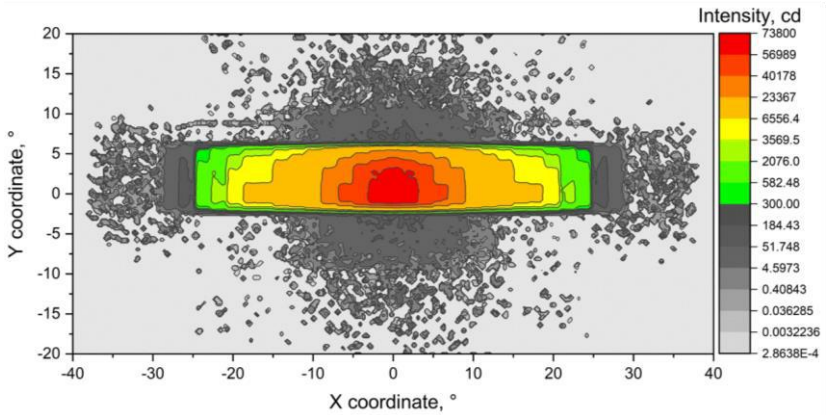
+ Completely **maskless** MLAs, irregular in vertical, regular in horizontal
+ Size reduction → room for sensors
+ 21 switchable dark tunnels of 2° are achieved





Simulation

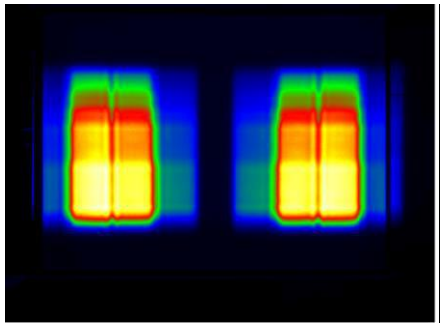
- MLA transmission → > 90%
- Efficiency (AR coated colli) ~ 40%. Limit → Etendue @ Colli



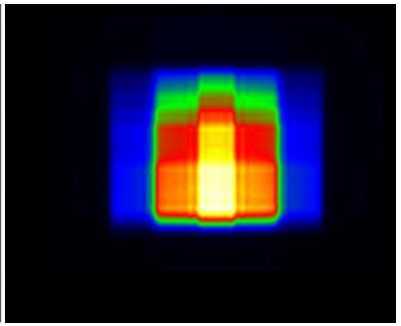
Measurement

- ~ **100** kcd with 2 modules (585 lm LED)
- Sharp "dark tunnels" of 2° full width
- **40** % total transmission
- **91** % MLA transmission (uncoated)

"Dark tunnel"



Hotspot part of the beam



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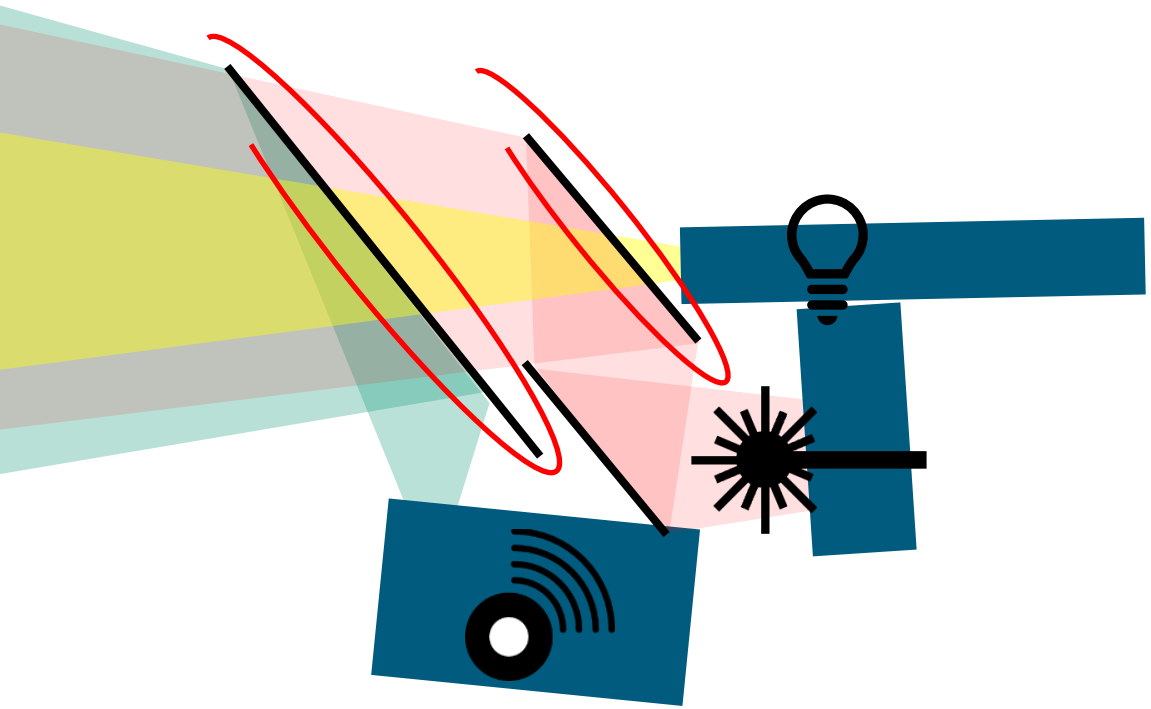
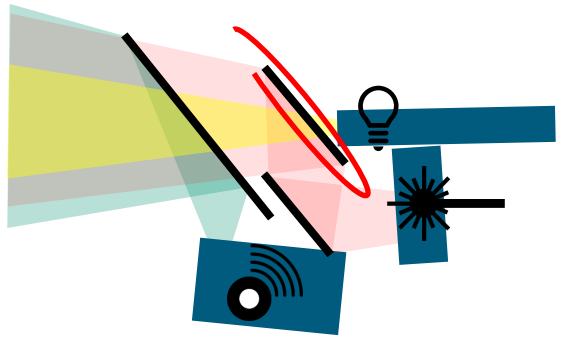
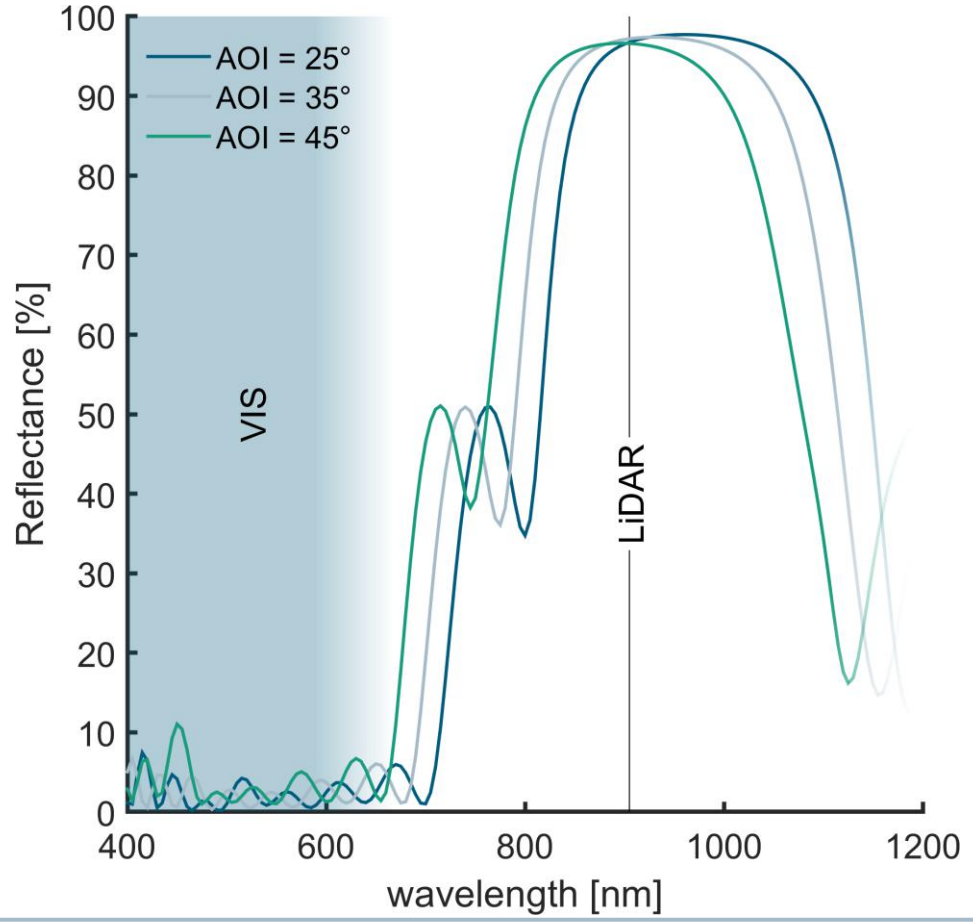


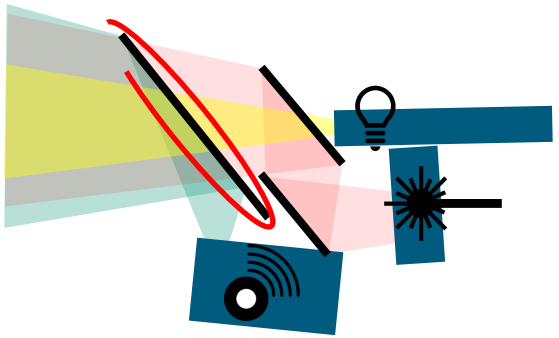
Combiner

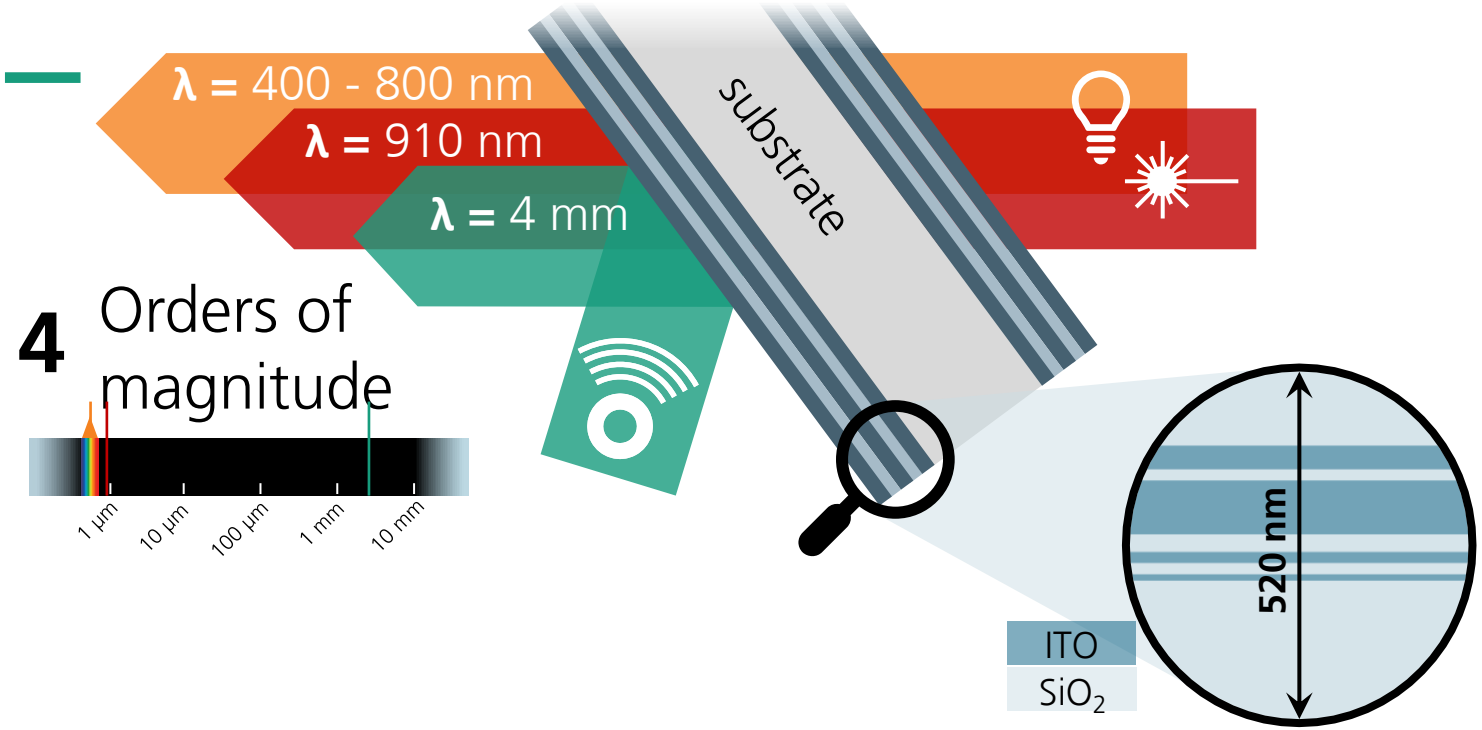
Combining Light and Lidar: Bi-Spectral Combiner

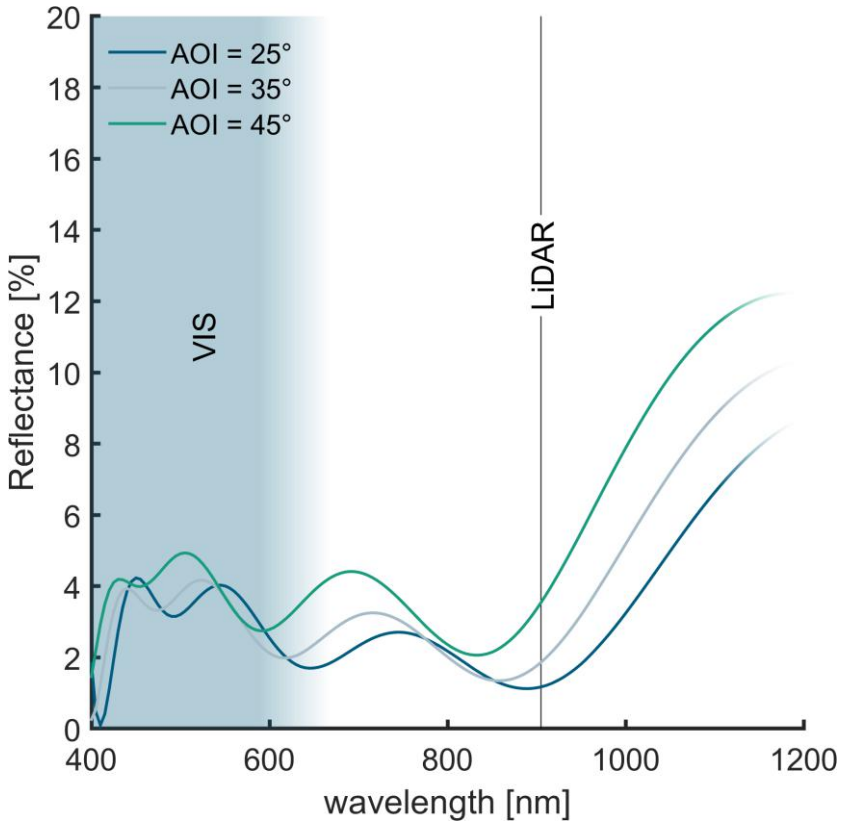




Everything comes together: Multi-Spectral Combiner

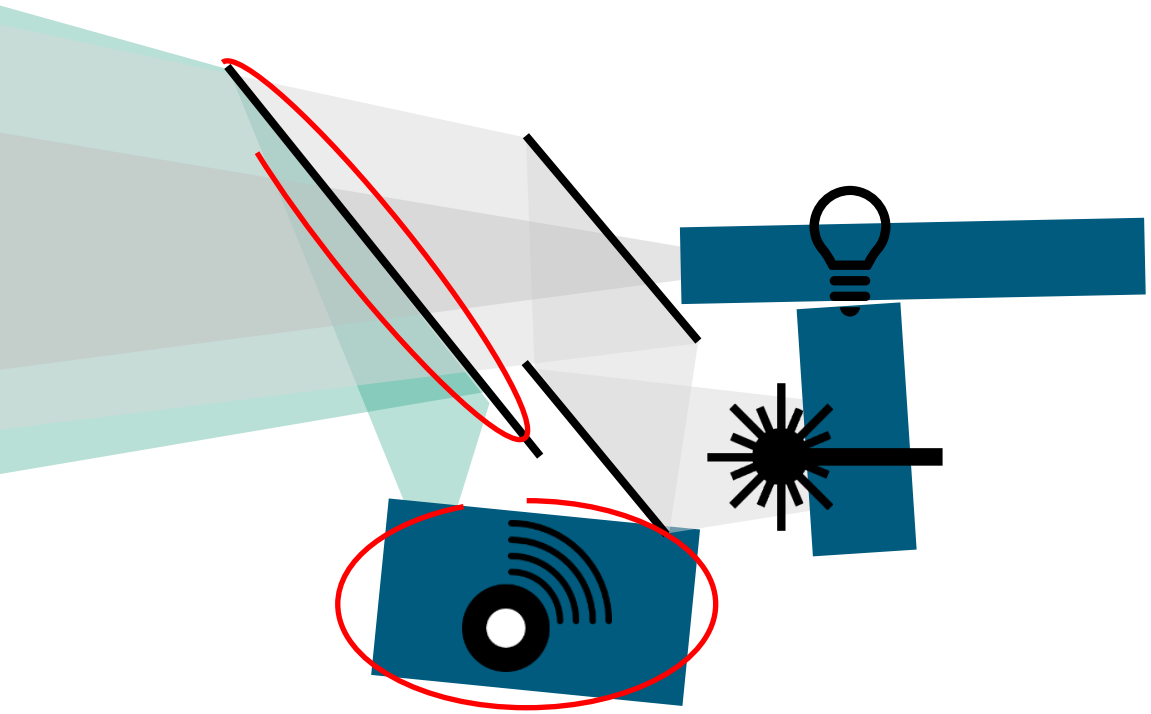






ITO transparent & conductive →
use as high refractive index material in AR coating

< 5% reflection losses for Lidar and Light

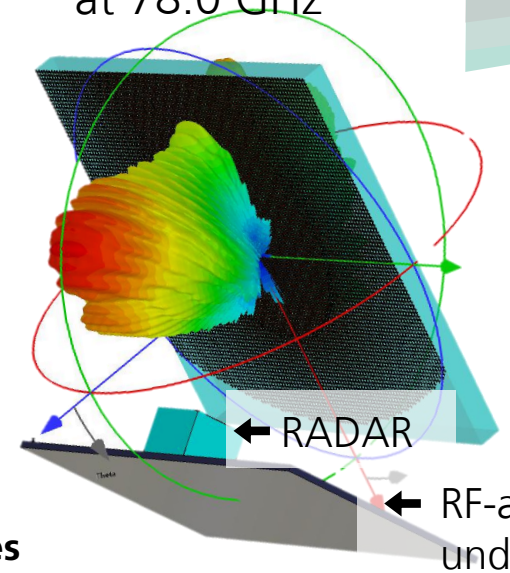


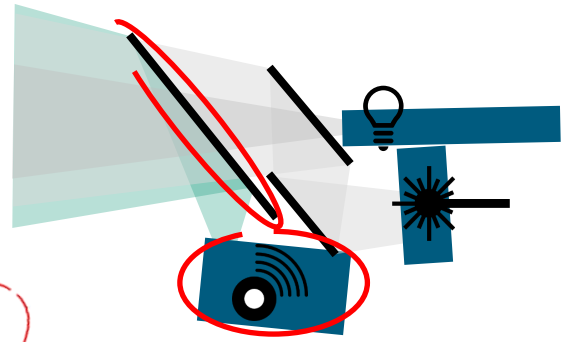
Multi-Spectral Combiner & RADAR

Multi-Spectral Combiner & RADAR

Specular Reflector

Radiation Pattern
at 78.0 GHz





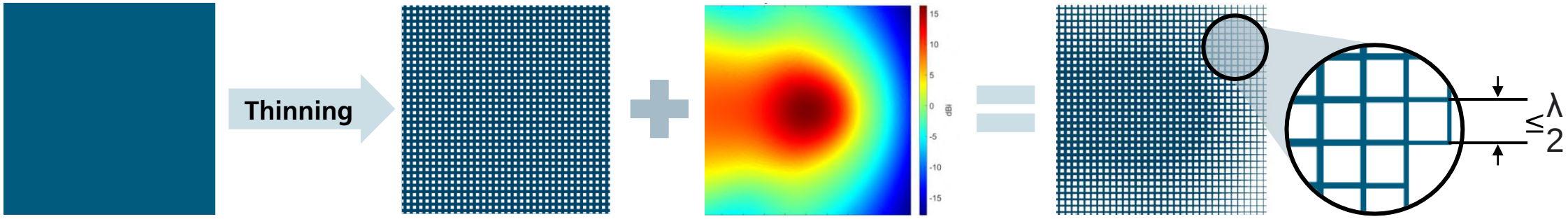
+ No change to radiation pattern of radar

+ High bandwidth

+ Only single sided metallization of combiner is necessary
  → increased optical transmission

→ **Design goal:** **metallization** **light transmission** **radar losses**

→ **Our Approach: Metallization reduction by adaptive patterning**



100% Avg. Metallization

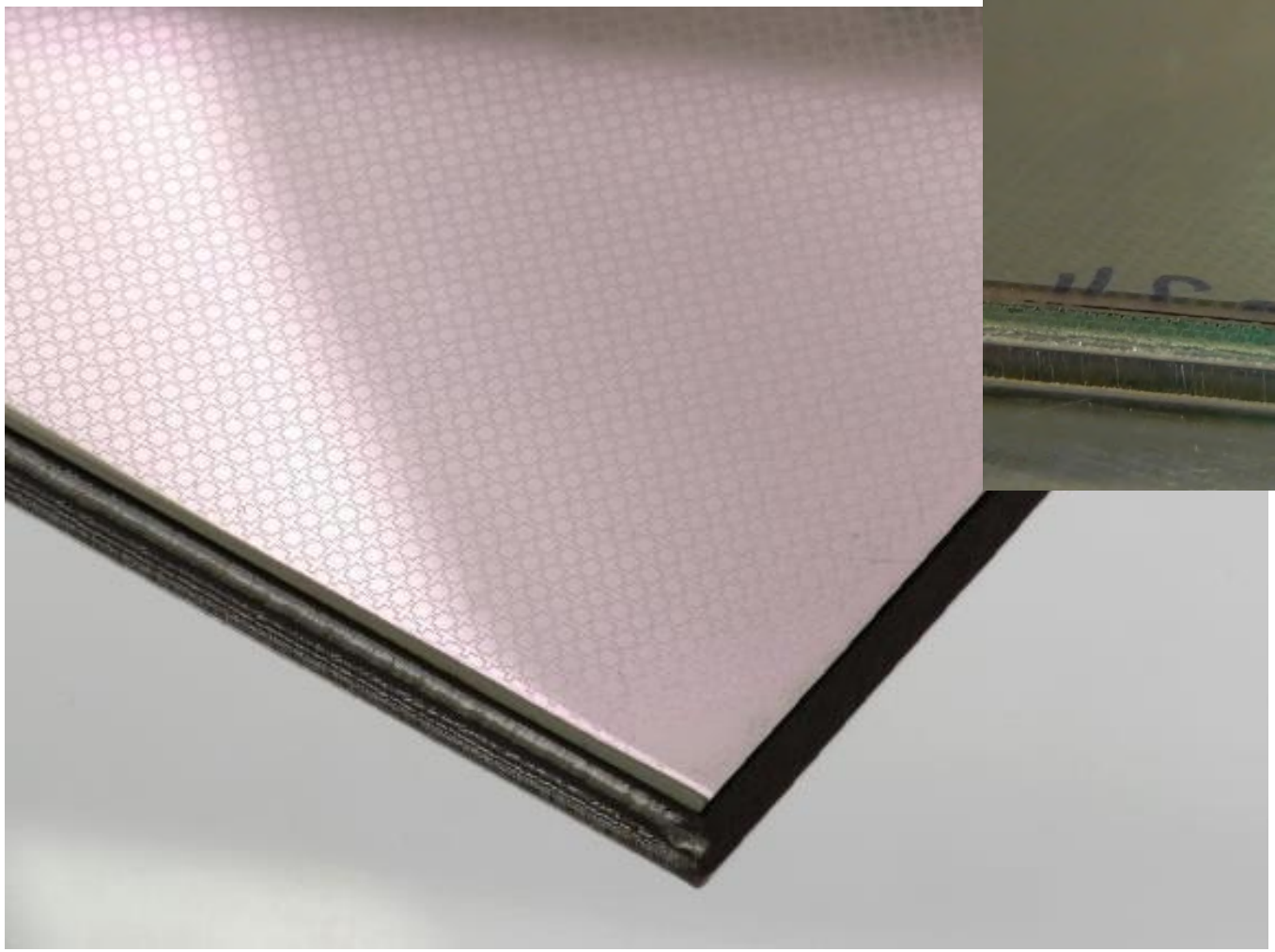
80% Avg. Metallization

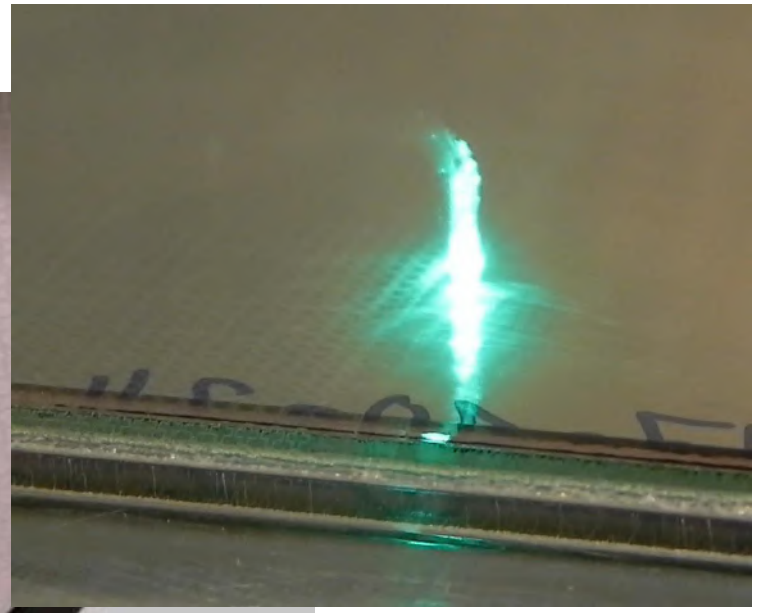
Radar Field Distribution on Combiner

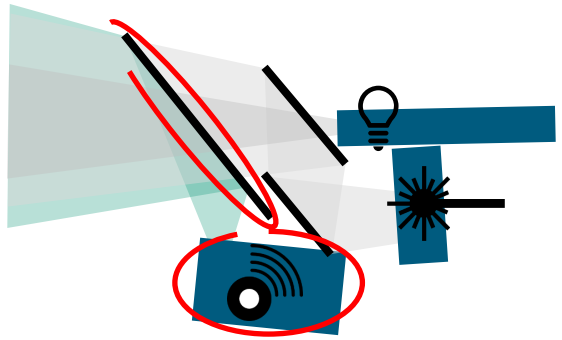
63% Avg. Metallization

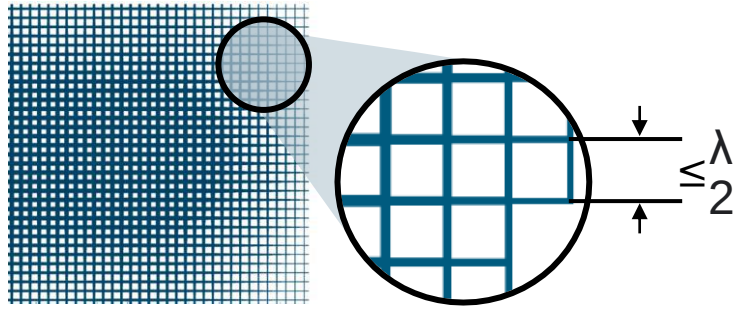
Multi-Spectral Combiner & RADAR

Specular Reflector





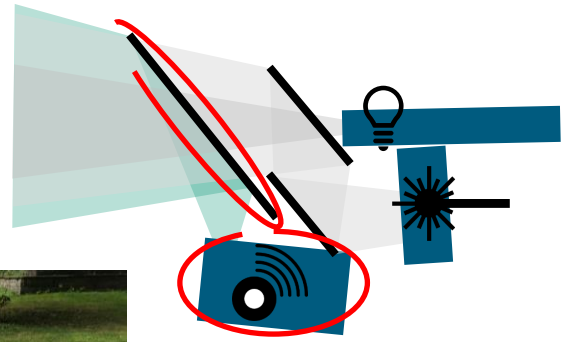




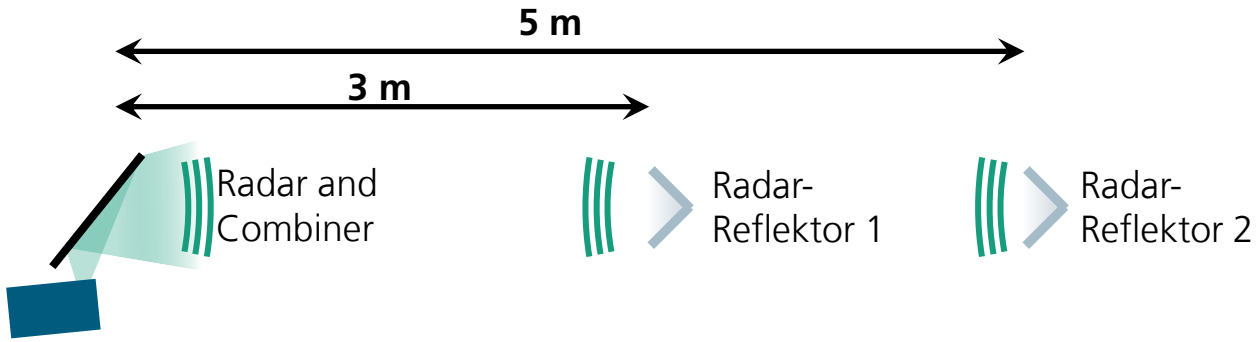
63% Avg.
Metallization

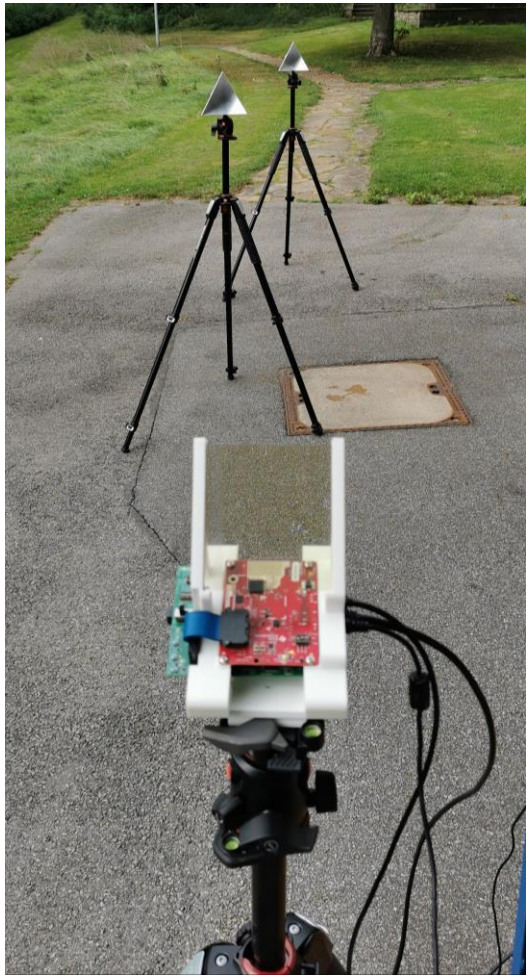
Multi-Spectral Combiner & RADAR

Specular Reflector



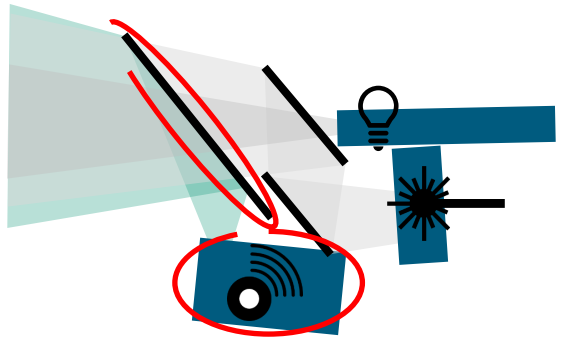
- Radar sensor: Texas Instruments AWR1843BOOST Evaluation Board
- All samples 10x10 cm^2 PC with conductive ITO coating on Radar-facing side
- Targets: Two retro-reflectors (trihedrals) in 3 m and 5 m distance
- 1D-measurement (range profile) of distance to target performed for each sample

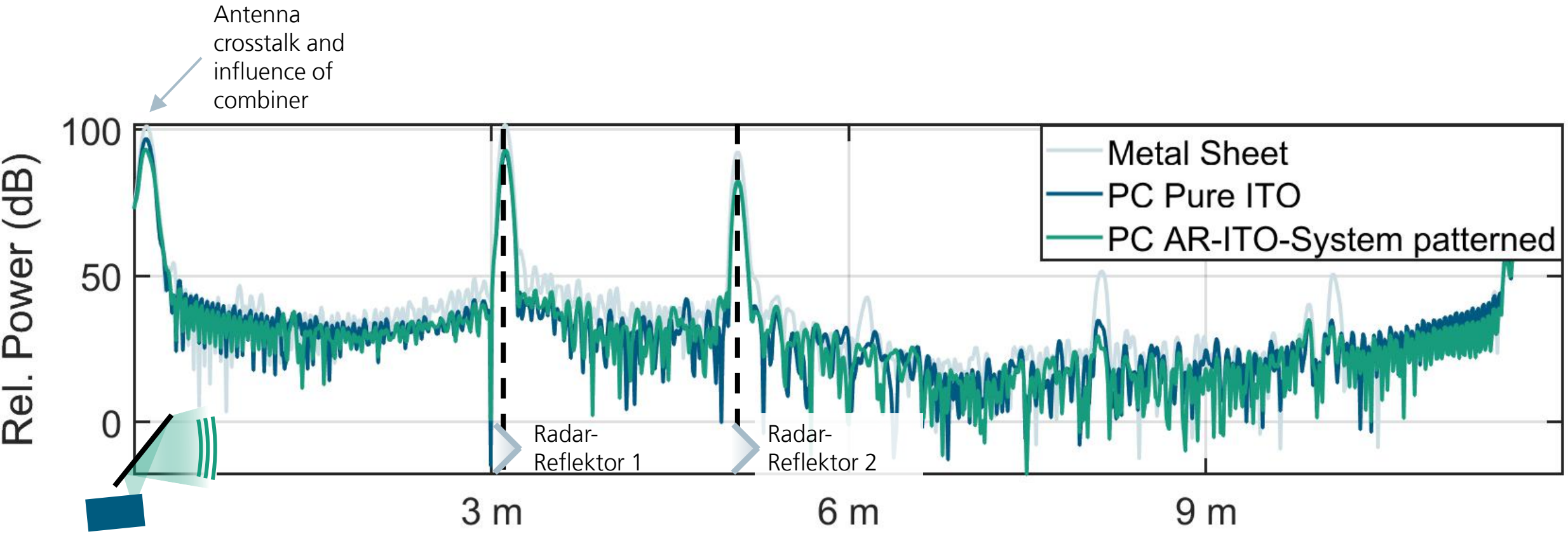




Multi-Spectral Combiner & RADAR

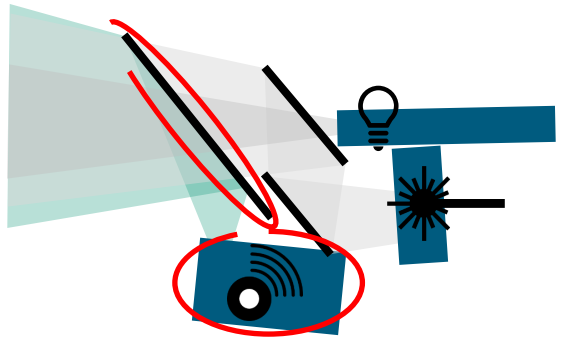
Specular Reflector

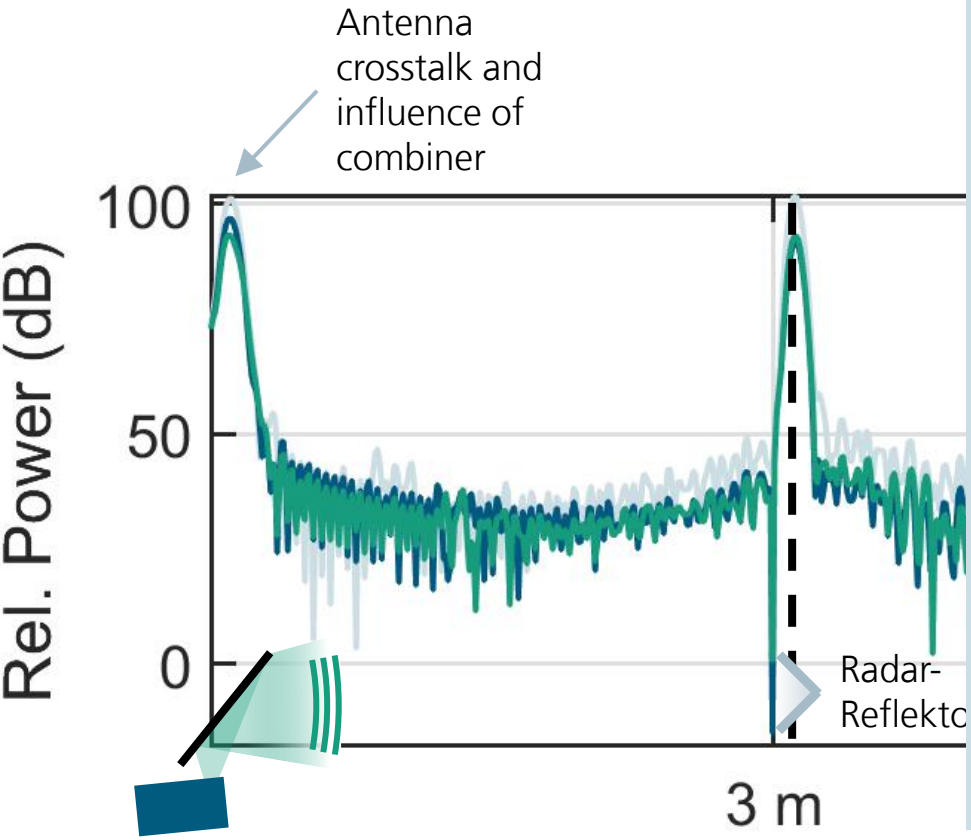




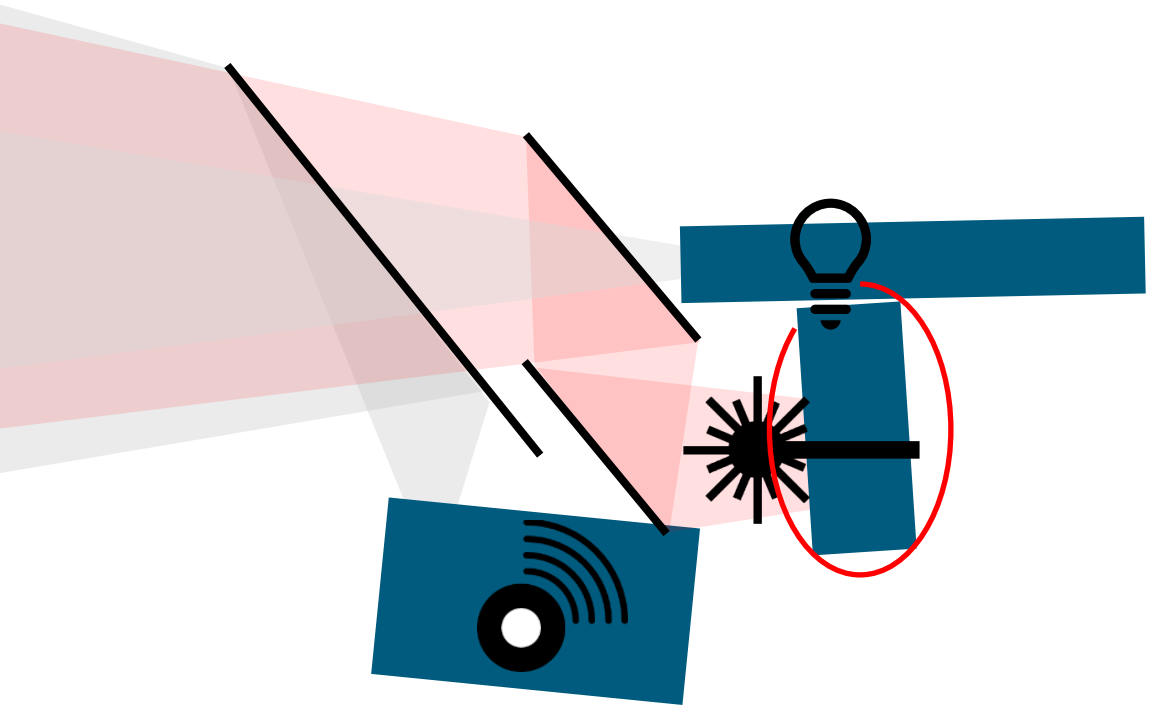
Multi-Spectral Combiner & RADAR

Specular Reflector



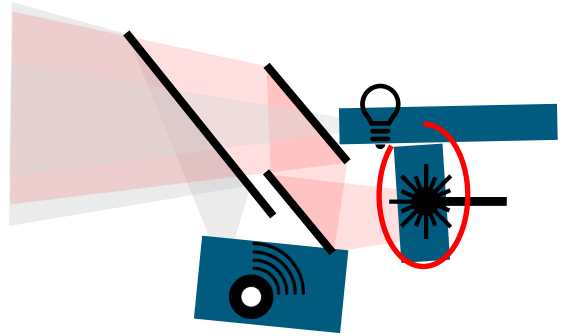


- Functionality of optically transparent radar reflector demonstrated successfully
- Reduced electrical conductivity of ITO causes losses
- 3 dB difference in signal strength between fully coated and structured combiner
  - → Translates to approx. 15% reduction in max. achievable range
- 7 dB difference in signal strength between best combiner and metal sheet
  - → Translates to approx. 33% reduction in max. achievable range



LiDAR

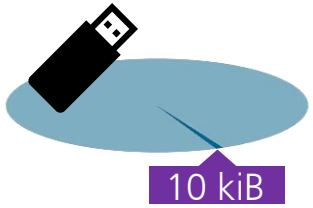
LiDAR



Efficient Algorithm

PATENT PENDING

for direct Time-of-Flight analysis



0.5 %
of previous memory needed

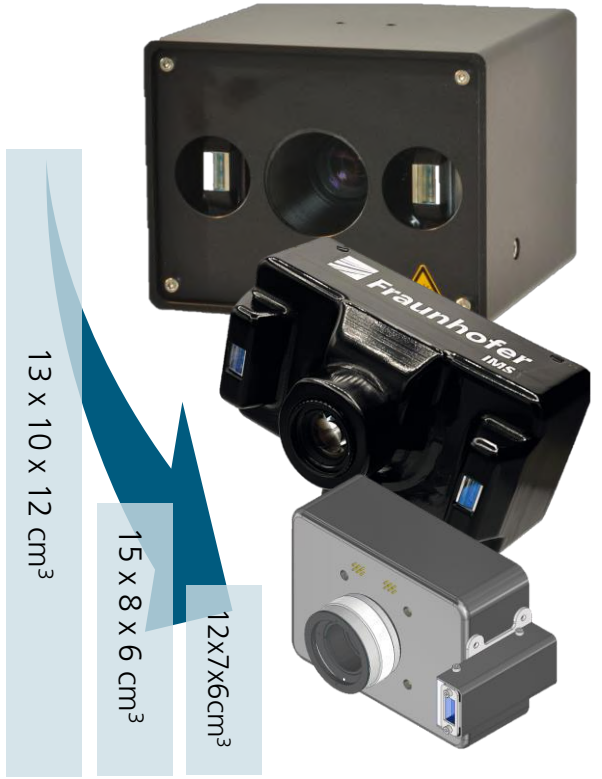
faster than today

Interference Supression

+ LiDAR Signal is individually encoded with random numbers in order to avoid interference with other LiDAR emitters
+ photon-based true random number generator simultaneous to distance measurement
+ Data rate for random number generation

10^5 bit/s

Size Reduction



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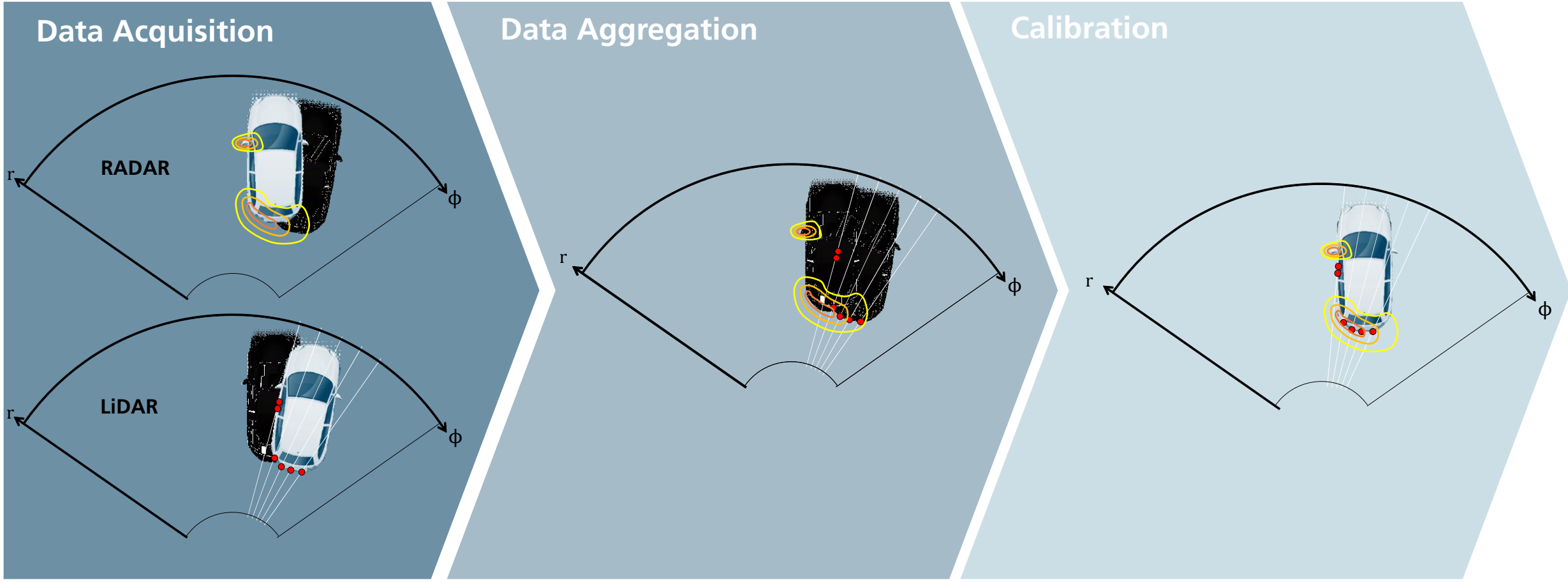
Data Fusion of LiDAR and RADAR in Smart Headlight



Smart Headlight

Take Away

Light

+ Maskless micro-optical beam shaping
+ ECE conformal low beam
+ Switchable segmented high beam
+ Size reduction

LiDAR

+ ~15 fps → 144 fps
+ 0.5 % memory consumption compared to state of the art
+ 10^5 bit/s random number generation for encoded signal

Radar

+ Optical transparent Radar reflector demonstrated successfully
+ Patterned reflector induces 15% range loss in favor of increased transmissivity

Thank you for your interest

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