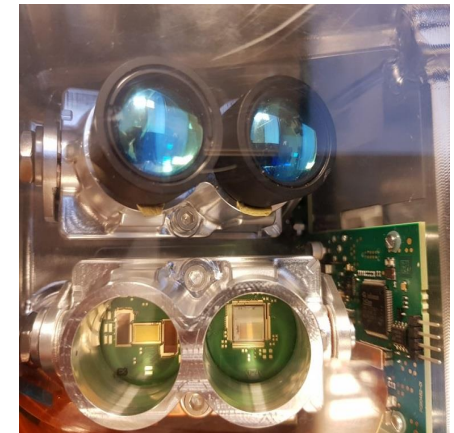


4D SOLID-STATE LIDAR UTILIZING VCSEL AND SPAD ARRAYS

EPIC Meeting on LIDAR Technologies for Automotive
Anteryon | Eindhoven | 2019-10-31
Hanno Holzhüter

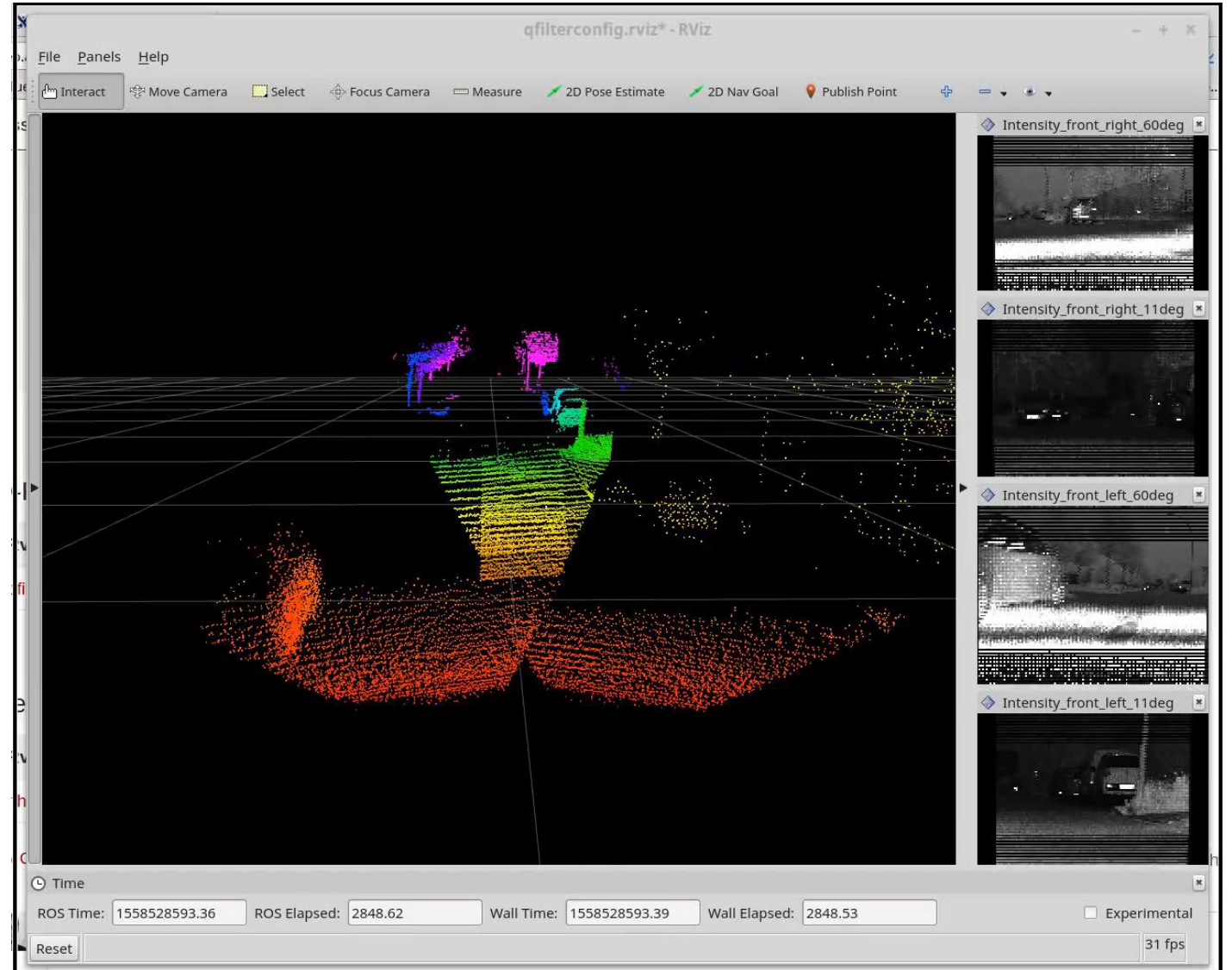
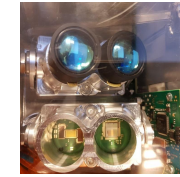
Why it's hard to build a solid-state LiDAR

One way to do it

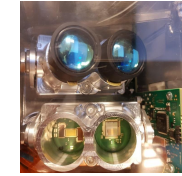


Dokumentenklasse: public





IBEO HISTORY



Specialized in the field of automotive LiDAR Sensors



Employees

- 380+ (2019)

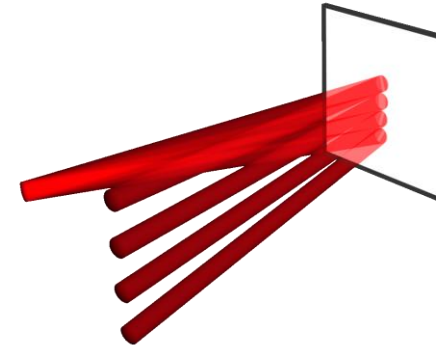
Offices

- Hamburg, Germany (Headquarters)
- Eindhoven NL, Detroit USA, China (coming soon)

Partnership with



Together with Valeo in automotive serial production

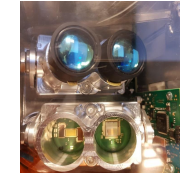


“too bulky”

“too expensive”

“limited vertical FOV”

NEXT GENERATION LIDAR REQUIREMENTS



“too bulky”
“too expensive”
“limited vertical FOV”



solid-state

high resolution	0.1° x 0.1° (H x V)
wide FOV	120° x 20° (H x V)
long range	300m (80m 10%)
frame rate	25 Hz

fast in 2020 (2022)

cost efficient and automotive qualified

$$d = \frac{c\Delta t}{2}$$

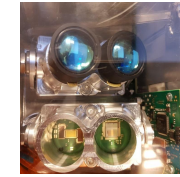
$$\Delta t_{300\text{ m}} = \frac{2 \cdot 300\text{ m}}{3 \times 10^8\text{ m s}^{-1}} = 2\ \mu\text{s}$$

$$\frac{40\text{ ms}}{2\ \mu\text{s}} = 20\,000$$

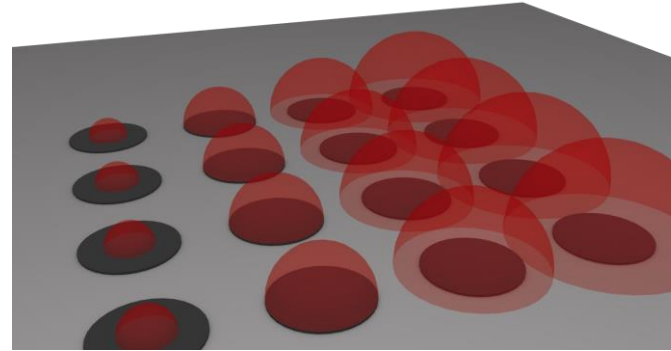
e.g. 500 x 40 Points

→ scanning FOV point-wise is not feasible

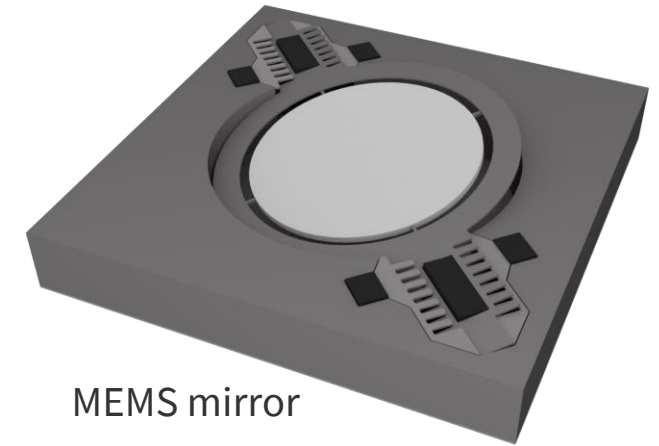
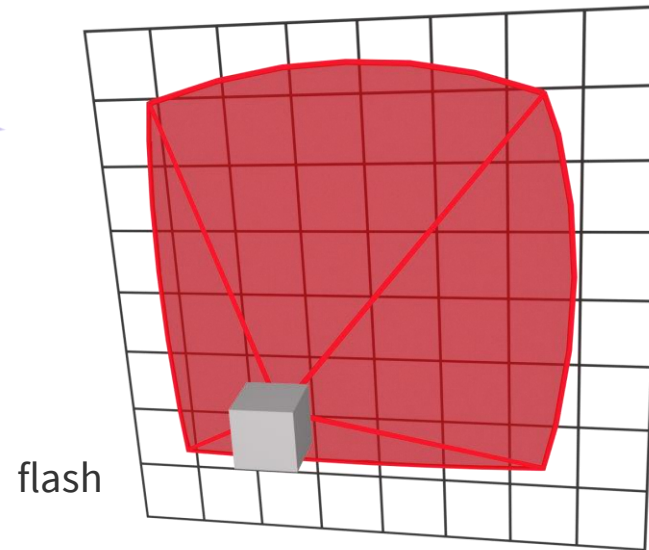
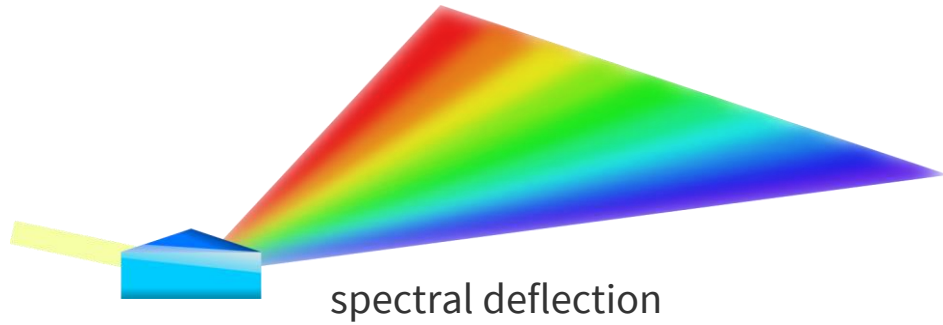
SOLID-STATE SCANNING



How to **solid-state** but **wide FOV** and **high resolution**?

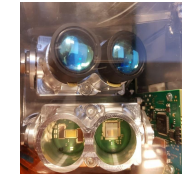


OPA



MEMS mirror

FOCAL PLANE ARRAY

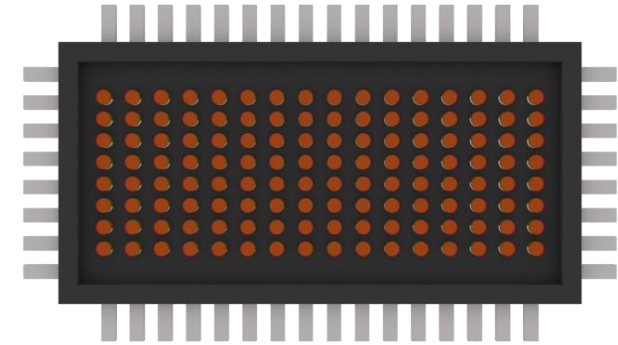
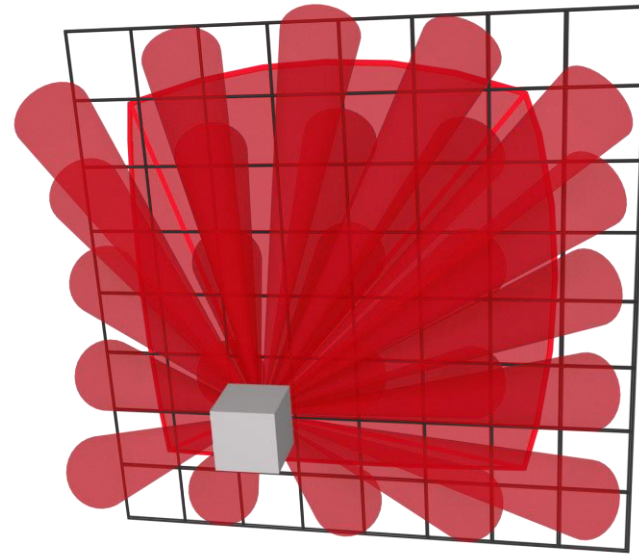


Power hungry (optical) with

- technical and
- eye-safety limitations

$$E_{\text{Pulse}, 905 \text{ nm}} \approx 100 \text{ nJ}$$

(DIN EN 60825)



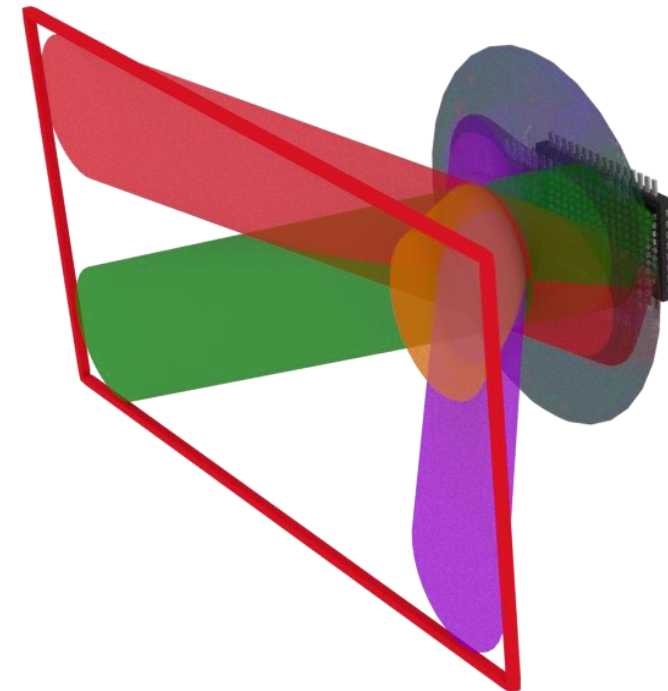
Array of emitter

→ no edge emitter but VCSELs

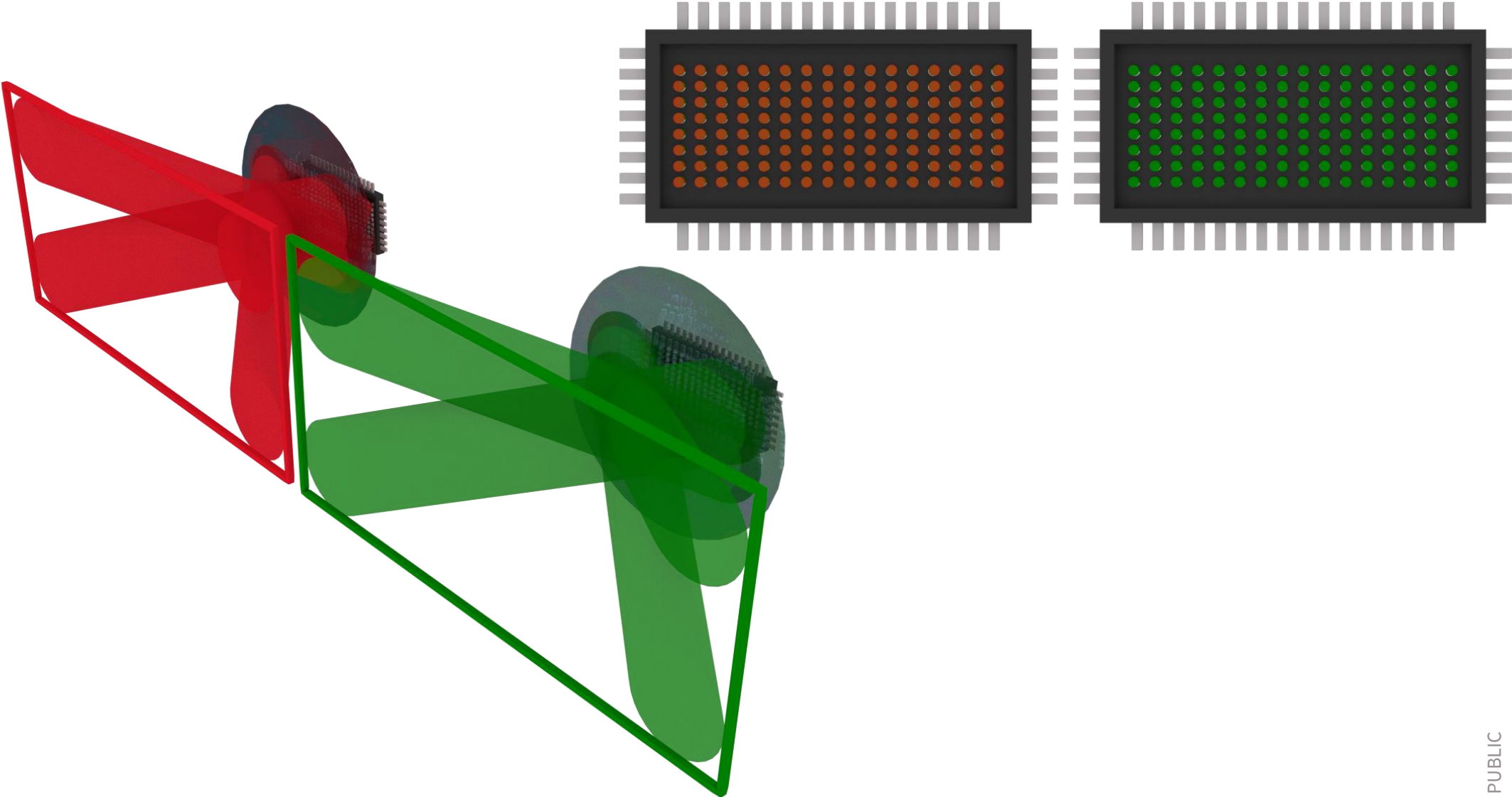
Focal Plane Array (FPA)

Map receiver to emitter

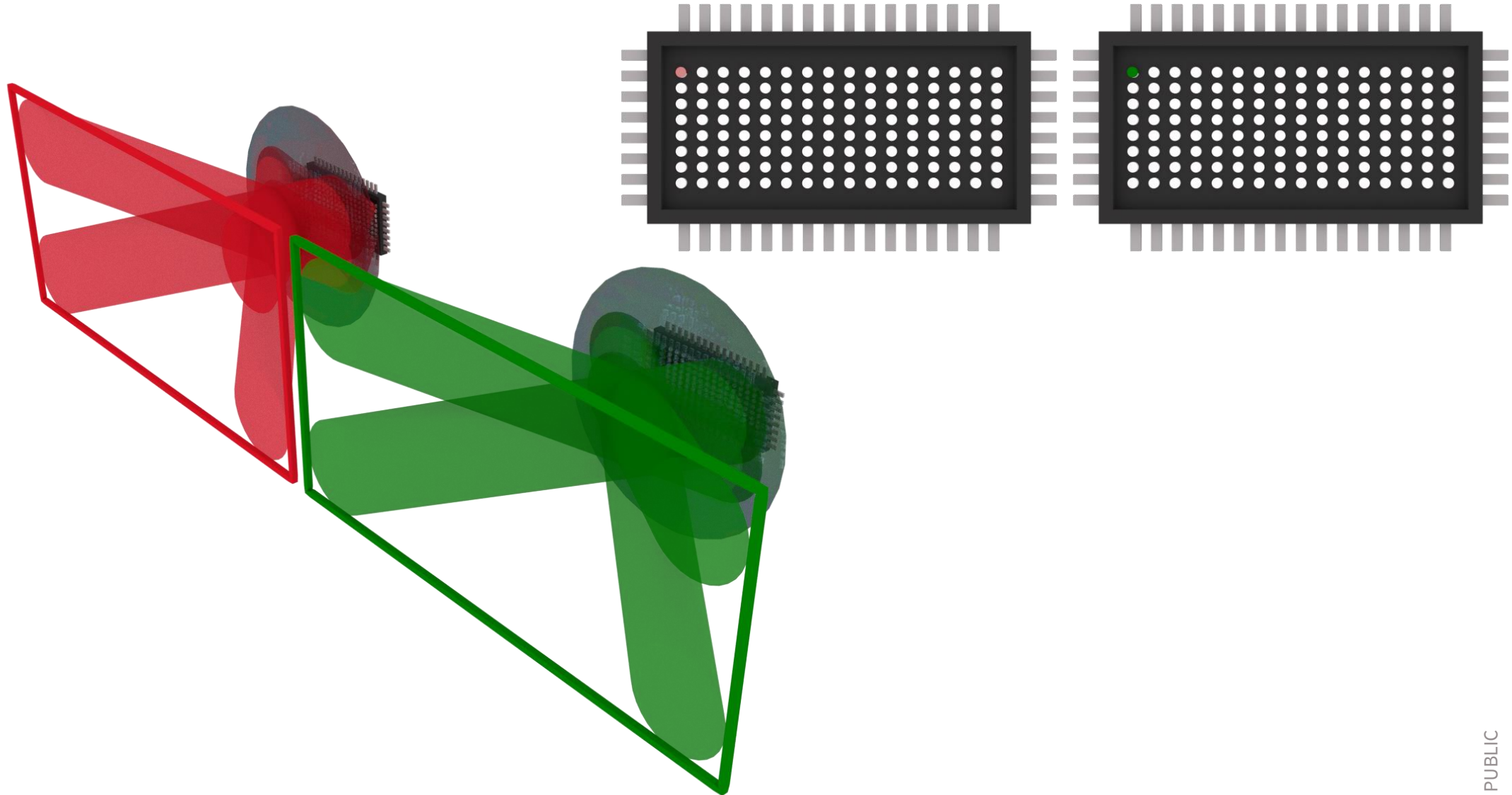
→ enhanced optical power budget



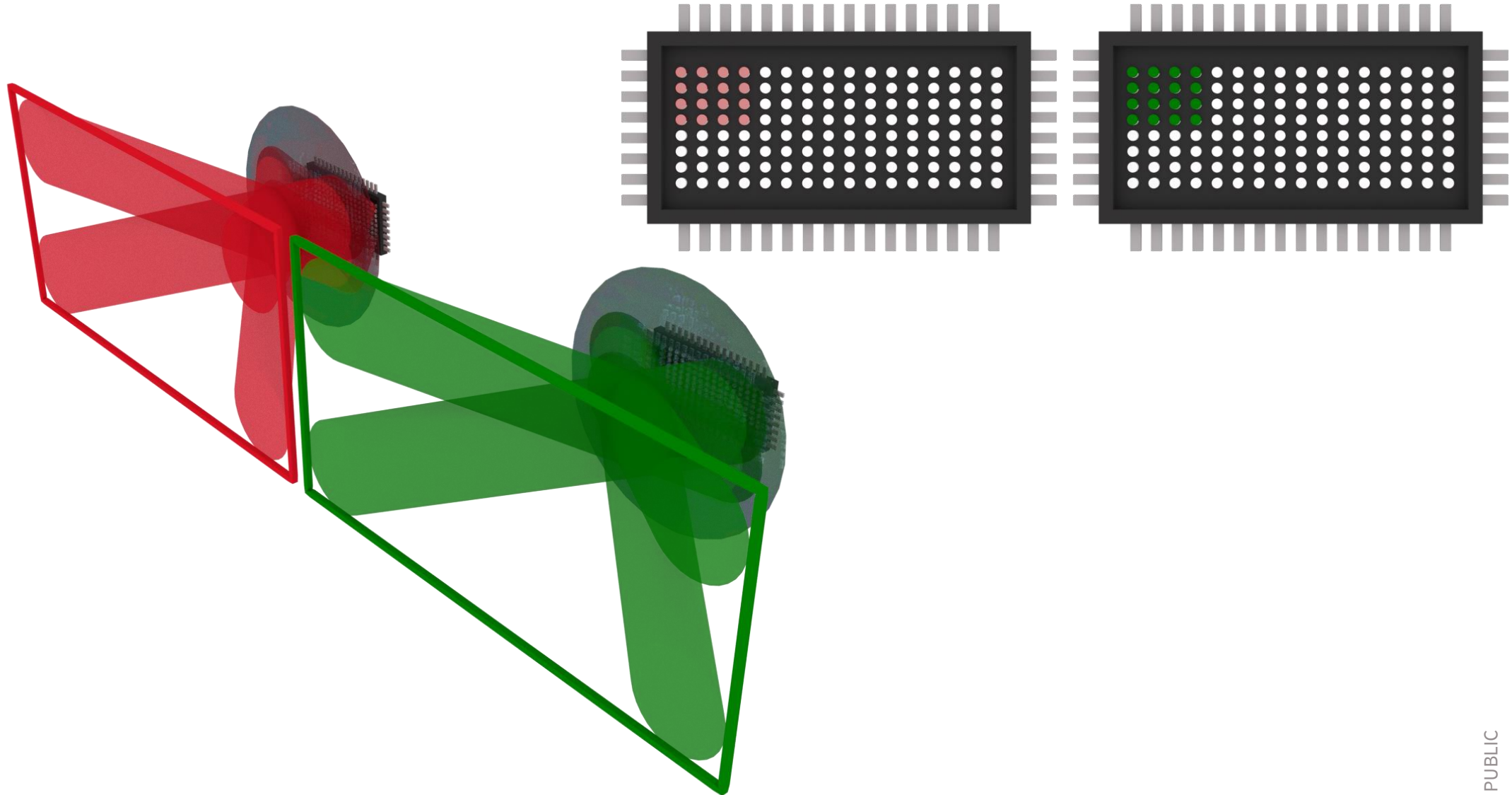
FOCAL PLANE ARRAY



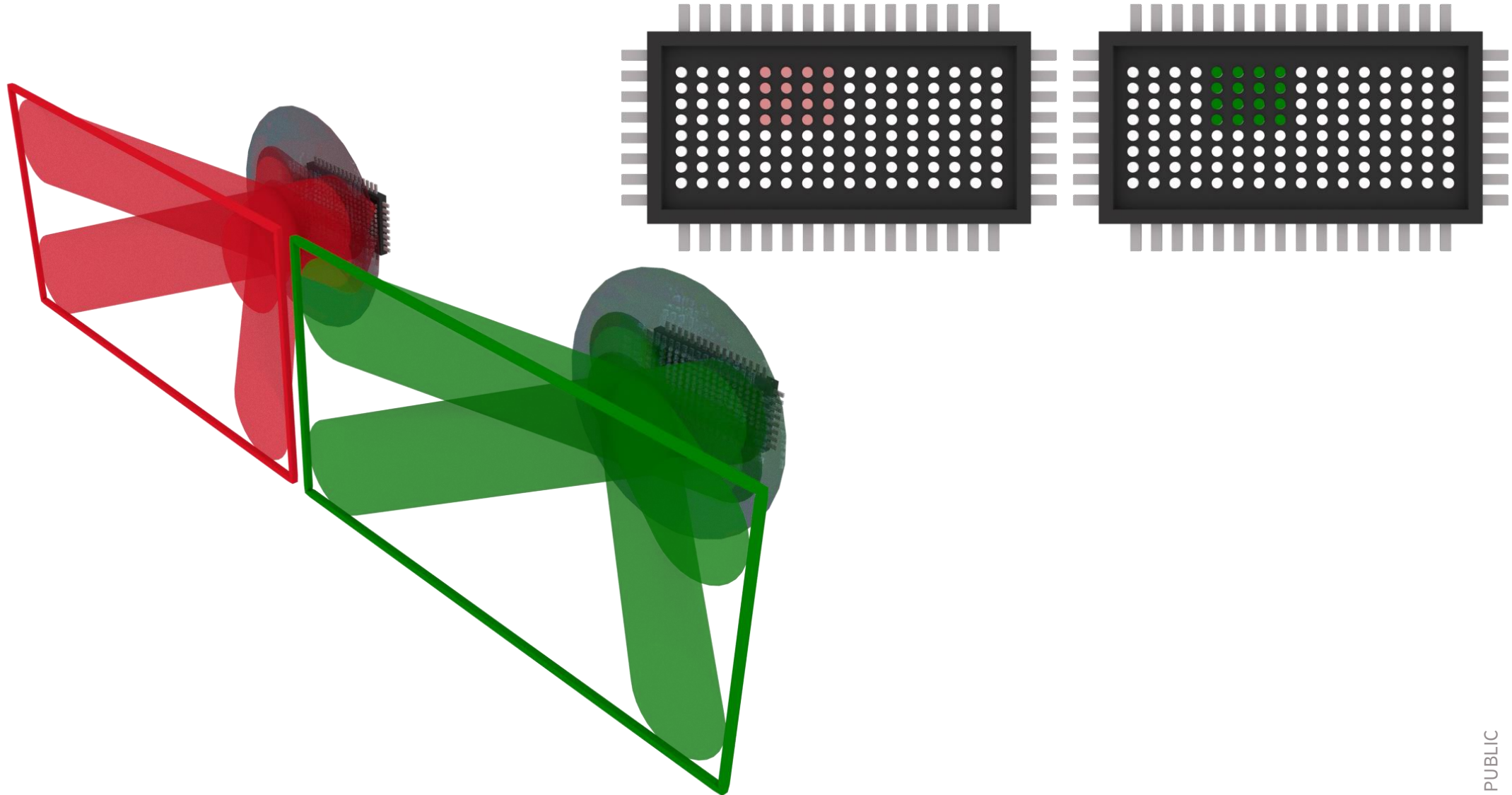
SOLID-STATE SCANNING



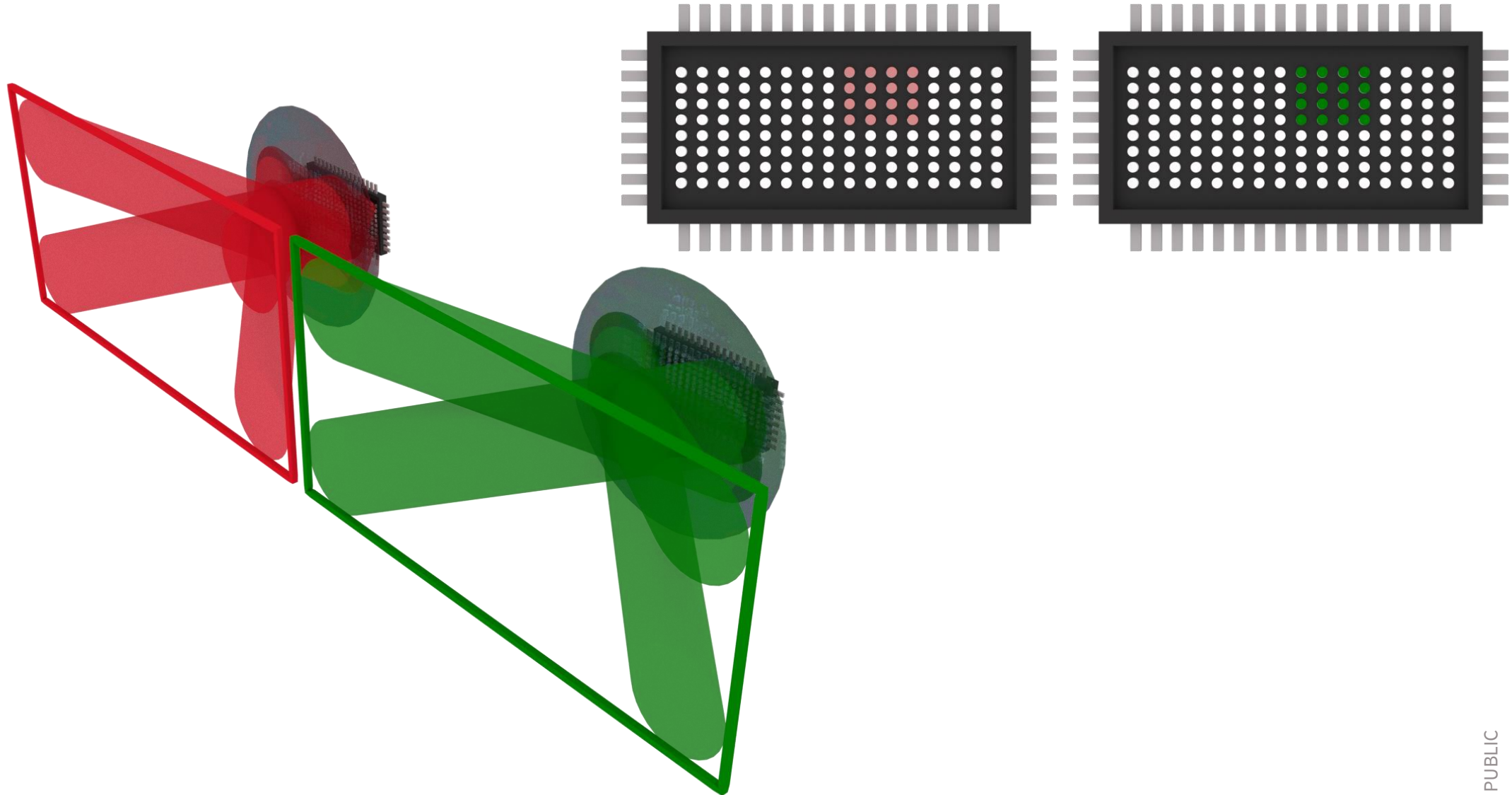
SOLID-STATE SCANNING



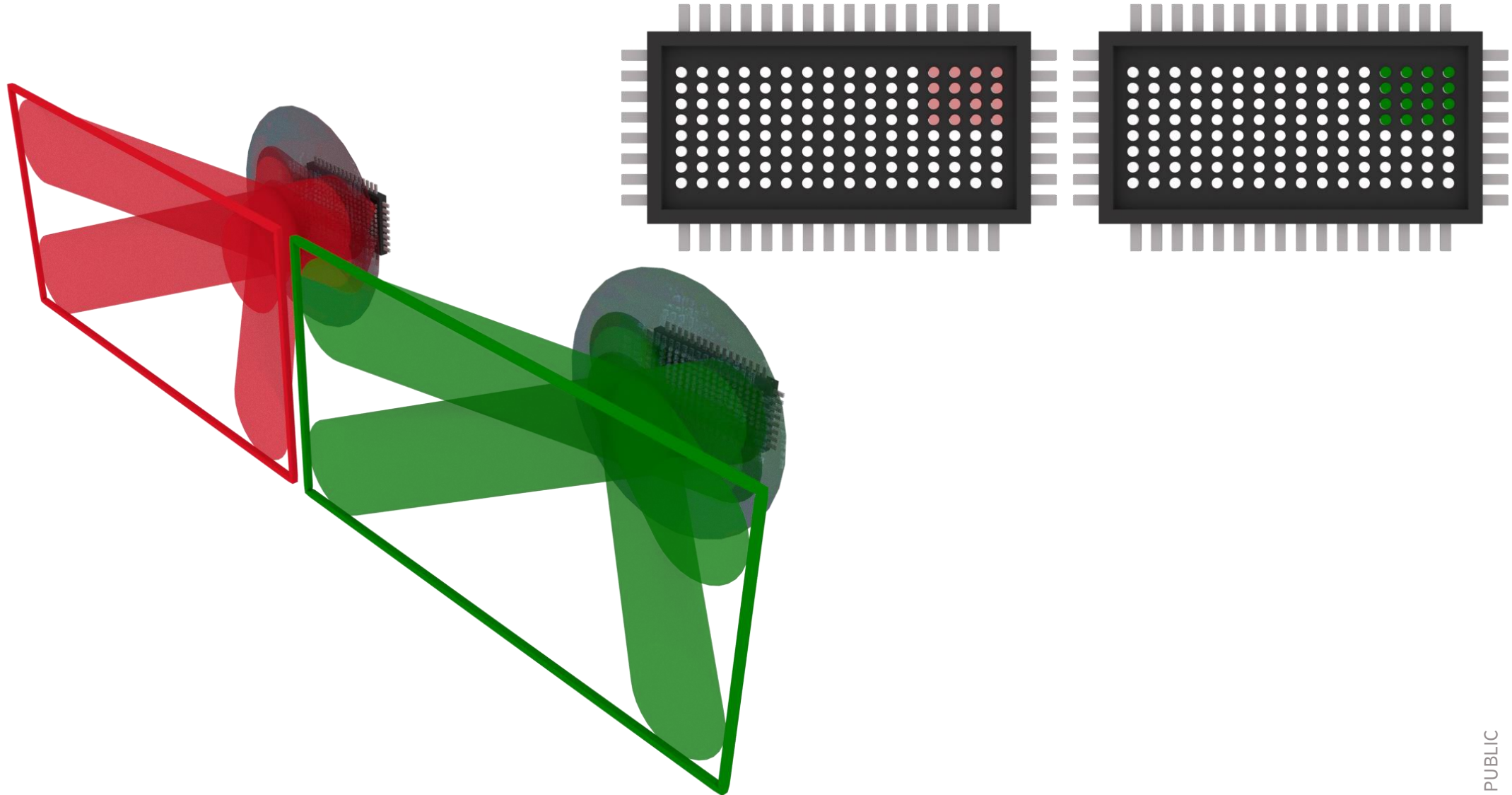
SOLID-STATE SCANNING



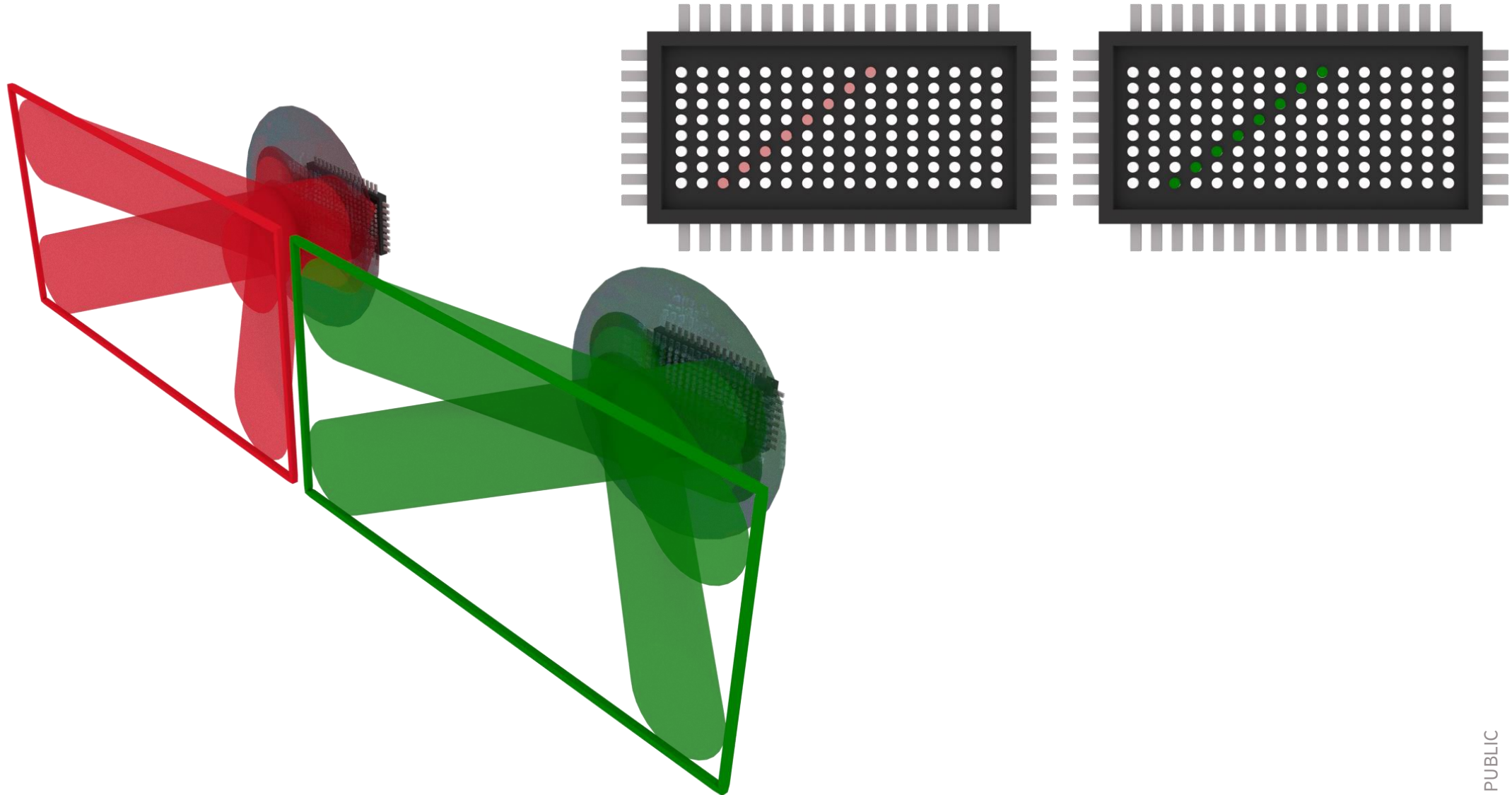
SOLID-STATE SCANNING



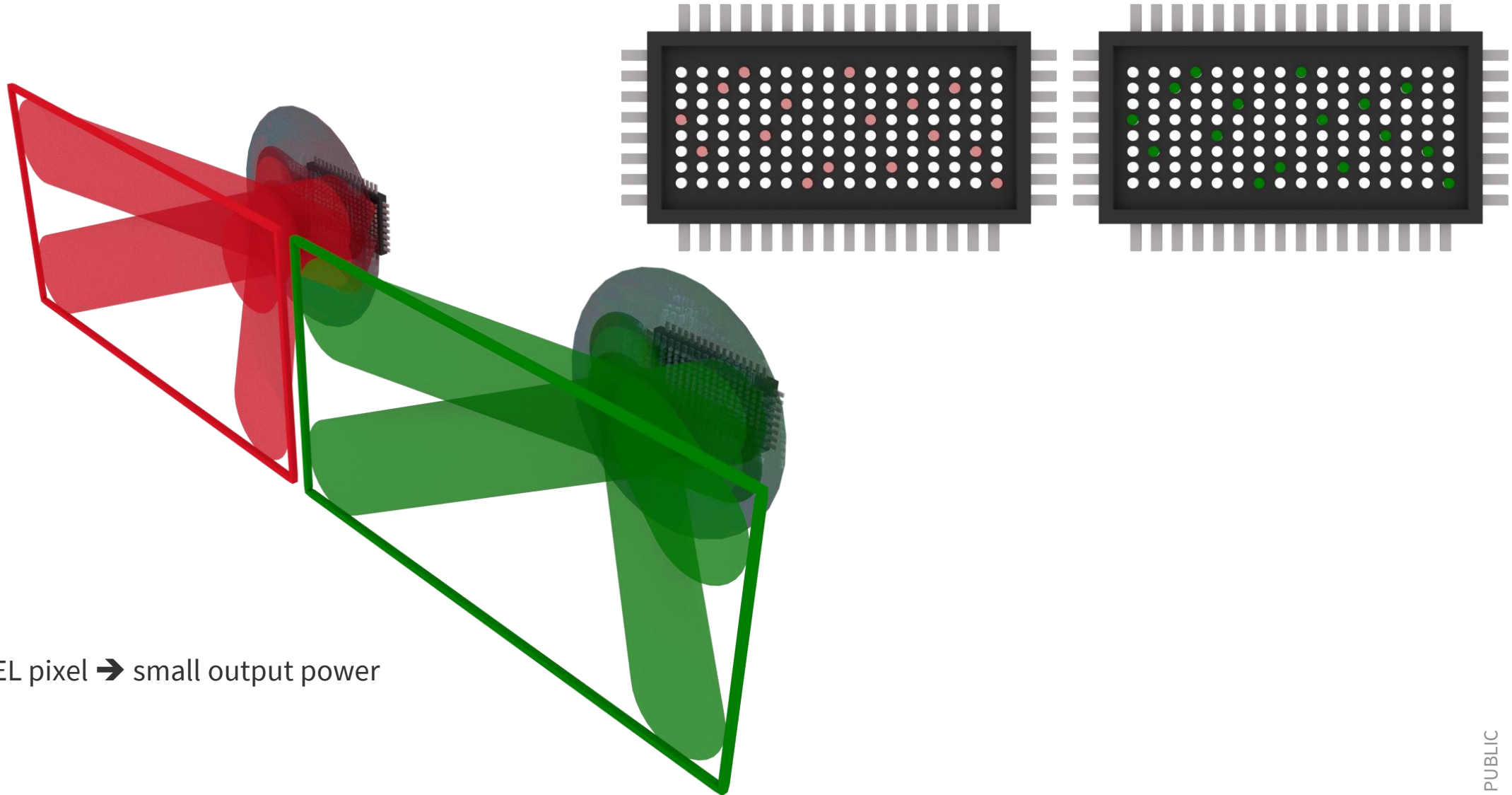
SOLID-STATE SCANNING



SOLID-STATE SCANNING



SOLID-STATE SCANNING



small VCSEL pixel → small output power

SINGLE PHOTON AVALANCHE DIODE (SPAD)

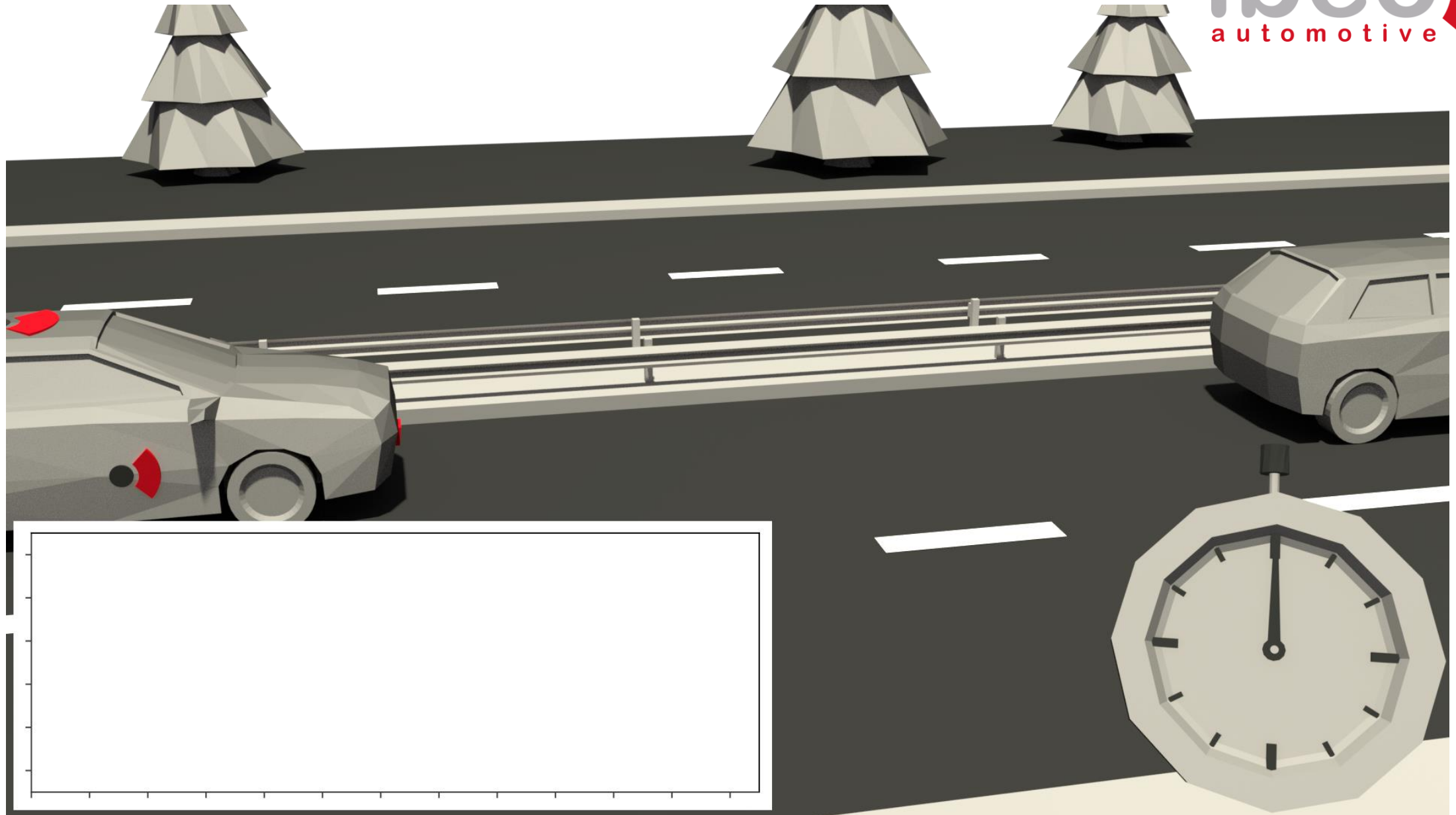


small VCSEL pixel → small output power

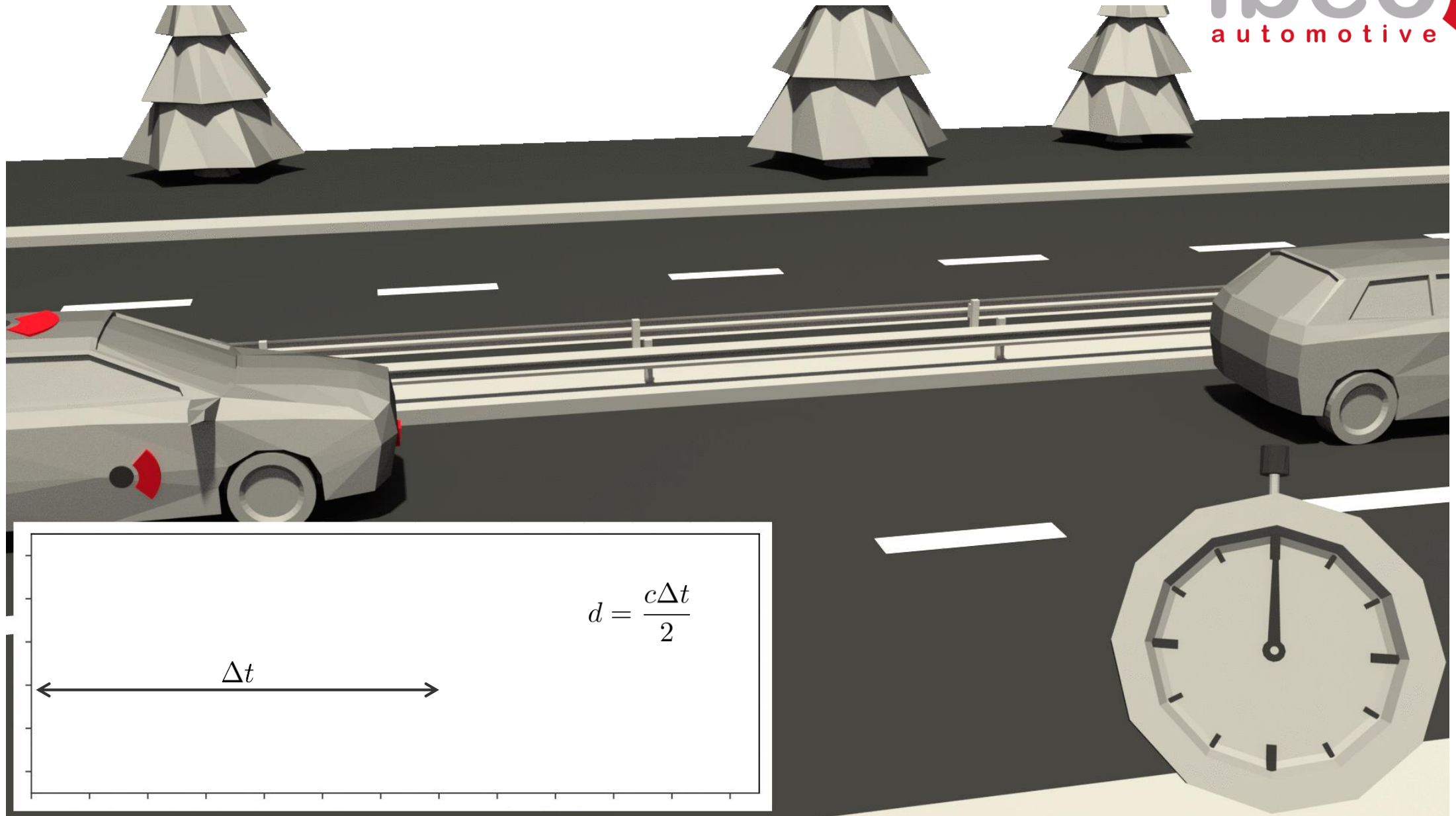
→ utilize SPADs instead of linear photodetectors

→ classical time-of-flight not possible

CLASSICAL TIME-OF-FLIGHT



CLASSICAL TIME-OF-FLIGHT



small VCSEL pixel → small output power

→ utilize SPADs instead of linear photodetectors

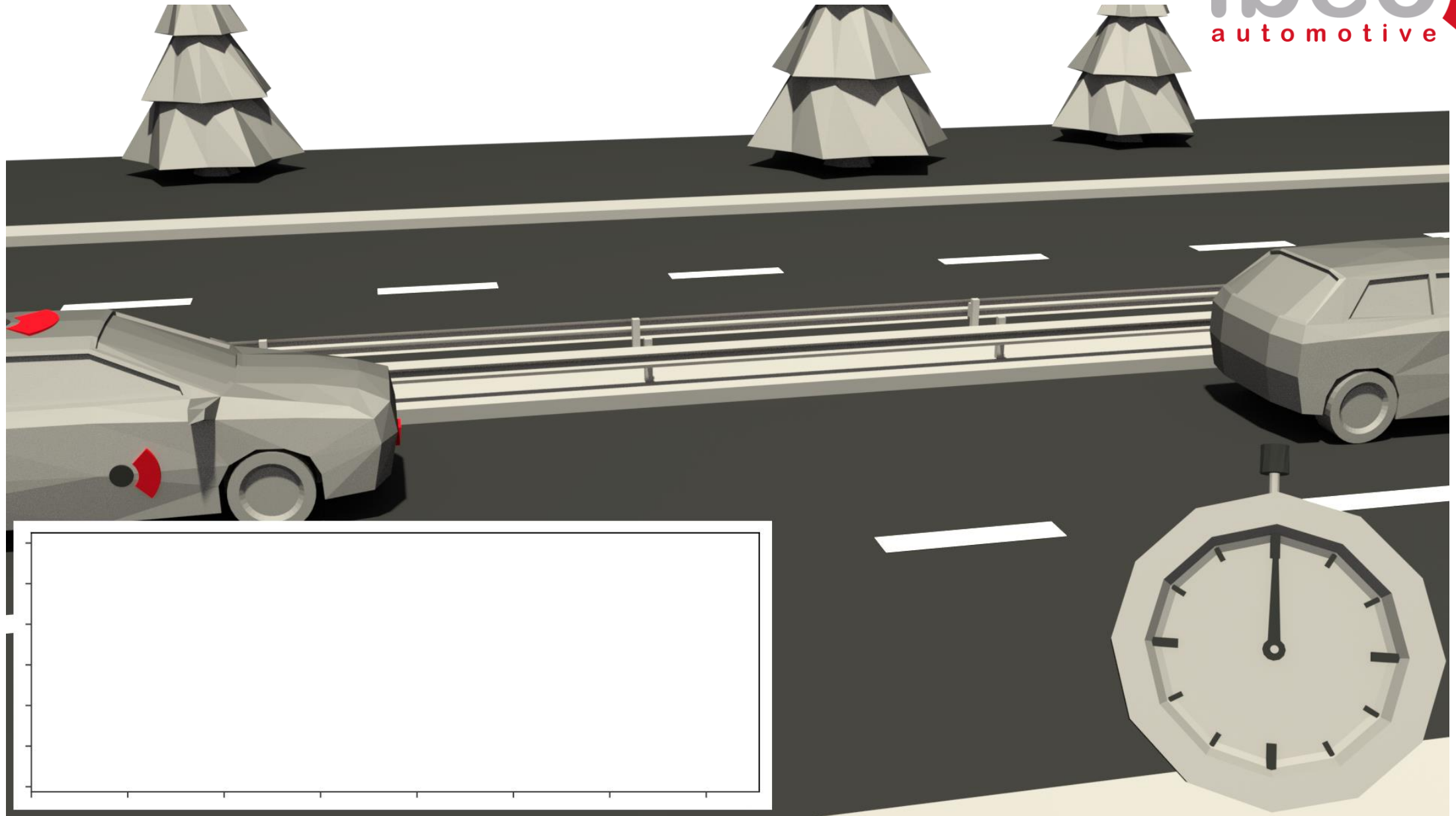
→ classical time-of-flight not possible

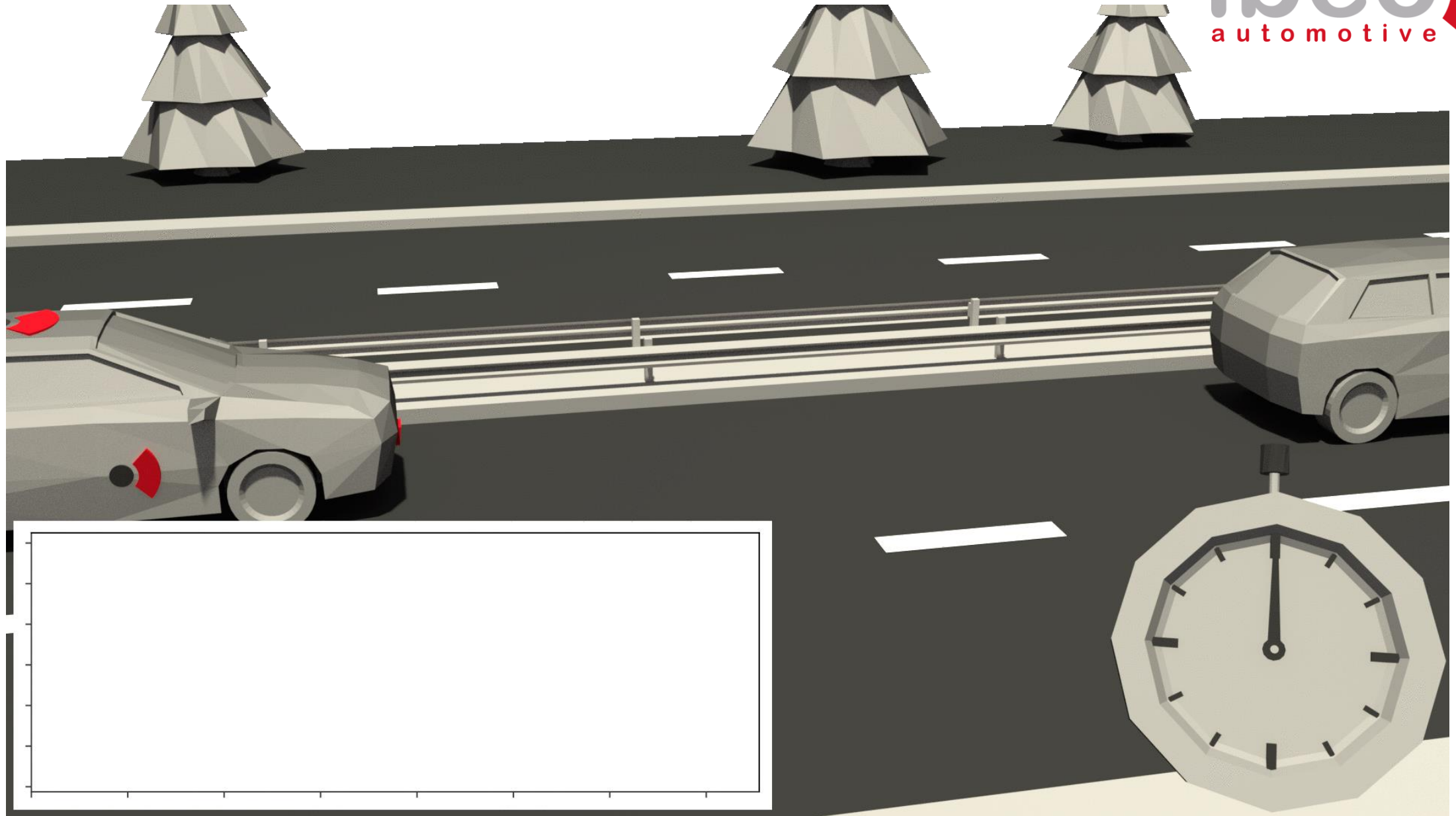
single-photon avalanche diodes (SPADs)

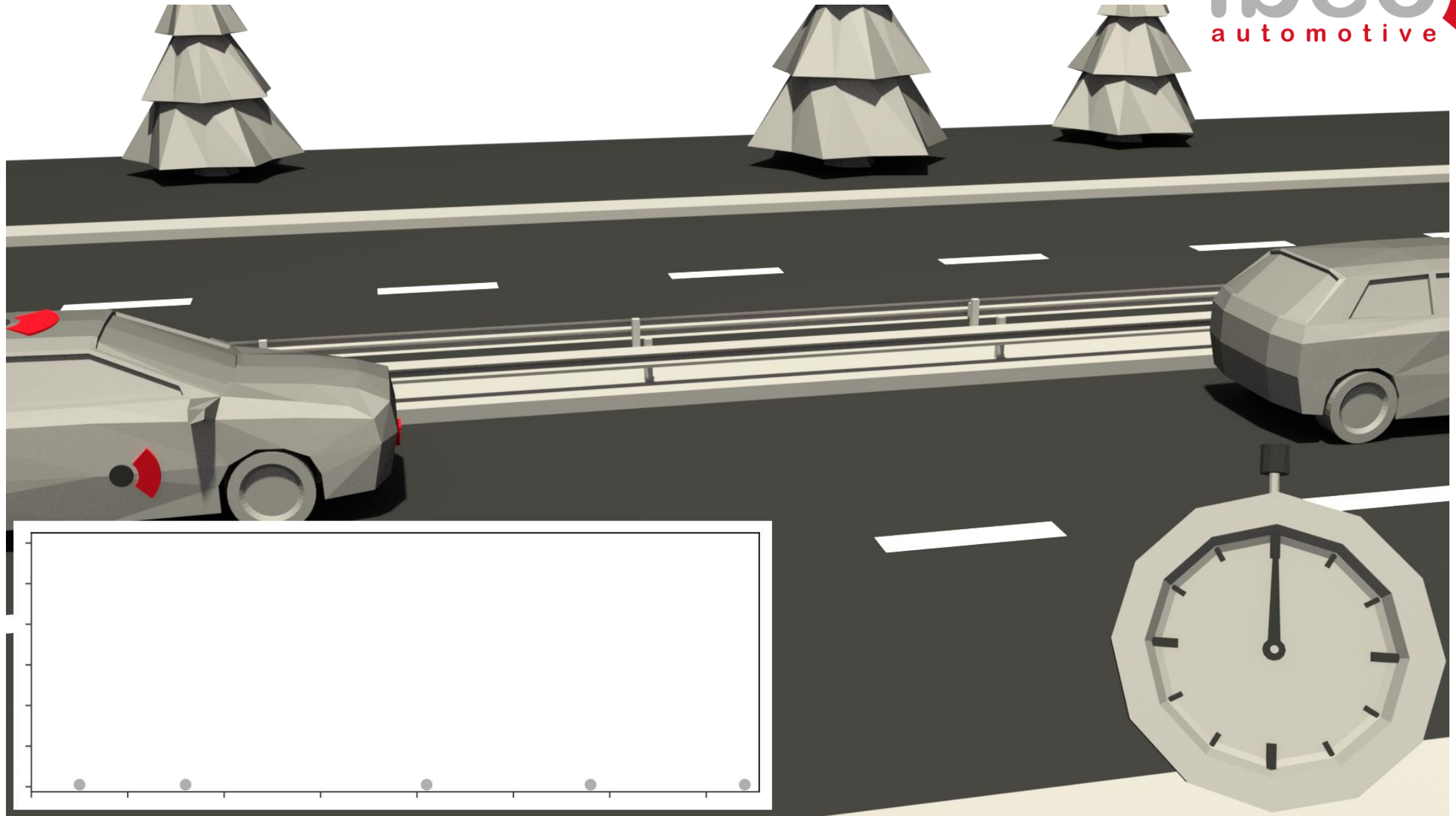
→ binary detection, i.e. trigger devices
(what is signal/noise?)

→ repeat measurements (build histograms)

→ time-correlated single-photon counting (TCSPC)
with new DSP possibilities in the automotive market

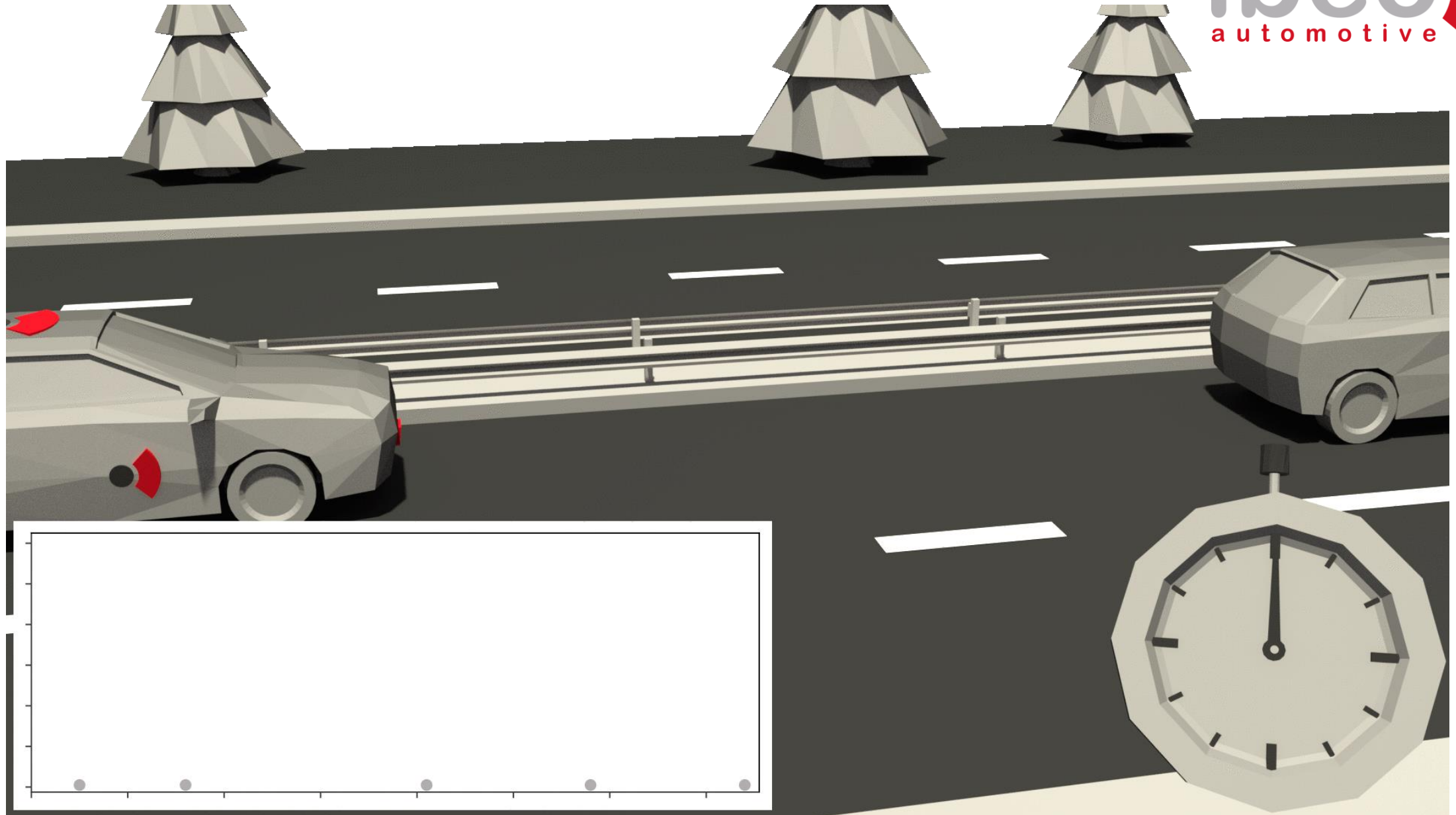


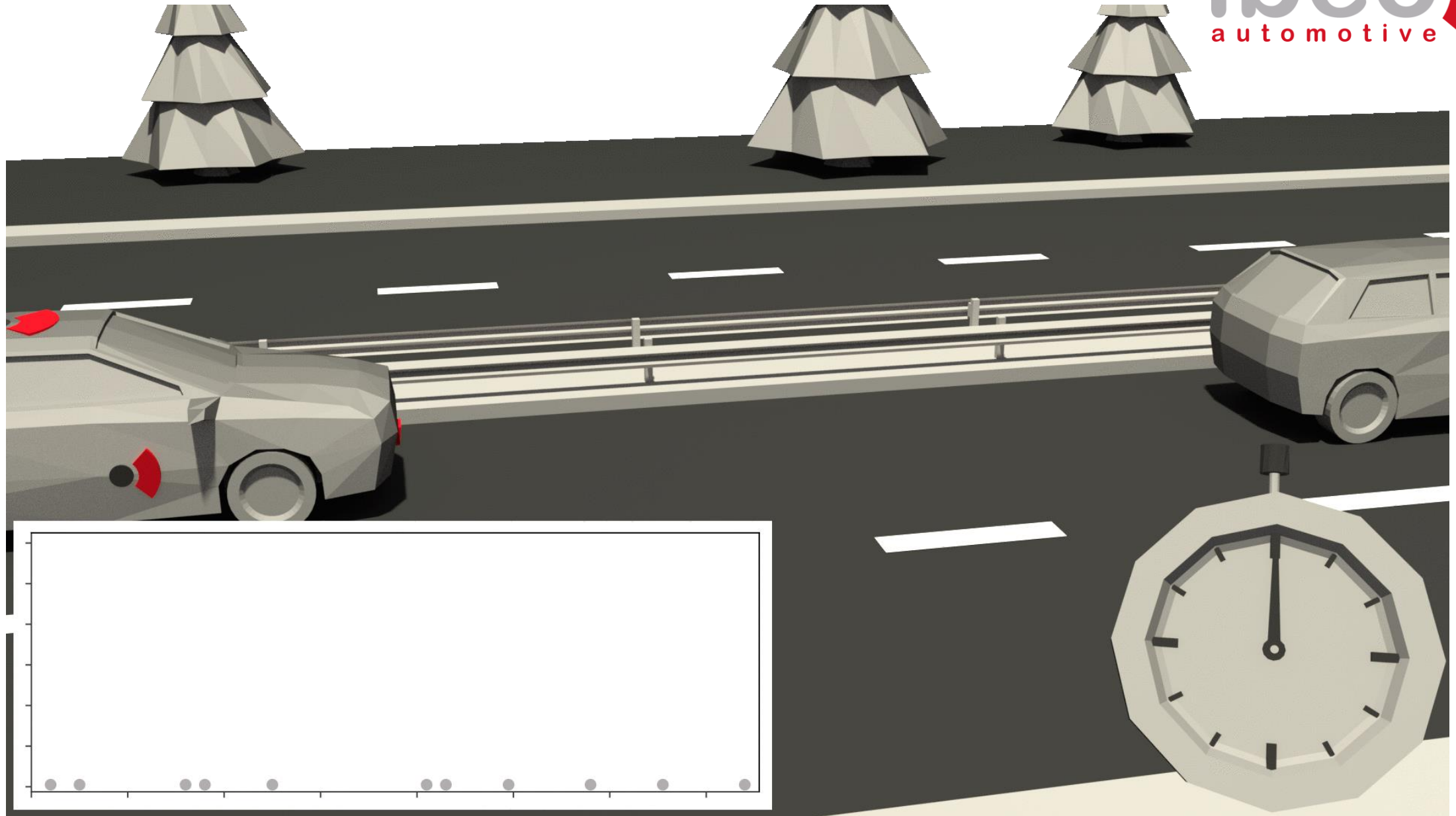


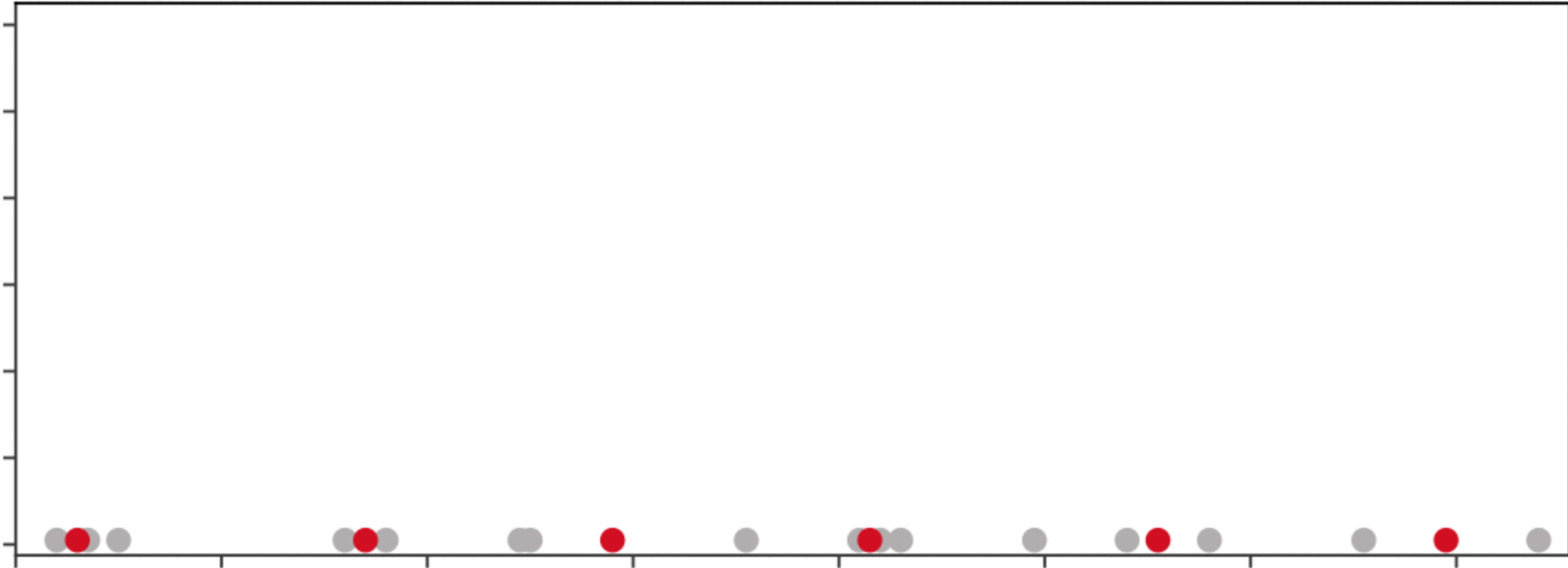


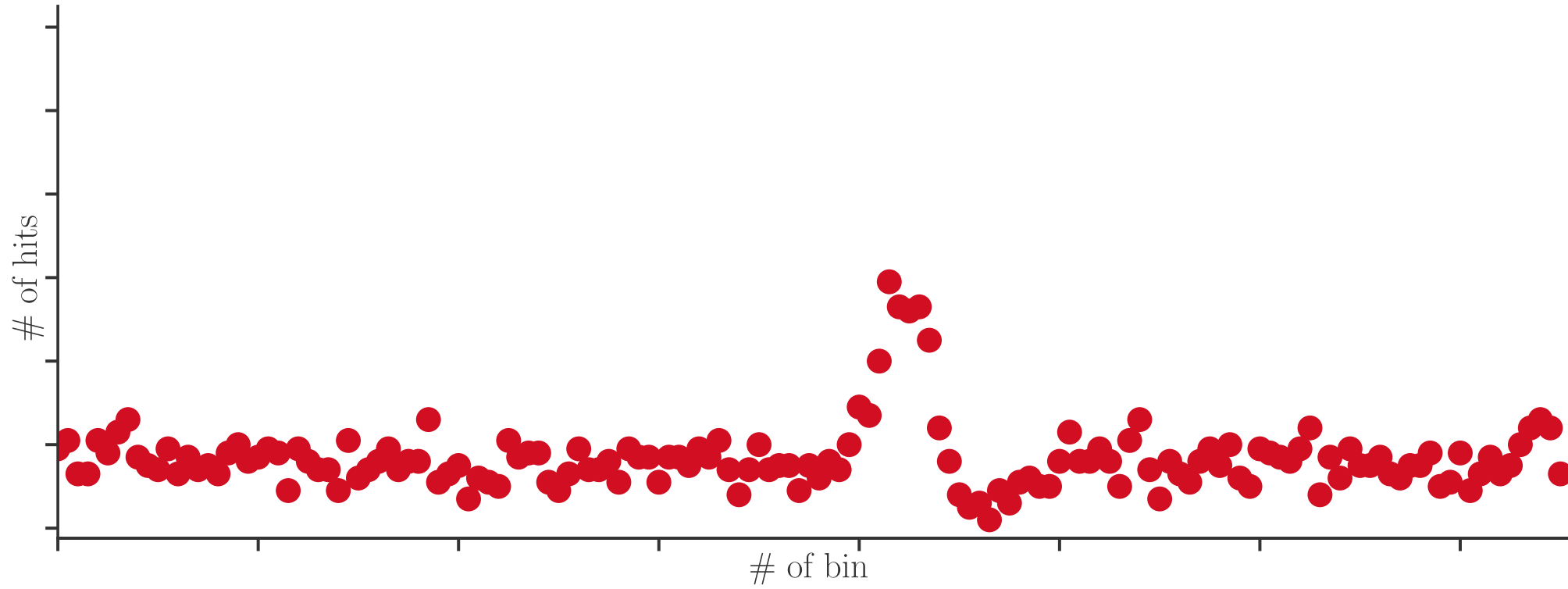
TCSPC

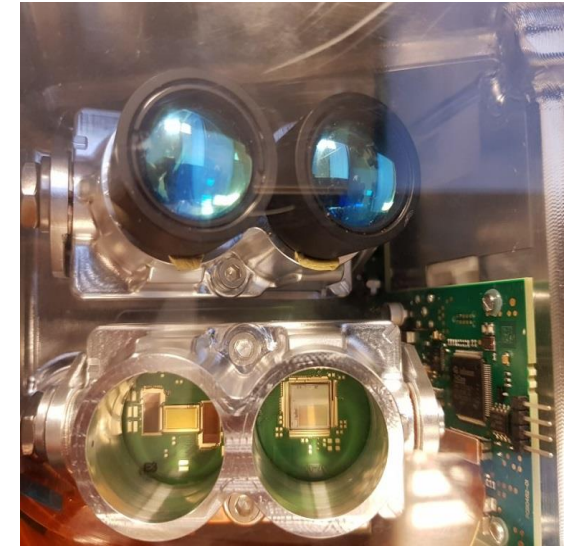
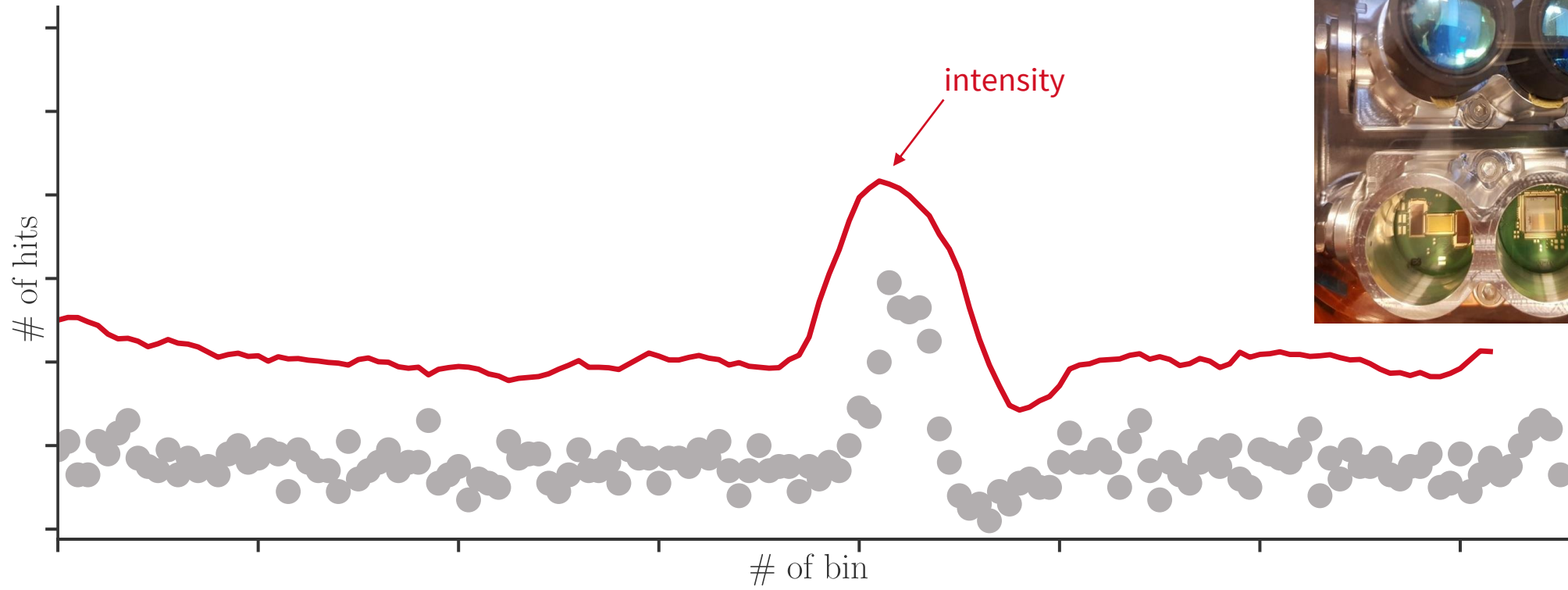
ibeo
automotive

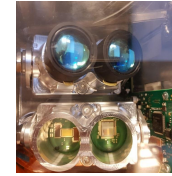












rvizConfig_2019_05_08.rviz* - RViz

File Panels Help

Interact Move Camera Select Focus Camera Measure 2D Pose Estimate 2D Nav Goal Publish Point

Displays

- Selectable
- Style Flat Squares
- Size (m) 0,15
- Alpha 1
- Decay Time 0
- Position Transformer XYZ
- Color Transformer Intensity
- Channel Name Intensity
- Use rainbow
- Min Color 0; 0; 0
- Max Color 255; 255;
- Autocompute Intensity Bounds
- Min Intensity 5
- Max Intensity 30

LdmiA2ImageDisplay

Add Duplicate Remove Rename

LdmiA2ImageDisplay

Views

Type: XYOrbit (rviz) Zero

Current View XYOrbit (rviz)	
Near Clip Distance	0,01
Invert Z Axis	<input type="checkbox"/>
Target Frame	ego_vehicle
Distance	34,5545
Focal Shape Size	0,05
Focal Shape Fixed ...	<input checked="" type="checkbox"/>
Yaw	2,56273
Pitch	0,0247966
Focal Point	6.2326; 5.5009; 6.9145e-05

Save Remove Rename

LdmiA2ImageDisplay

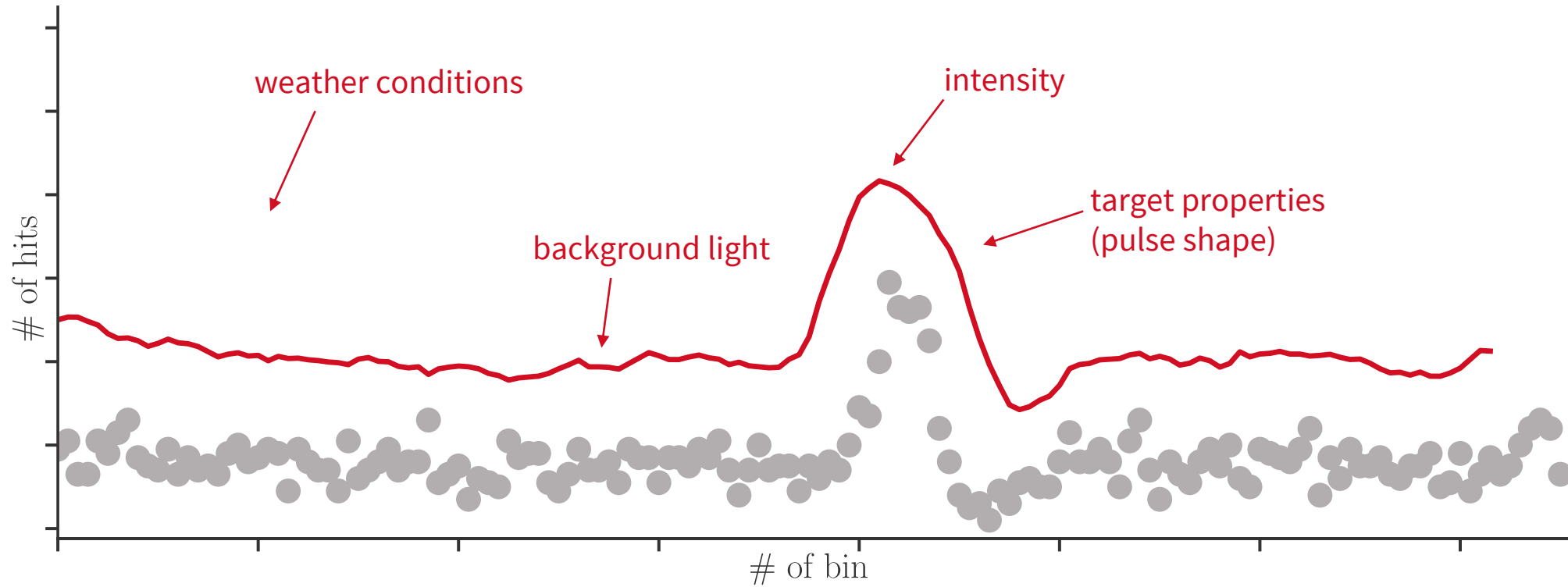
Time

ROS Time: 1557329552.83 ROS Elapsed: 5198.30 Wall Time: 1557329552.86 Wall Elapsed: 5198.30

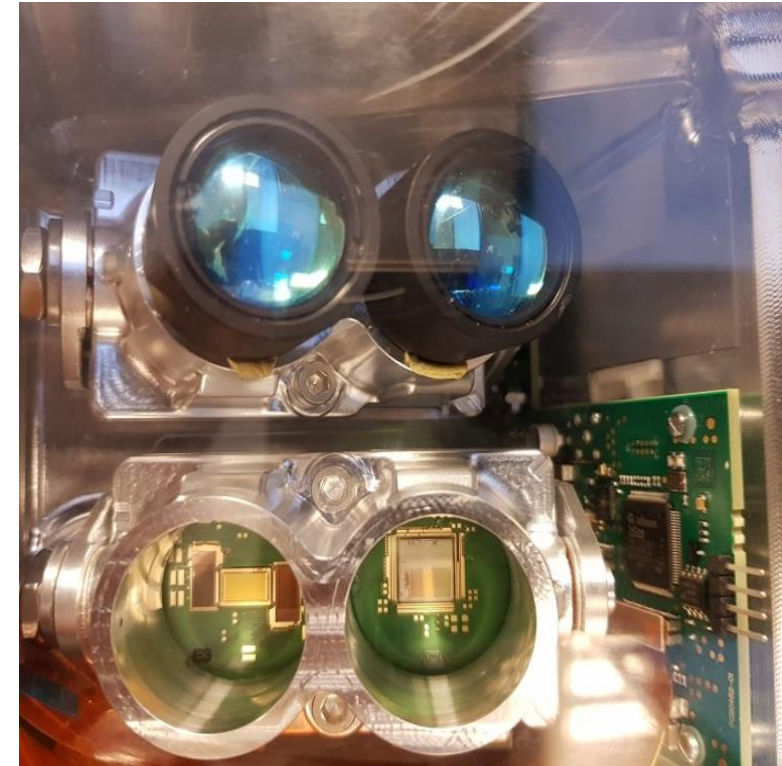
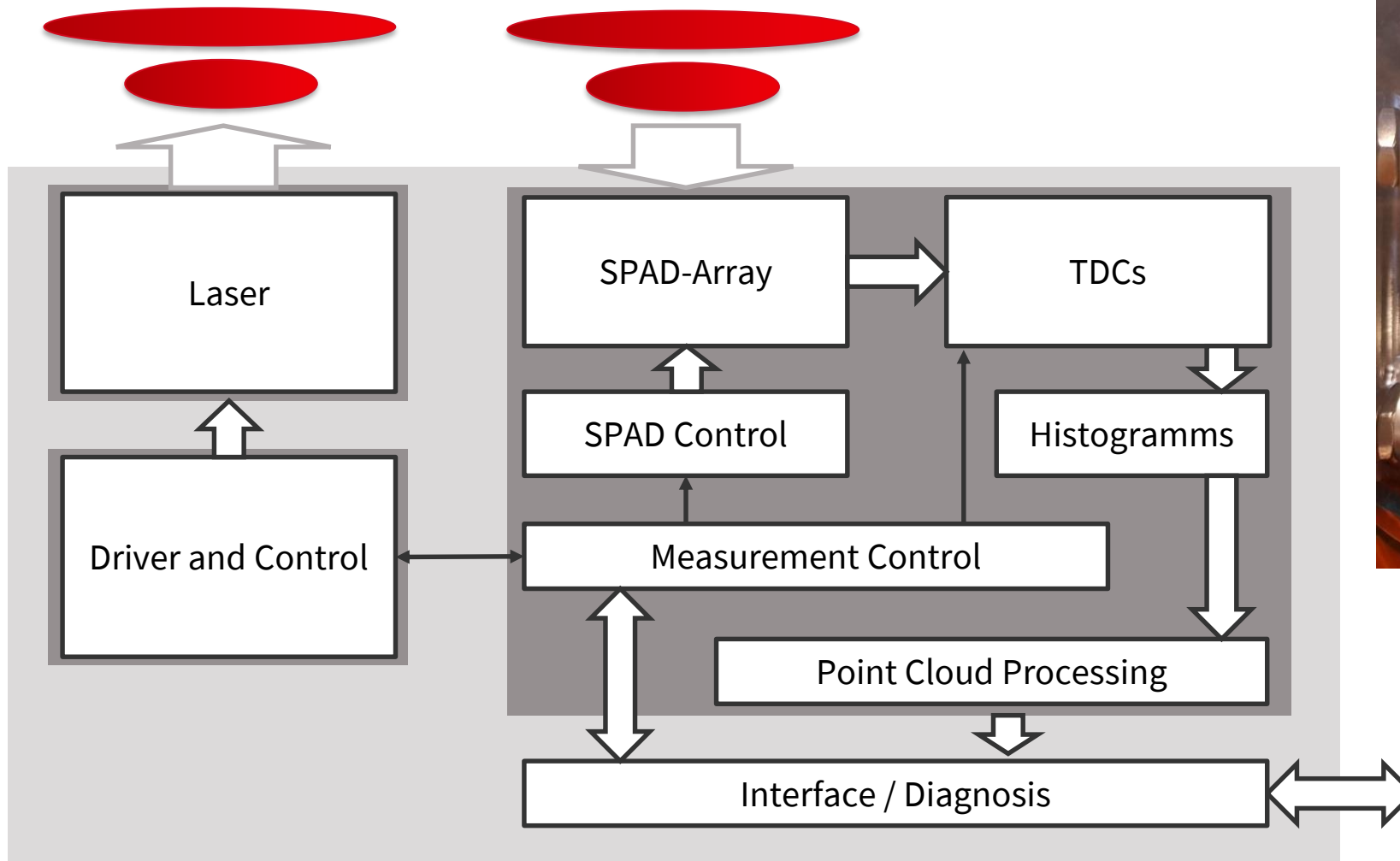
Reset

Experimental

31 fps



SUMMARY



SUMMARY

Why it's hard to build a solid-state LiDAR

Requirements are tough

solid-state
high resolution

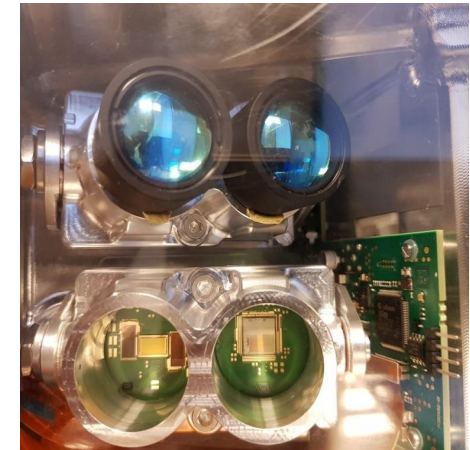
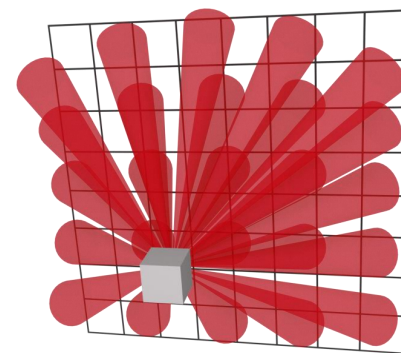
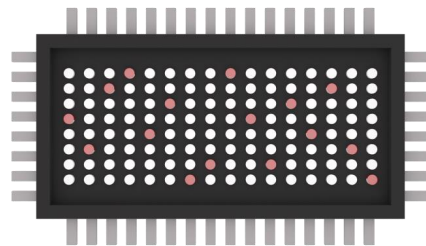
wide FOV
long range

frame rate
fast

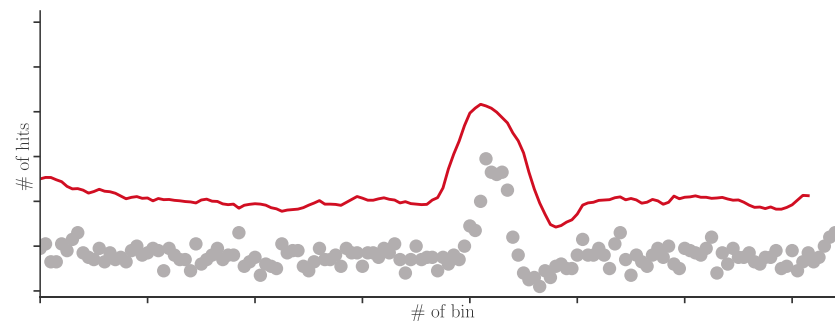
cost efficient and
automotive qualified

One way to do it

Truly solid-state LiDAR



Allows for advanced signal processing



Hanno Holzhüter
Sensor Development

Ibeo Automotive Systems GmbH
Merkurring 60-62
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Web: www.ibeo-as.com



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