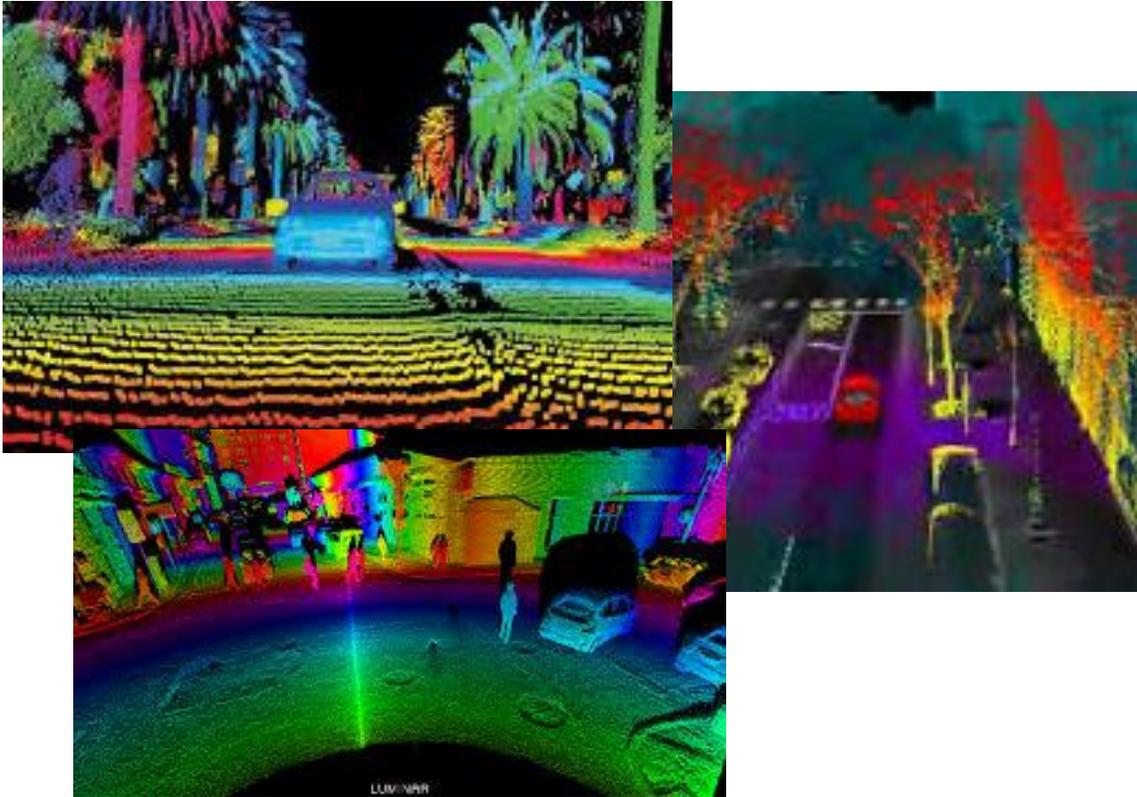

USING SPAD DETECTORS FOR LIDAR

Dr. Jennifer Ruskowski
Head of 3D Sensors



LiDAR in its point cloud beauty...



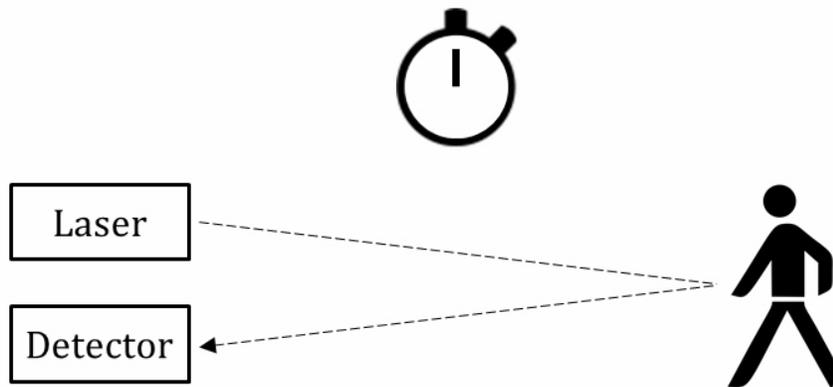
What are/will be the successful LiDAR architecture(s)?

What is new on the component level ?

<https://www.electronicdesign.com>, <https://www.eenewsanalog.com>,
<https://techcrunch.com>

LiDAR

Light Detection And Ranging



$$d = \frac{c}{2} T_{\text{TOF}}$$

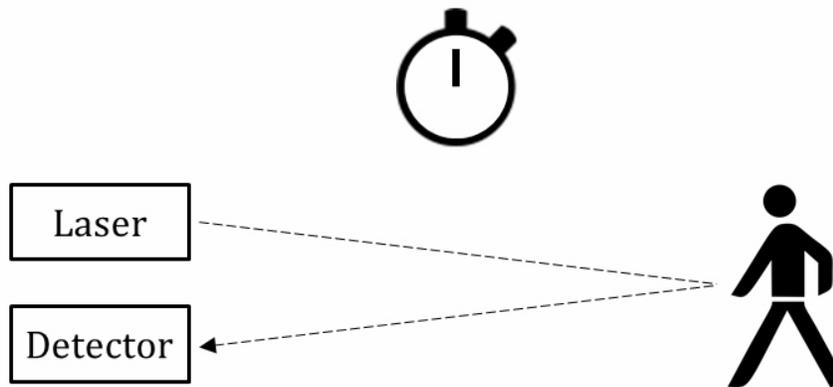
■ Light is incredible fast

→ High demands on electronic:

- Timing resolution
 - Sensor read-out / data rate
 - No heat generation
- (...)
- High amount of active channels at the same time

LiDAR

Light Detection And Ranging



$$d = \frac{c}{2} T_{\text{TOF}}$$

- Light is incredible fast

- Optical wavelengths

- High spatial resolution

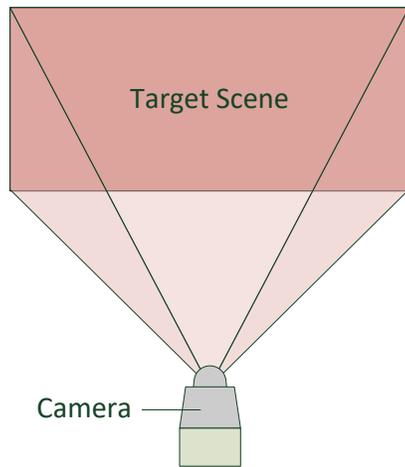
- Eye safety (Laser Class 1)

choice of
wavelength
(905 nm / 1550 nm)

pulsed laser light
& beam motion

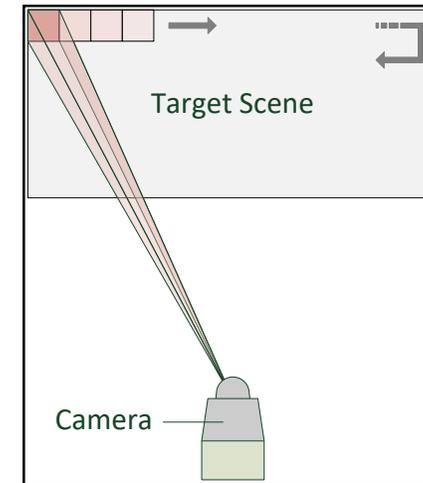
LiDAR methods

Flash



- Illumination of the full scene in one shot
- 👍 Easy data processing as global shutter image
- 👎 Distribution of laser power on the whole scene

Solid State

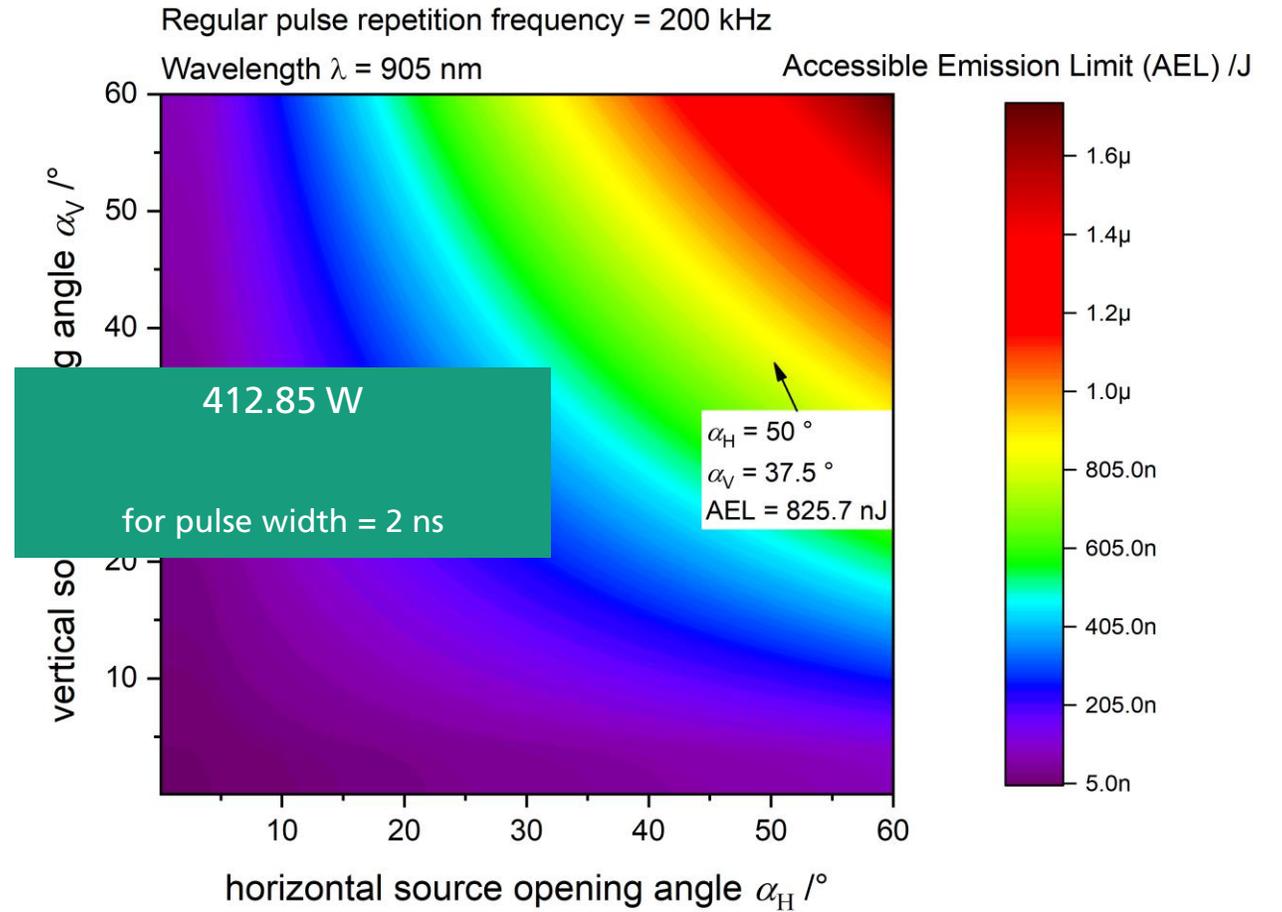
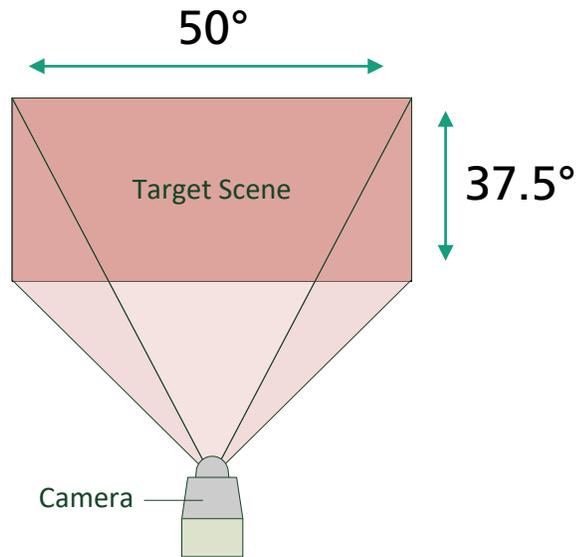


- Sequential illumination of the scene in smaller solid angles
- 👎 Steering unit needed (Mirror, MEMS, OPA,..)
- 👍 Higher laser power can be used

Eye safety

Accessible Emission Limit (AEL)

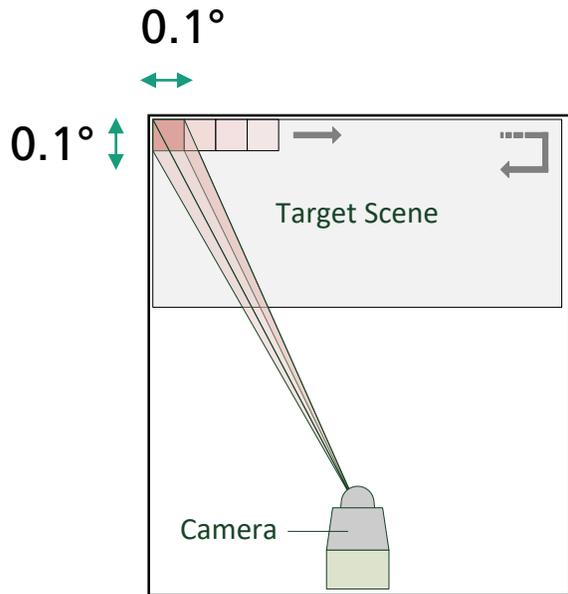
Flash



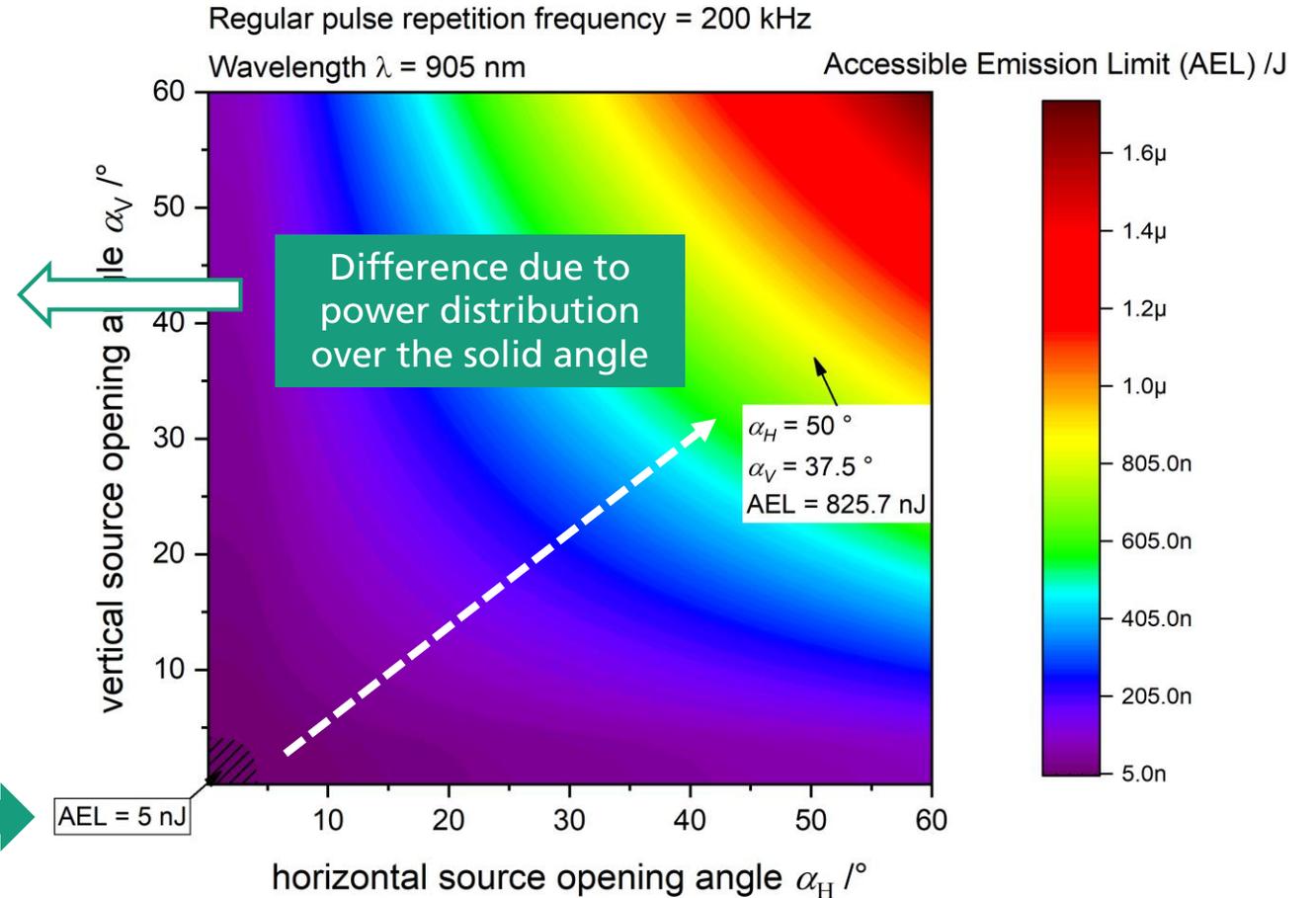
Eye safety

Accessible Emission Limit (AEL)

Solid State



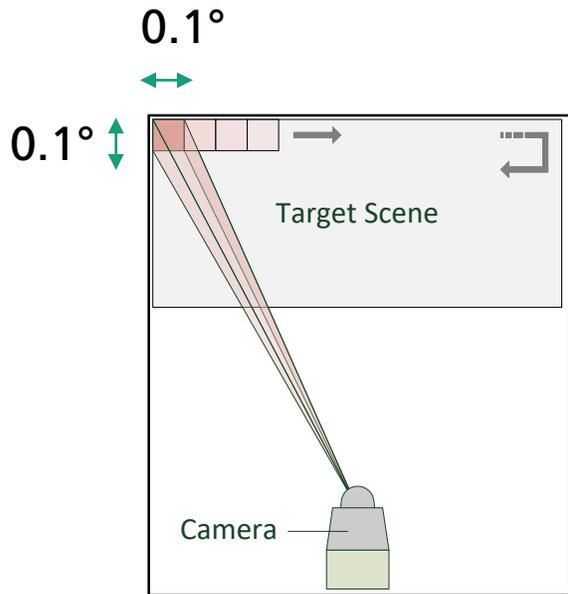
Resulting in (nearly) the same emitted intensity for Flash and Solid State (in 0.1°x 0.1°)



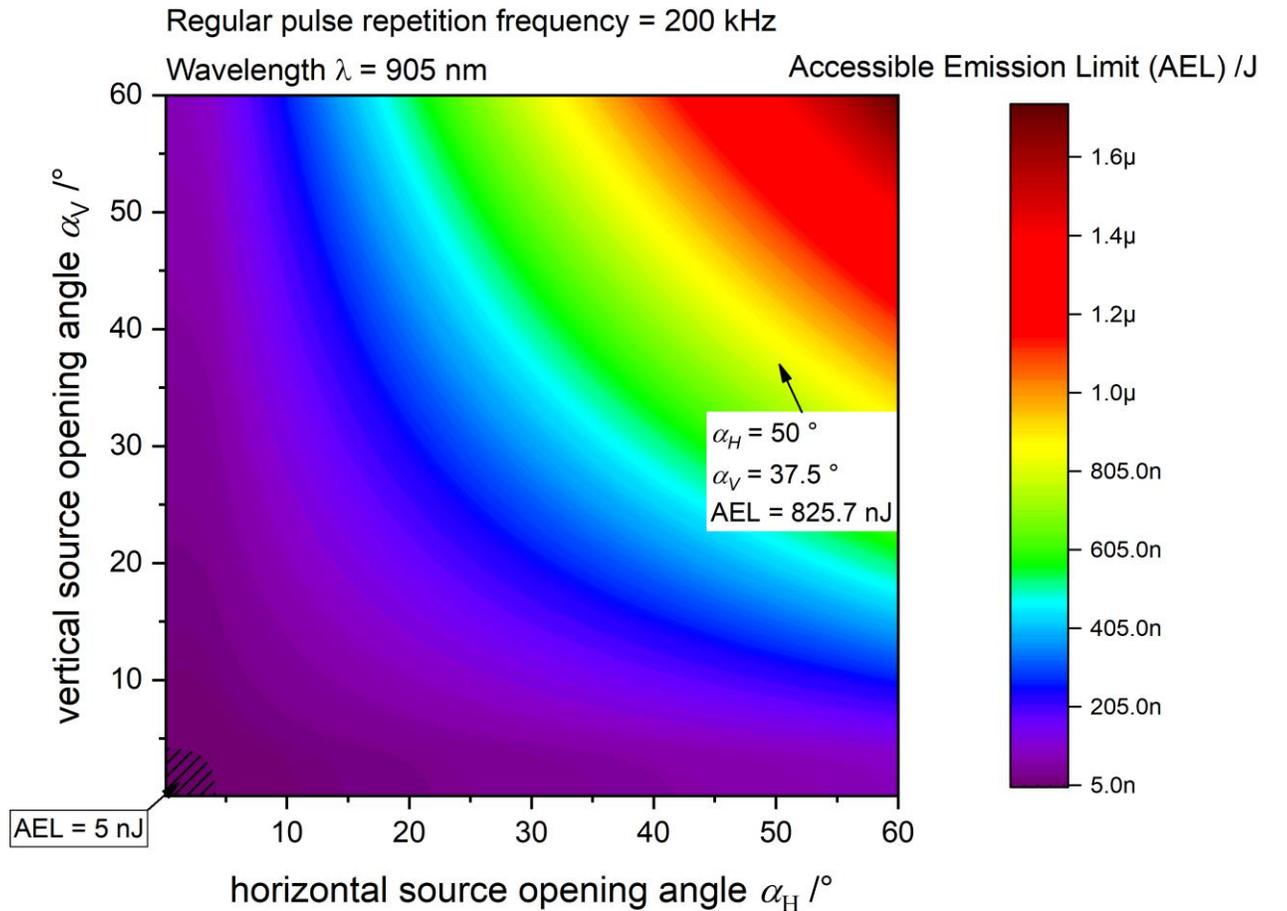
Eye safety

Accessible Emission Limit (AEL)

Solid State **AEL = 5 nJ**



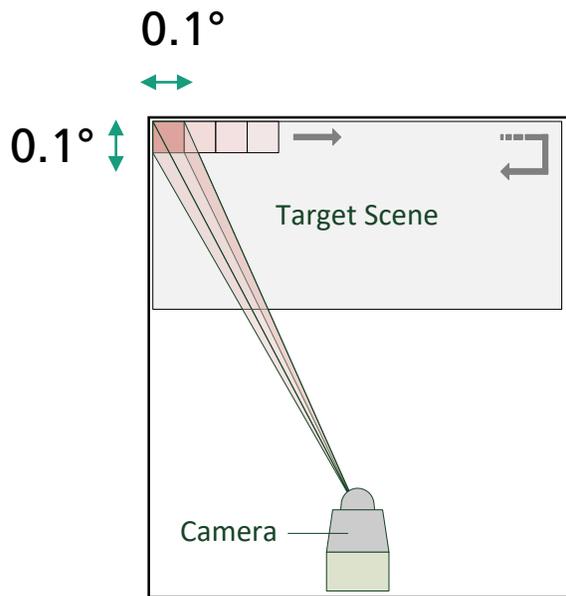
Movement of beam is not included



Eye safety

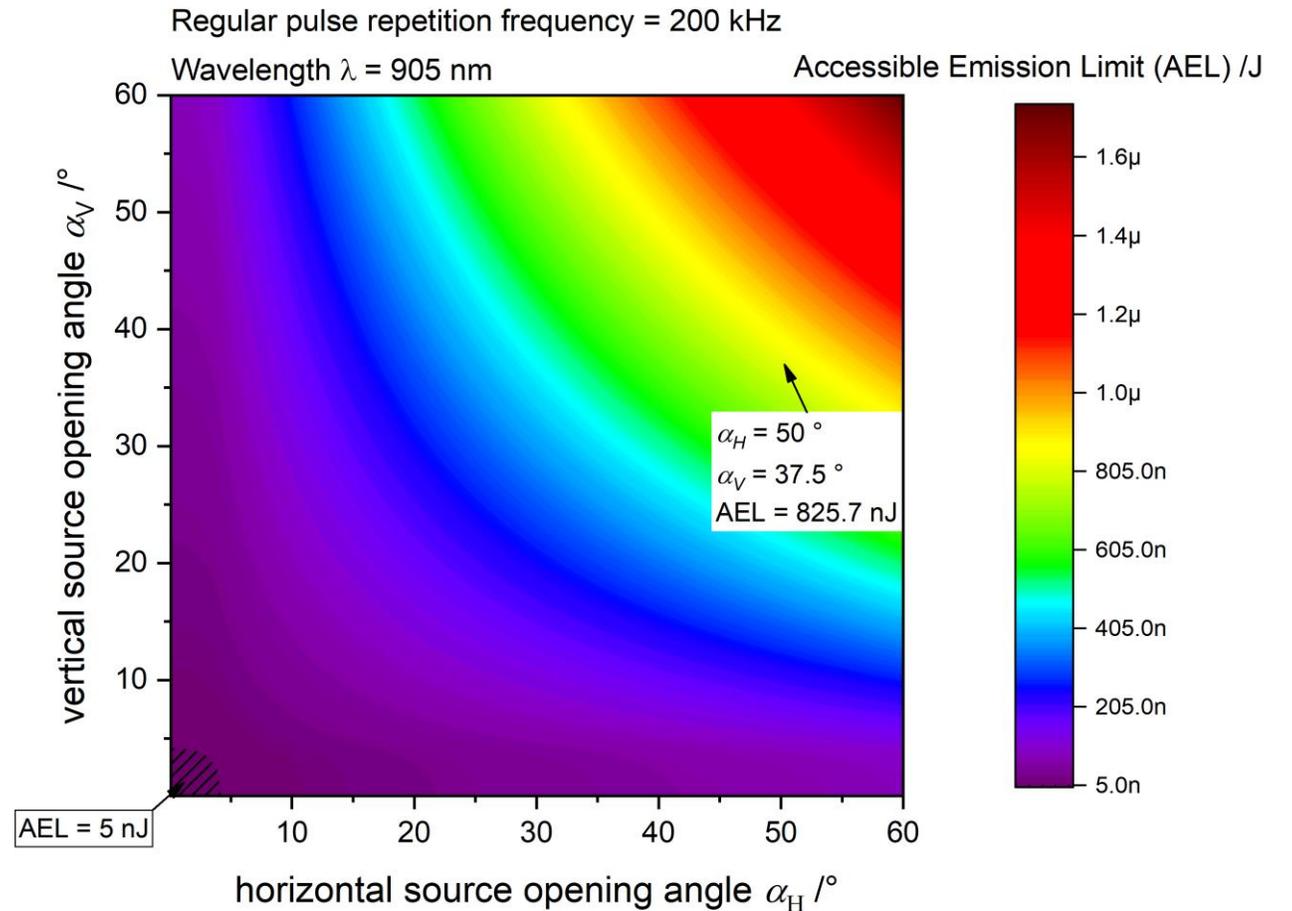
Accessible Emission Limit (AEL)

Solid State $AEL = 5 \text{ nJ} * 15$



Additional factor of up to ~ 15

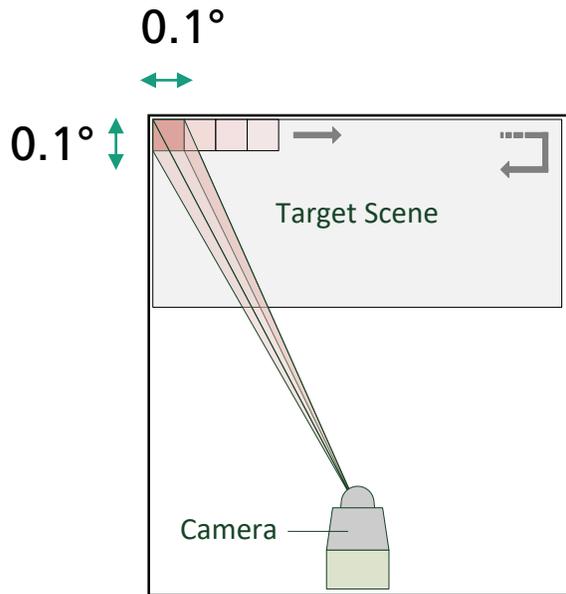
With beam movement



Eye safety

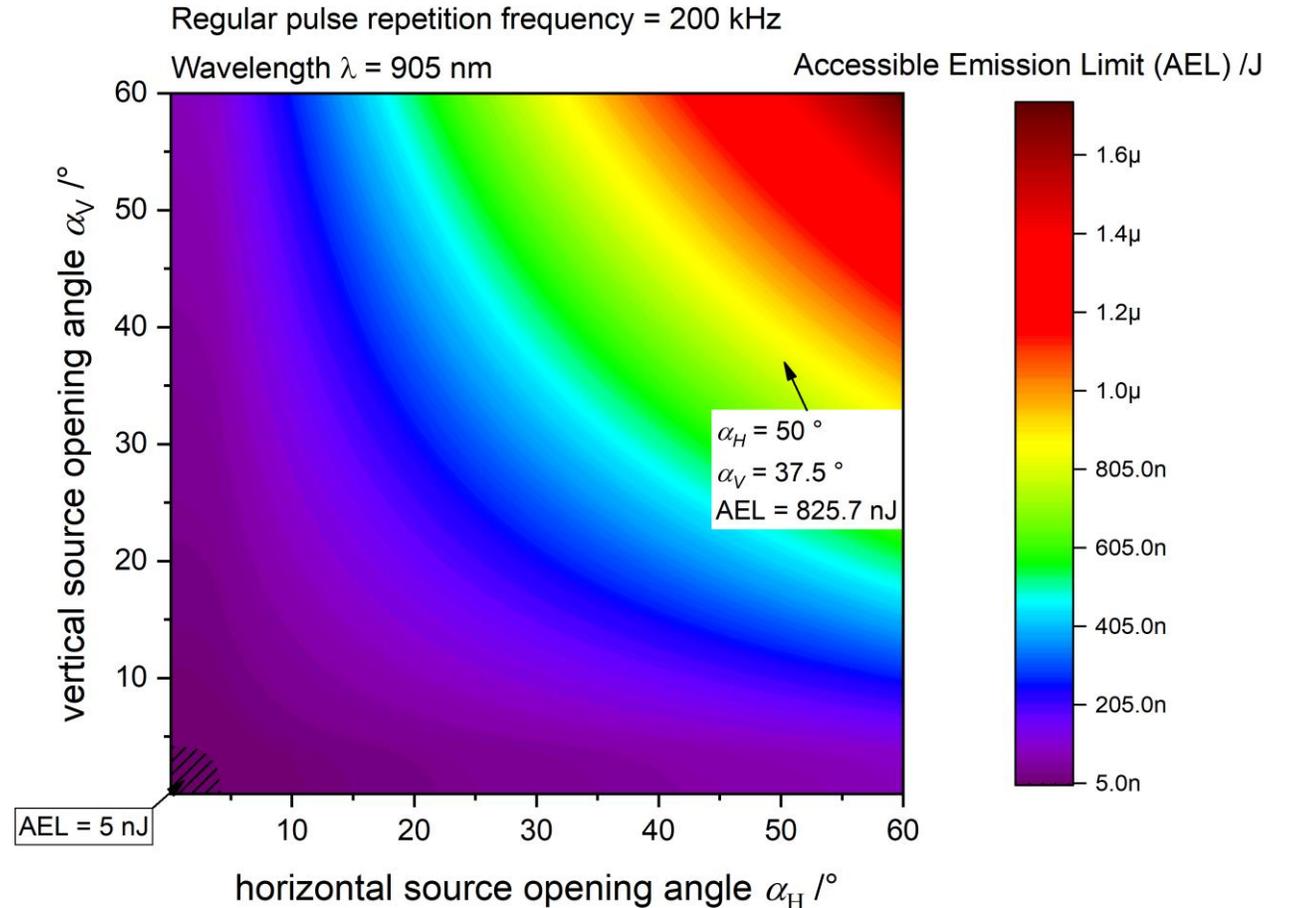
Accessible Emission Limit (AEL)

Solid State $AEL = 5 \text{ nJ} * 15$



Additional factor of up to ~ 15

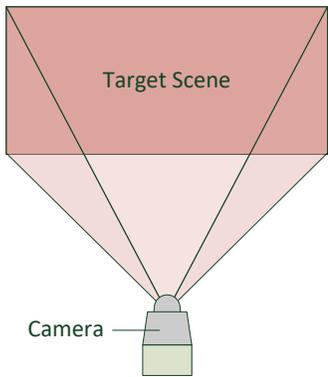
Results in possible higher Signal-to-Noise Ratio than for Flash LiDAR



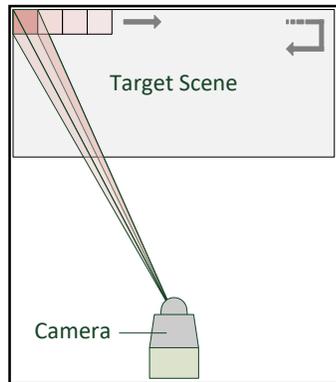
Eye safety

Accessible Emission Limit (AEL)

Flash



Solid State



~ 15 times higher AEL

Be careful...

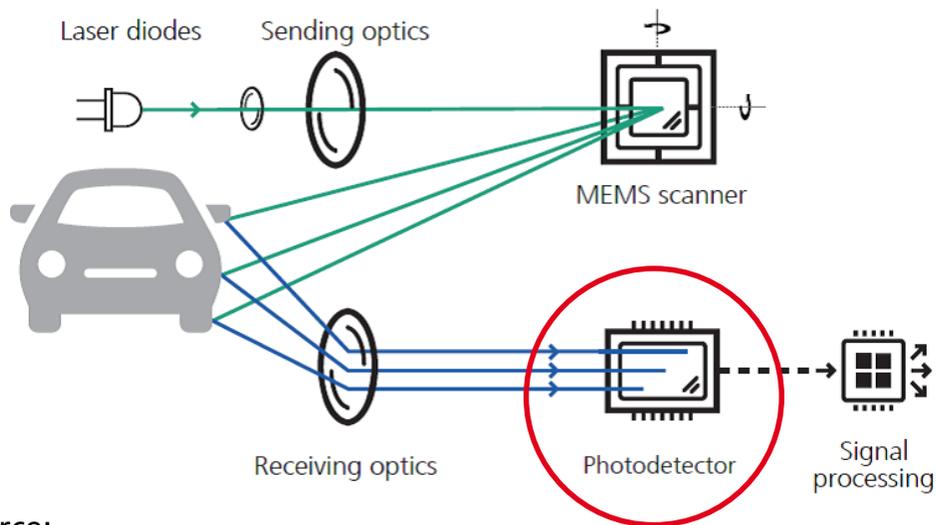
Laser power is the only system parameter

Others

- System cost (number and cost of components)
- Detector sensitivity / background light immunity
- Detector resolution → system resolution

Photodetectors for Solid State LiDAR

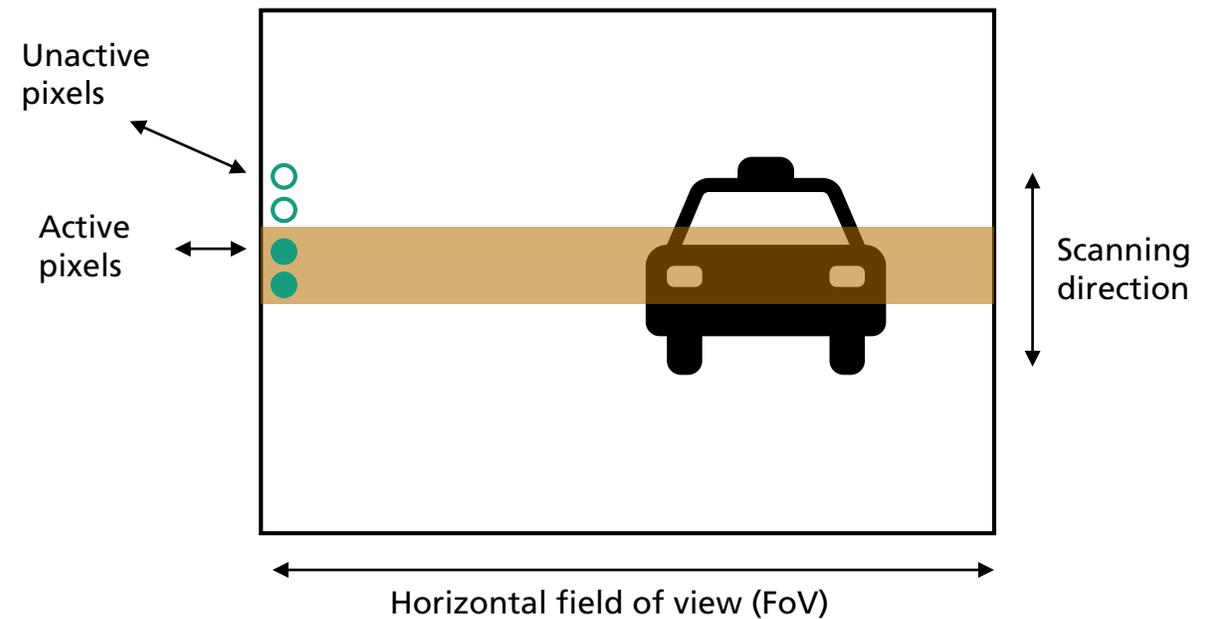
MEMS LiDAR (with separated receiving light path)



source:
 **Forschungsfabrik
Mikroelektronik
Deutschland**

Photodetector

Here: 1D scanning



Photodetectors for Solid State LiDAR

Pixel resolution

- MEMS LiDAR (with separated receiving light path)

For instance:

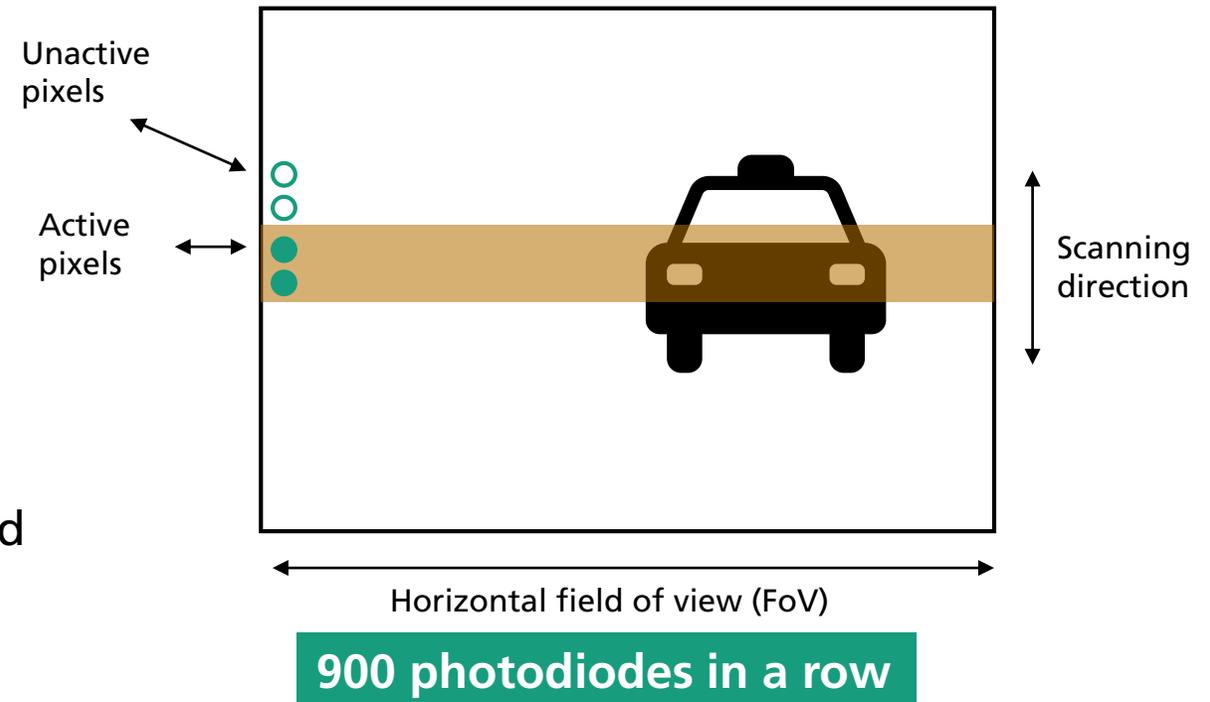
FoV – horizontal = 90°
with 0.1° angle resolution
→ 900 photodiodes in a row



2D photodetector arrays are required

Photodetector

Here: 1D scanning



Photodiodes Benchmark

- Best choice for creating 2D arrays: **Single Photon Avalanche Diodes (SPAD)**

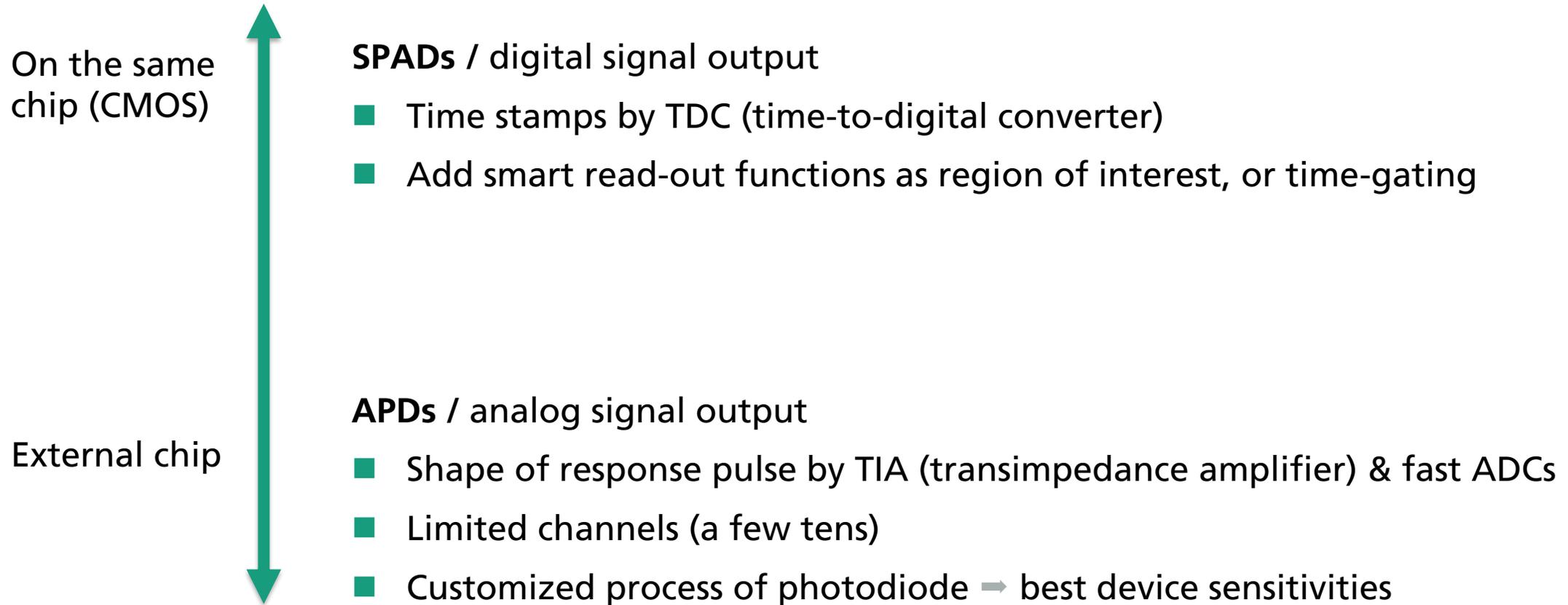
Silicon-based detectors

	PIN-PD	APD	SiPM	SPAD
Gain	1	10^3	10^6	10^6
Single photon detection	No	No	Yes	Yes
Operational Bias	Low	Medium	Medium	Medium
Temperature Sensitivity	Low	High	Low	Low
Array possible	Limited X	Limited X	Limited X	Yes +
Readout / Electronics	Complex	Complex	Medium	Simple
Rise time	Medium	Slow	Fast	Fast

SOURCE:

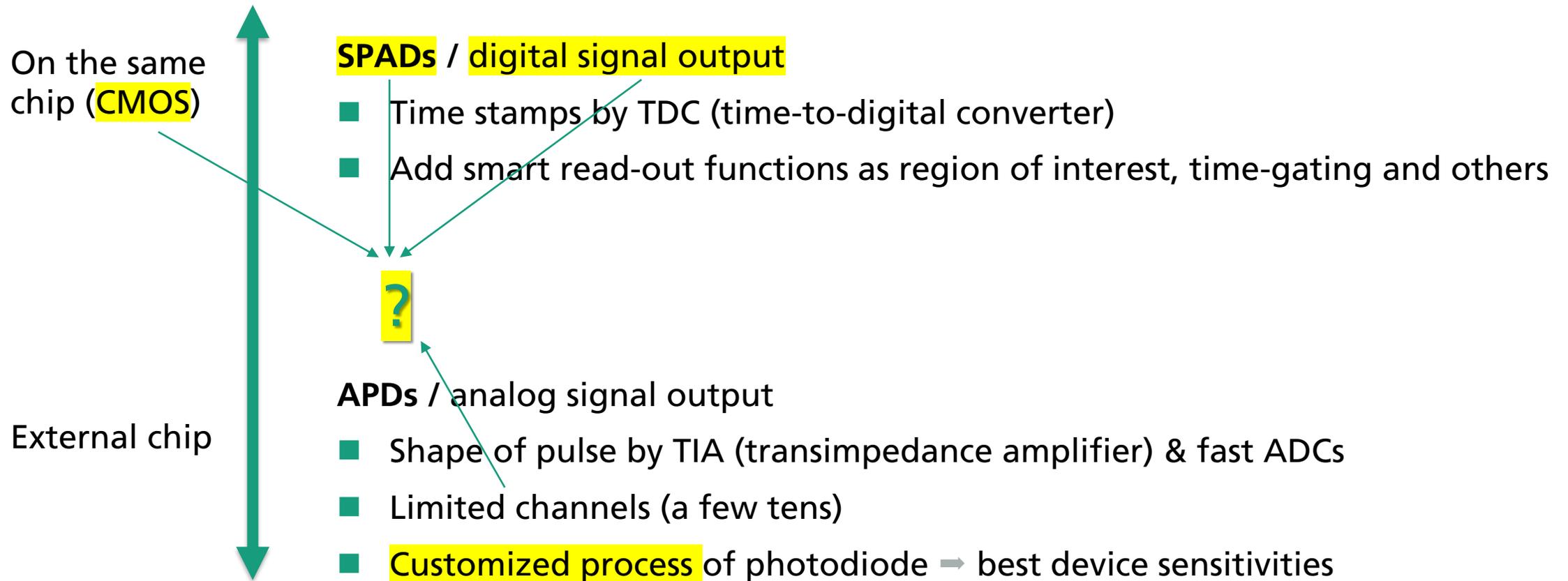


Chip architecture depends on photodiode choice



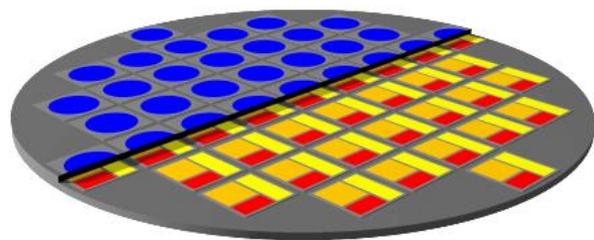
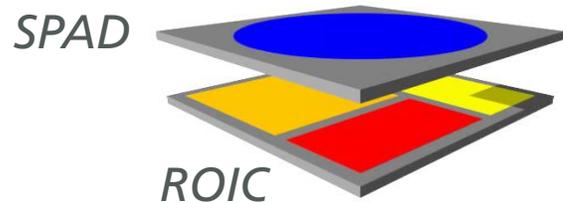
Chip architecture depends on photodiode choice

Best features



CSPADs

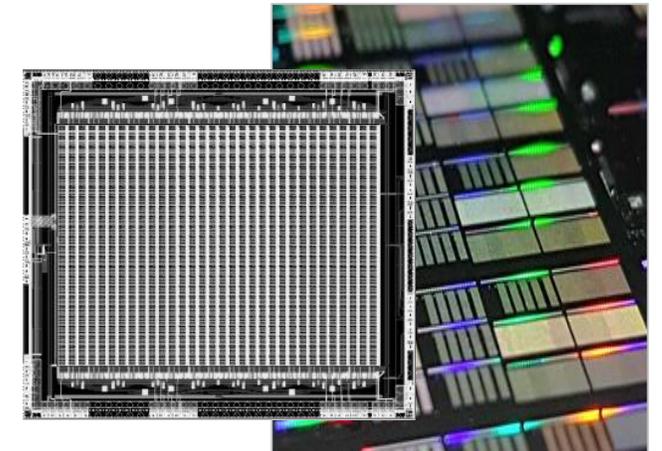
Chiplets combining Back Side Illuminated SPADs and CMOS



CSPAD

- High pixel resolution and simultaneous pixel time-stamps
- High SPAD sensitivity in the NIR region
- Wafer-to-wafer bonding: easy post-processing (ARC & micro lenses)

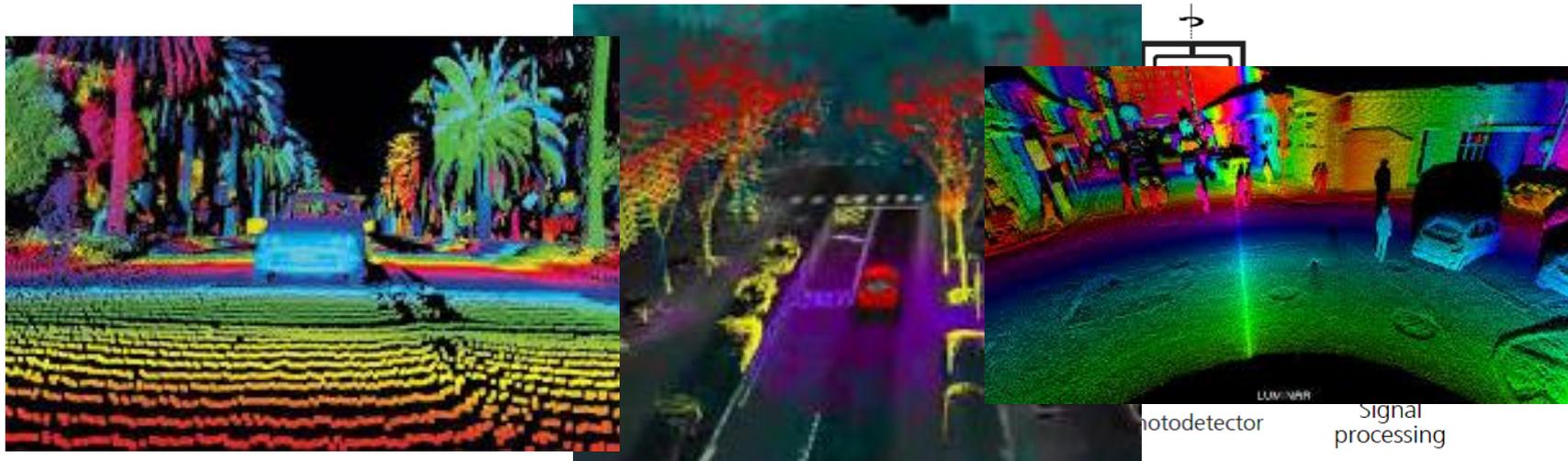
- First device: CSPAD3000light
 - 32 x 24 active pixel resolution
 - 350 nm CMOS on 8 inch wafer
 - 4 cm distance resolution
 - Sunlight suppression algorithms



CSPAD3000light

Conclusion

- Ongoing SPAD developments and new arrivals of 2D-arrays in 2020
- Contribution to low cost Solid State LiDAR solutions



Thank you for your attention

- Visit us at the exhibition

