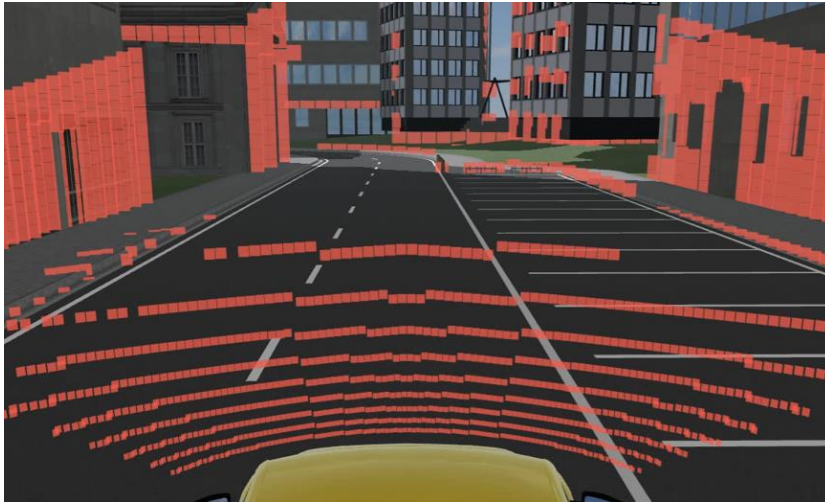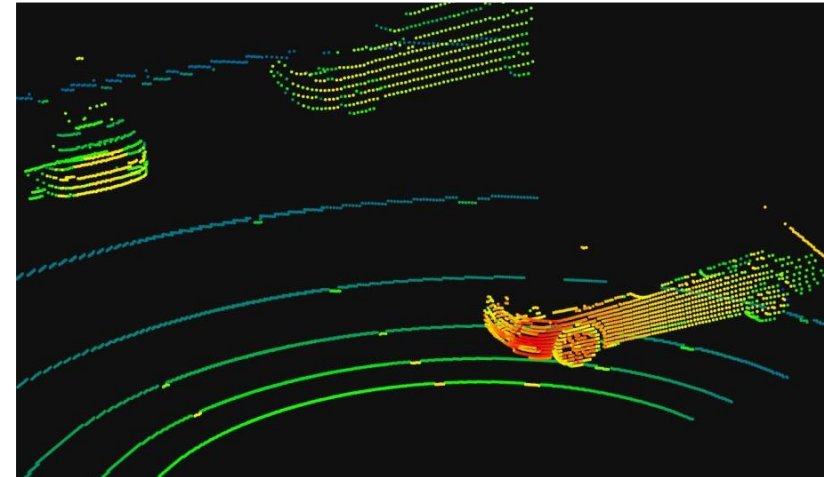**IVAN STEPANOV, CDV-E-SIM**

SYNTHETIC LIDAR DATA GENERATION USING CARMAKER FREE SPACE SENSOR PLUS

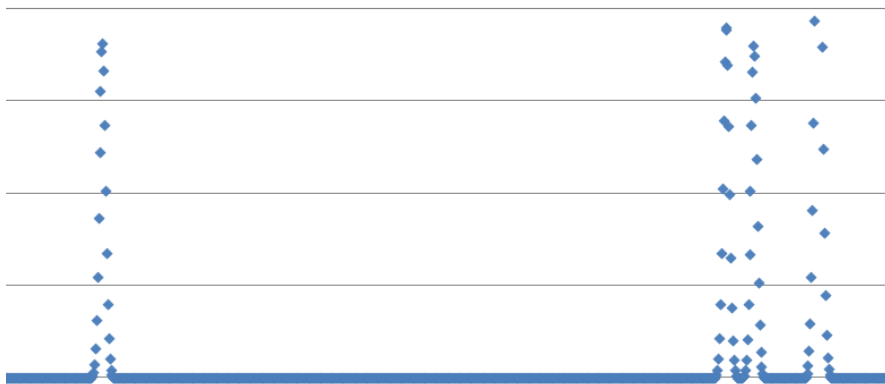# OUTLINE

CarMaker Free Space Sensor Plus

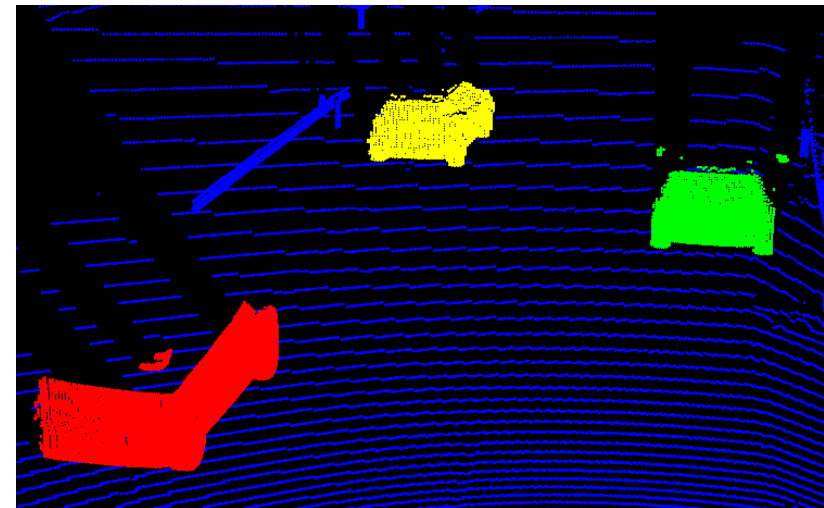## Light Intensity Calculation

Optical and electrical effects

Semantic segmentation
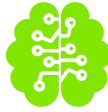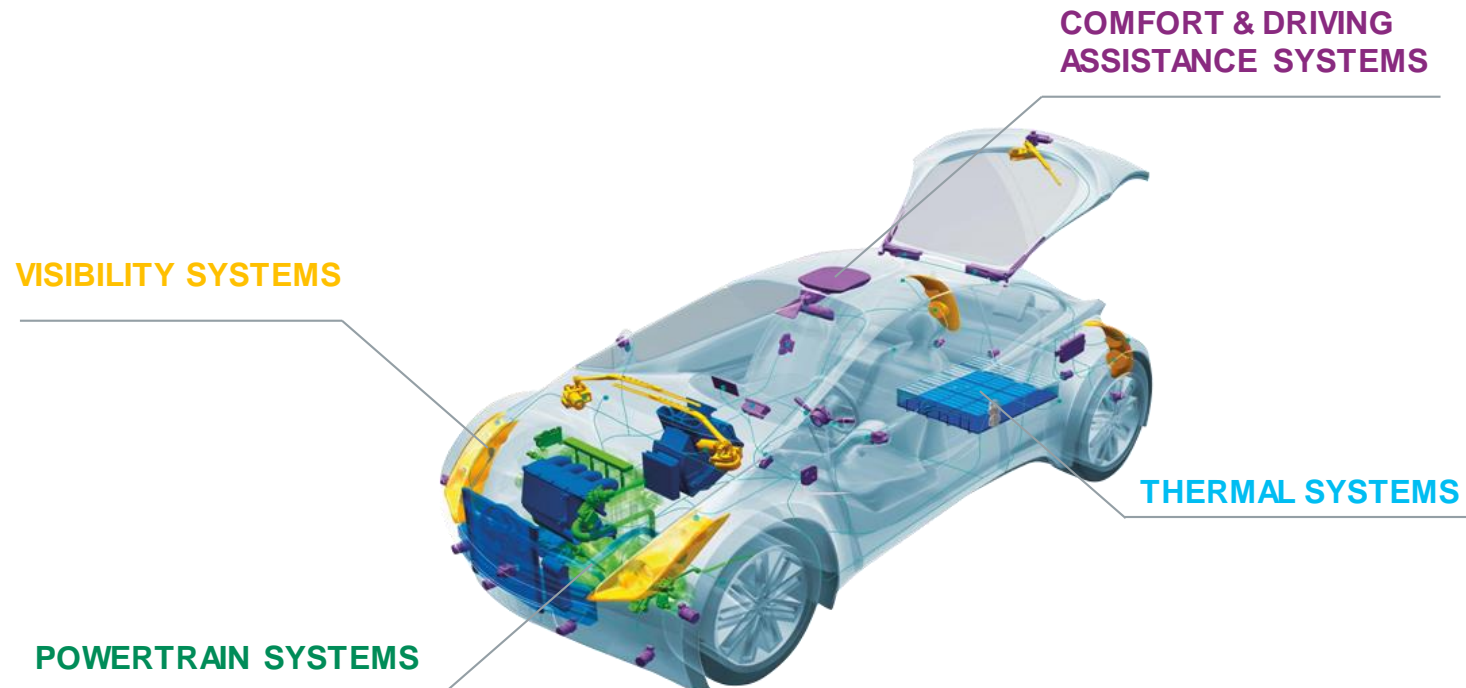
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VALEO IN OVERVIEW

114,700
EMPLOYEES

19,990
PEOPLE IN R&D

140
NATIONALITIES

BUSINESS GROUPS

COMFORT & DRIVING ASSISTANCE SYSTEMS

VISIBILITY SYSTEMS

THERMAL SYSTEMS

POWERTRAIN SYSTEMS

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CDA SITE BIETIGHEIM, KEY PRODUCTS

Park4U®

AUTOMATED PARKING SYSTEMS

ADAS & ACTIVE SAFETY SYSTEMS

AUTOMATED DRIVING SYSTEMS

Cruise4U

Drive4U®

RAIN-LIGHT HUMIDITY SENSOR

ULTRASONIC SENSORS

VIEWING CAMERA

FRONT CAMERA

RADAR SENSOR

LASER SCANNER

FUSION CONTROLLERS

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MOTIVATION

Why do we want to generate synthetic LiDAR data?

➢ Virtual validation: save costs performing test driving in simulation

➢ Large quantities of annotated data for neural network training

➢ Generate data for very specific or dangerous scenarios not available in real data

➢ Support development of new sensors or algoirthms

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Output values:

➢ Distance
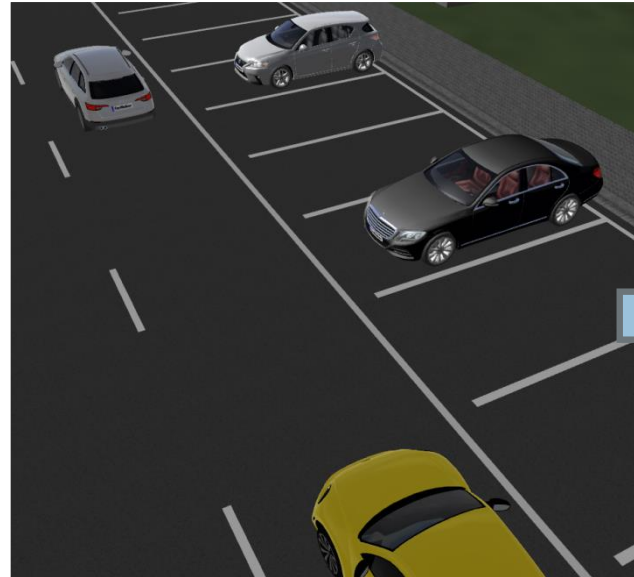➢ Material ID
➢ Object ID
➢ Incidence angle

Limitations:

➢ No intensity calculation
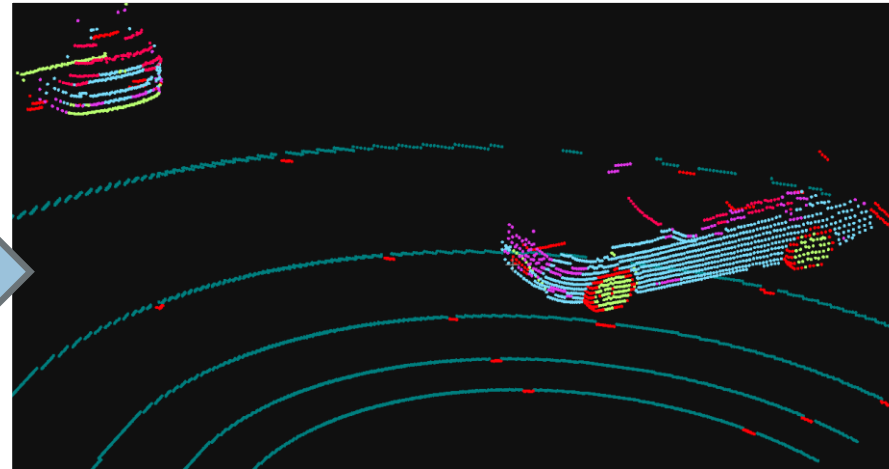➢ No time-resolved wave-form
➢ No optics simulation

FSS+ provides a very good basis for complex sensor simulation
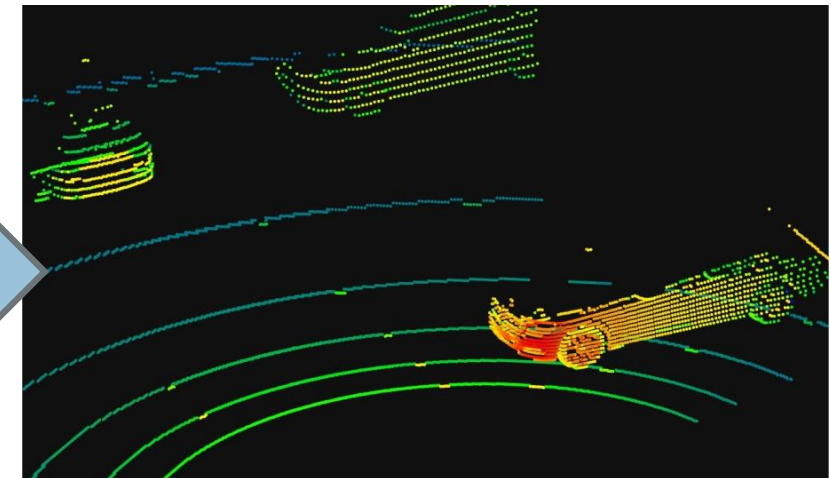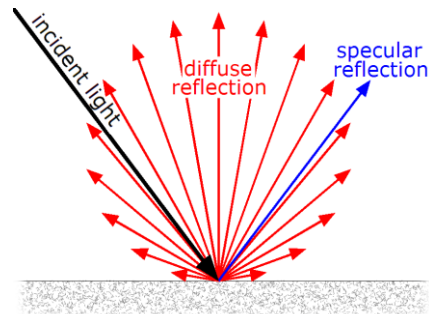
RETURN SIGNAL INTENSITY CALCULATION
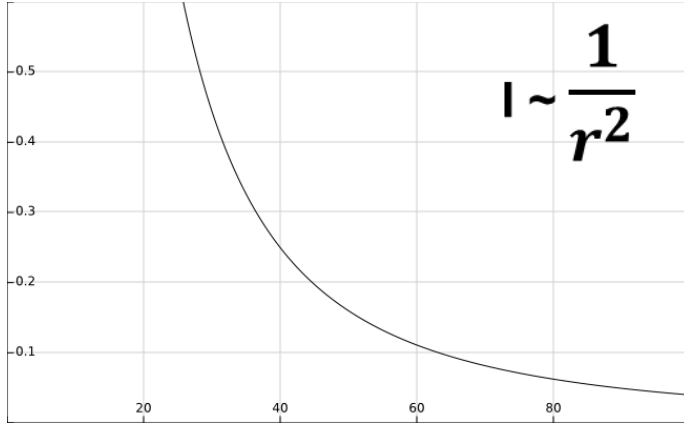

Scene

Distance

+

Material ID

+

Incidence angle

incident light

diffuse reflection

specular reflection

Intensity

RETURN SIGNAL INTENSITY CALCULATION

Distance

$$I \sim \frac{1}{r^2}$$

Material Library

Material name	Material ID	Kdiff	Kspec	Nspec
asphalt	5	0.5	0.1	5
car_paint_1	18	0.9	0.5	20

Incidence angle

Normal line

Angle of incidence

Incident ray
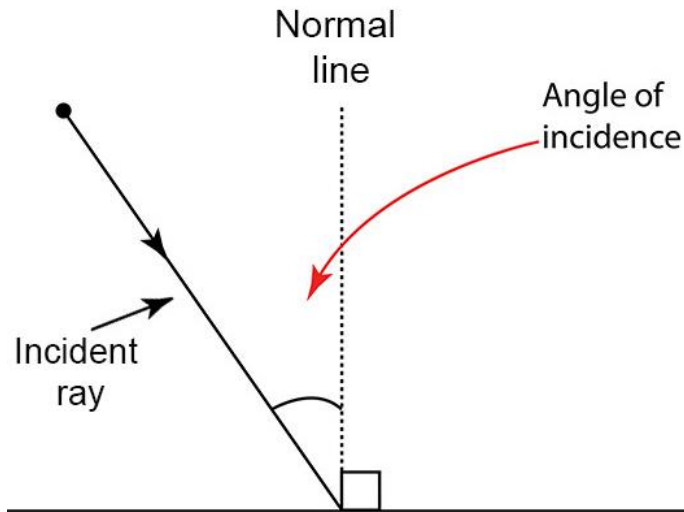
Intensity by Blinn-Phong or BRDF

specular

diffuse

θ[°]

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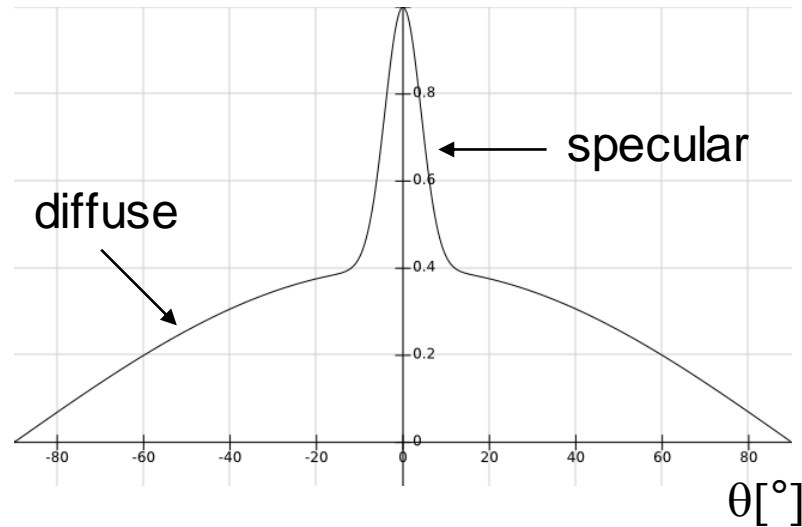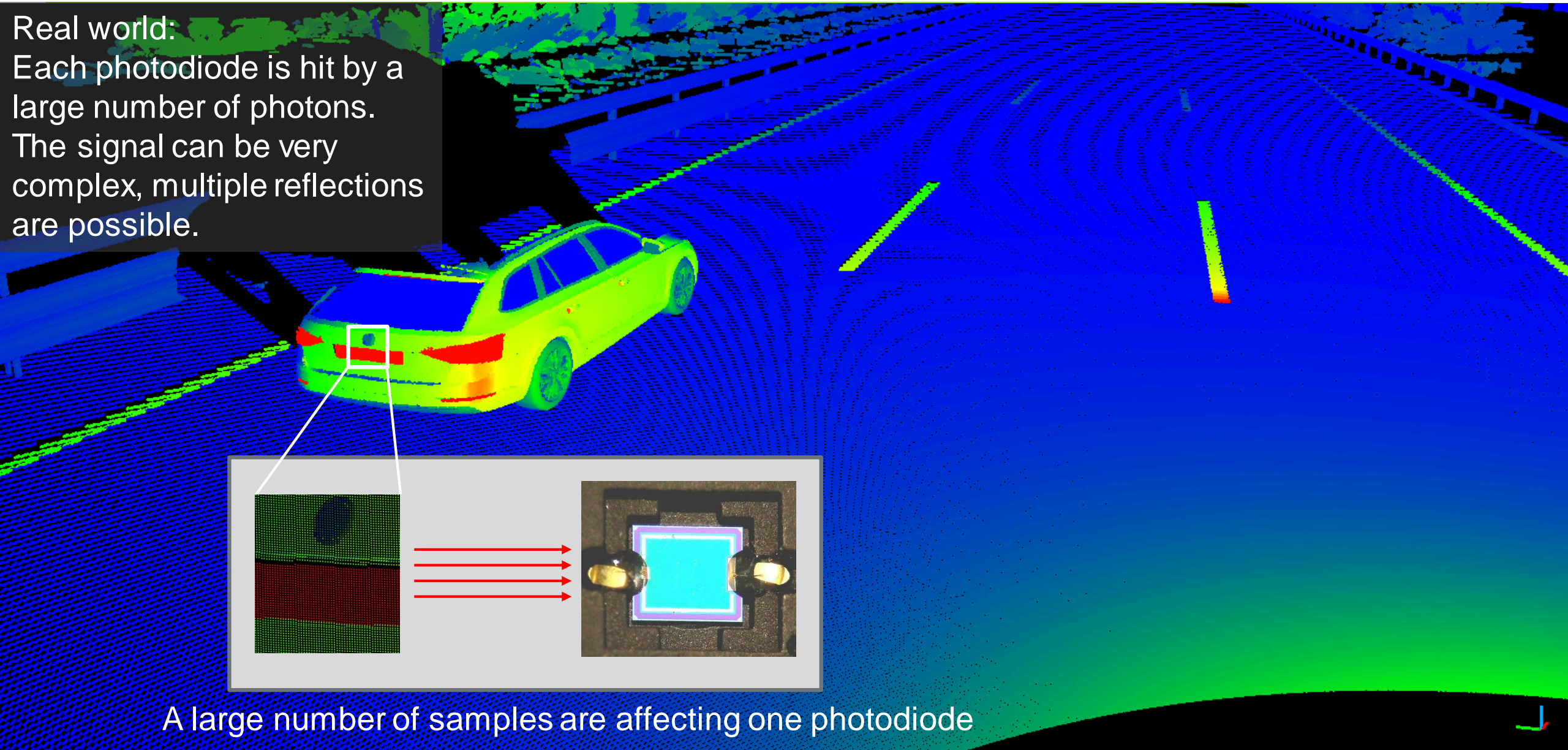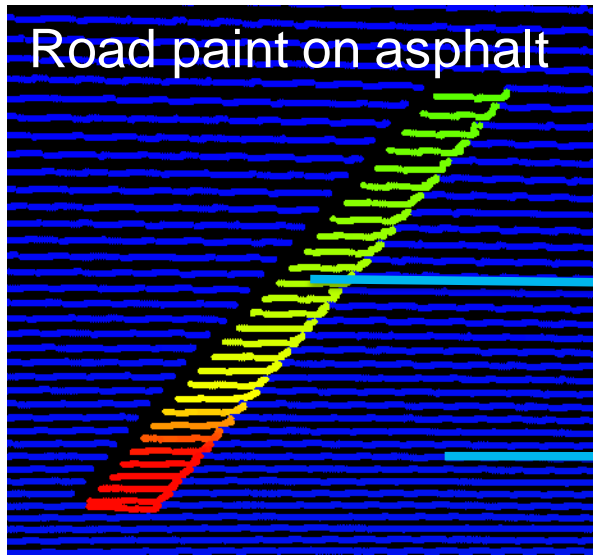
HIGH-RESOLUTION INTENSITY MAP

Real world:
Each photodiode is hit by a large number of photons.
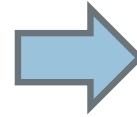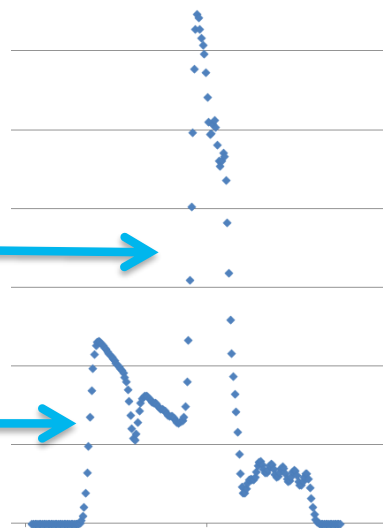The signal can be very complex, multiple reflections are possible.

A large number of samples are affecting one photodiode
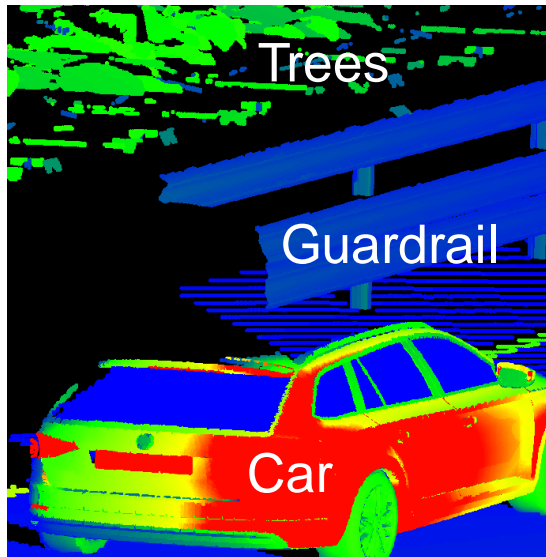
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TIME-RESOLVED WAVEFORM SIGNAL

Road paint on asphalt

Complex waveform

Apply noise
Apply threshold
Get object distance
Get peak positions

Trees

Guardrail

Car

Multiple reflections

Car

Guardrail

Trees

ILLUMINATION AND SENSITIVITY PROFILES

High-resolution intensity-map

Laser illumination profile

Photodiode sensitivity profile

Photodiode sensitivity profile:

Bell-shaped

Gauss-shaped
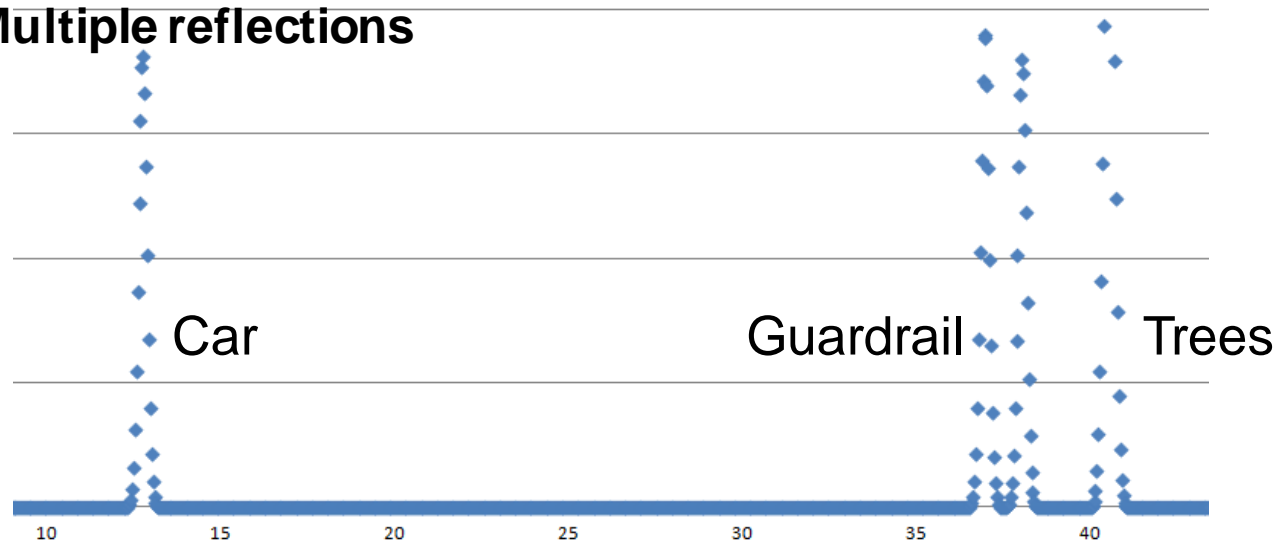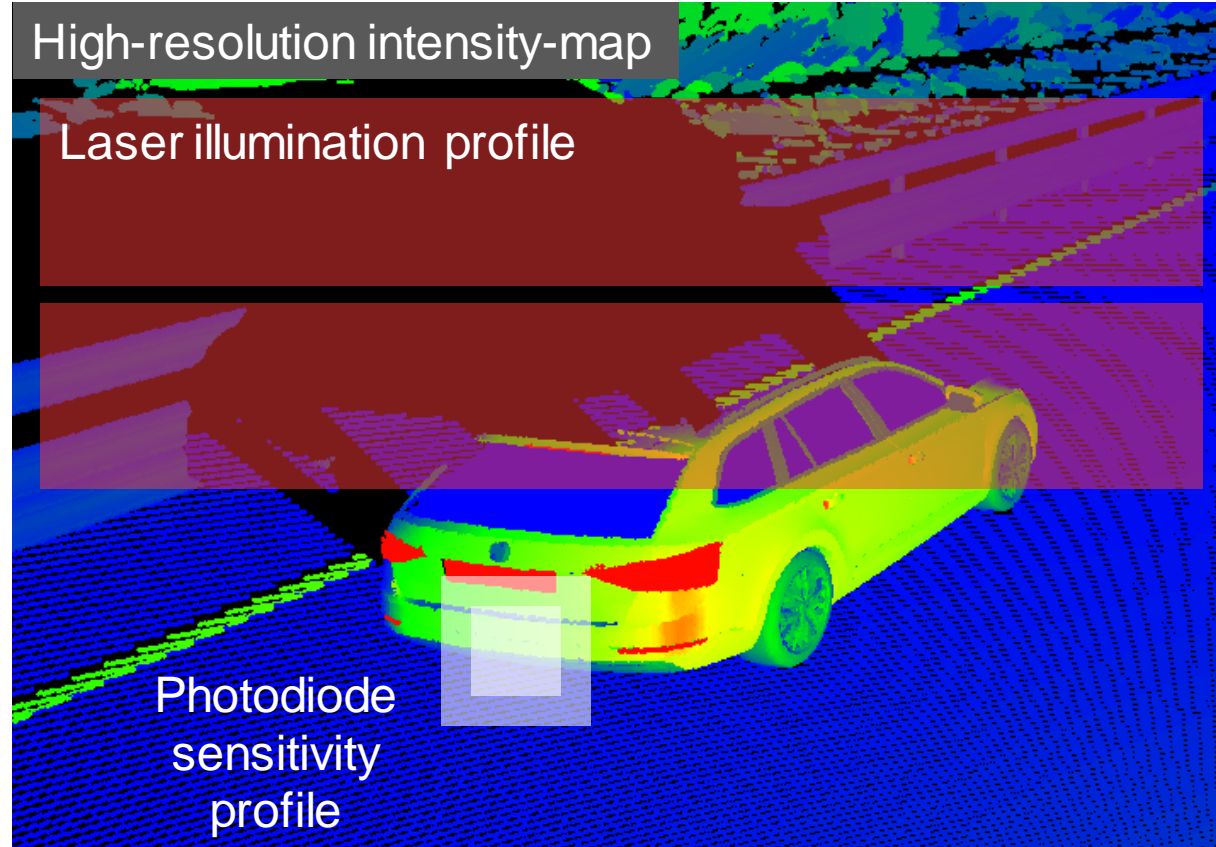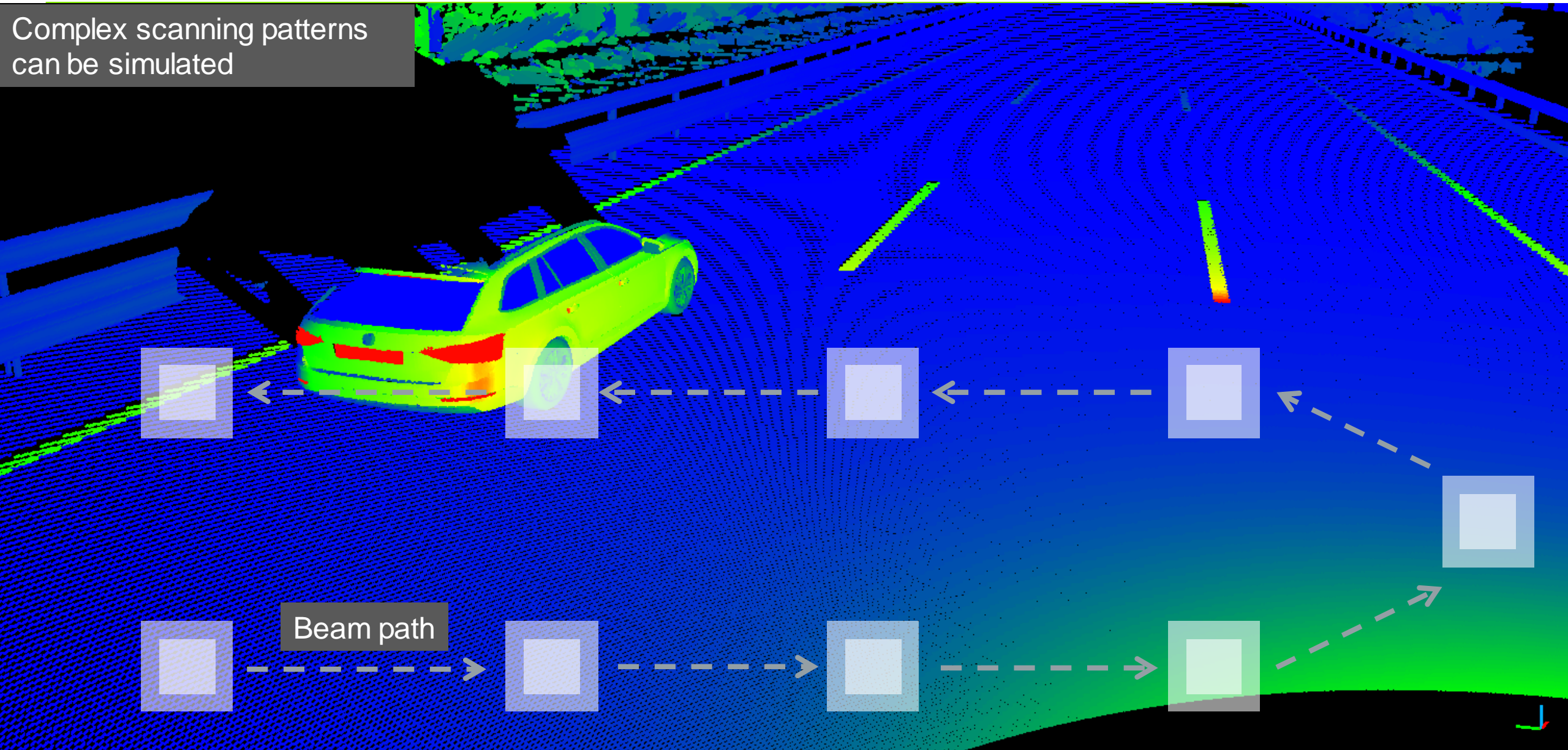
angle
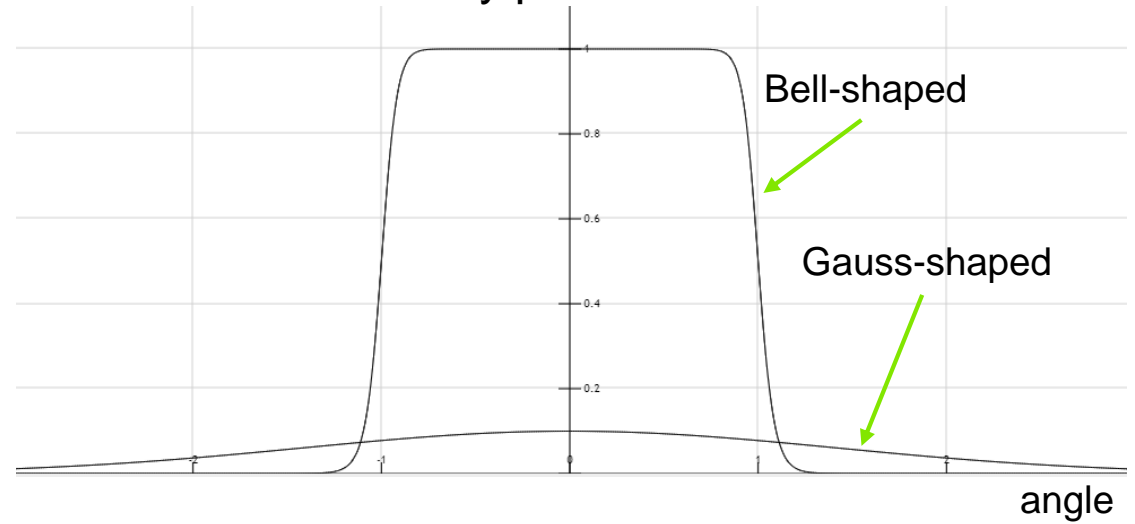
Blooming-like effects:

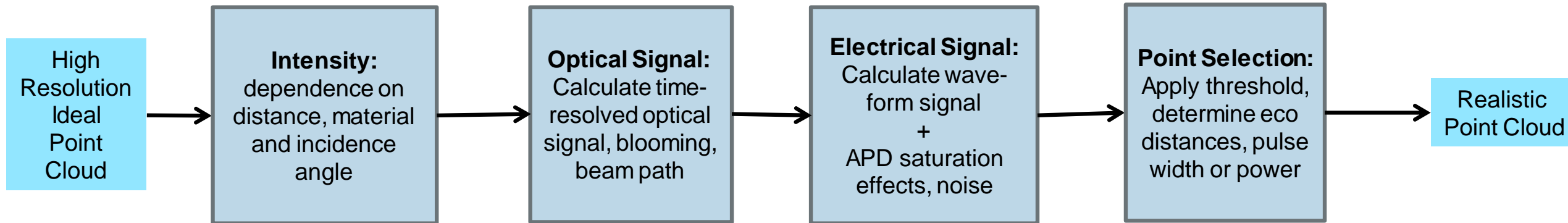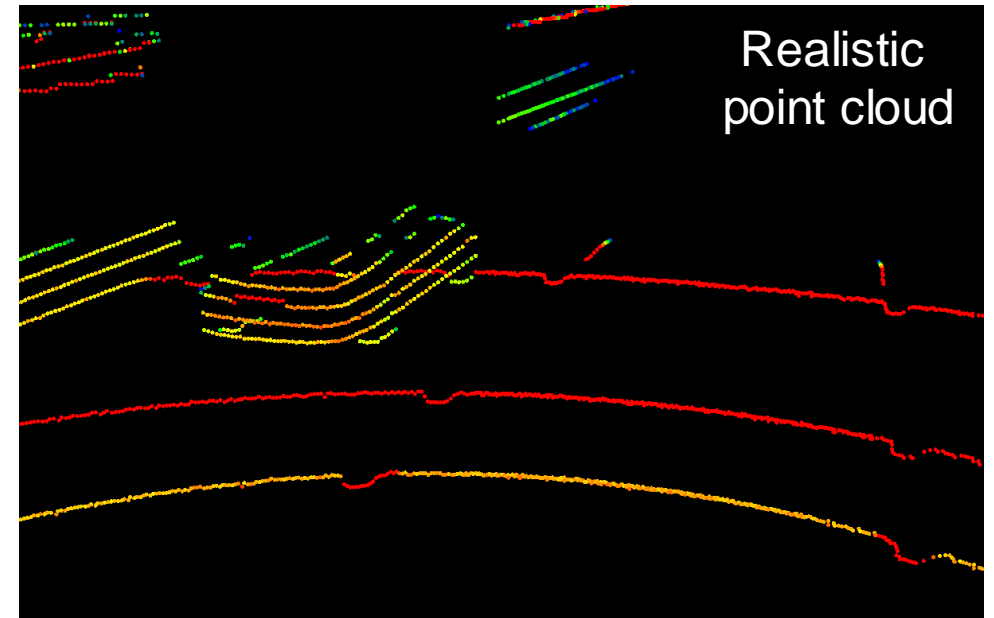A photodiode can be affected by a traffic sign outside of ist main FOV

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BEAM PATH

Complex scanning patterns can be simulated

Beam path

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SENSOR MODEL FLOW DIAGRAM

High resolution Ideal point cloud

Realistic point cloud

| High Resolution Ideal Point Cloud | → | **Intensity:** dependence on distance, material and incidence angle | → | **Optical Signal:** Calculate time-resolved optical signal, blooming, beam path | → | **Electrical Signal:** Calculate wave-form signal + APD saturation effects, noise | → | **Point Selection:** Apply threshold, determine eco distances, pulse width or power | → | Realistic Point Cloud |

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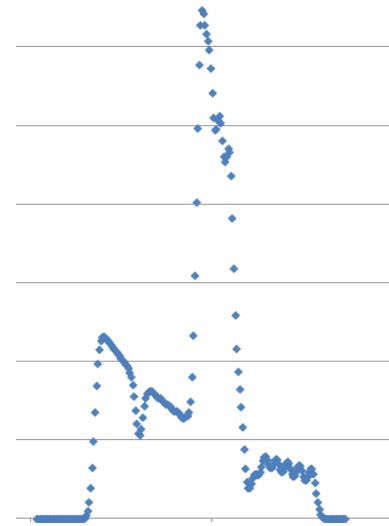
SEGMENTATION BY OBJECT ID
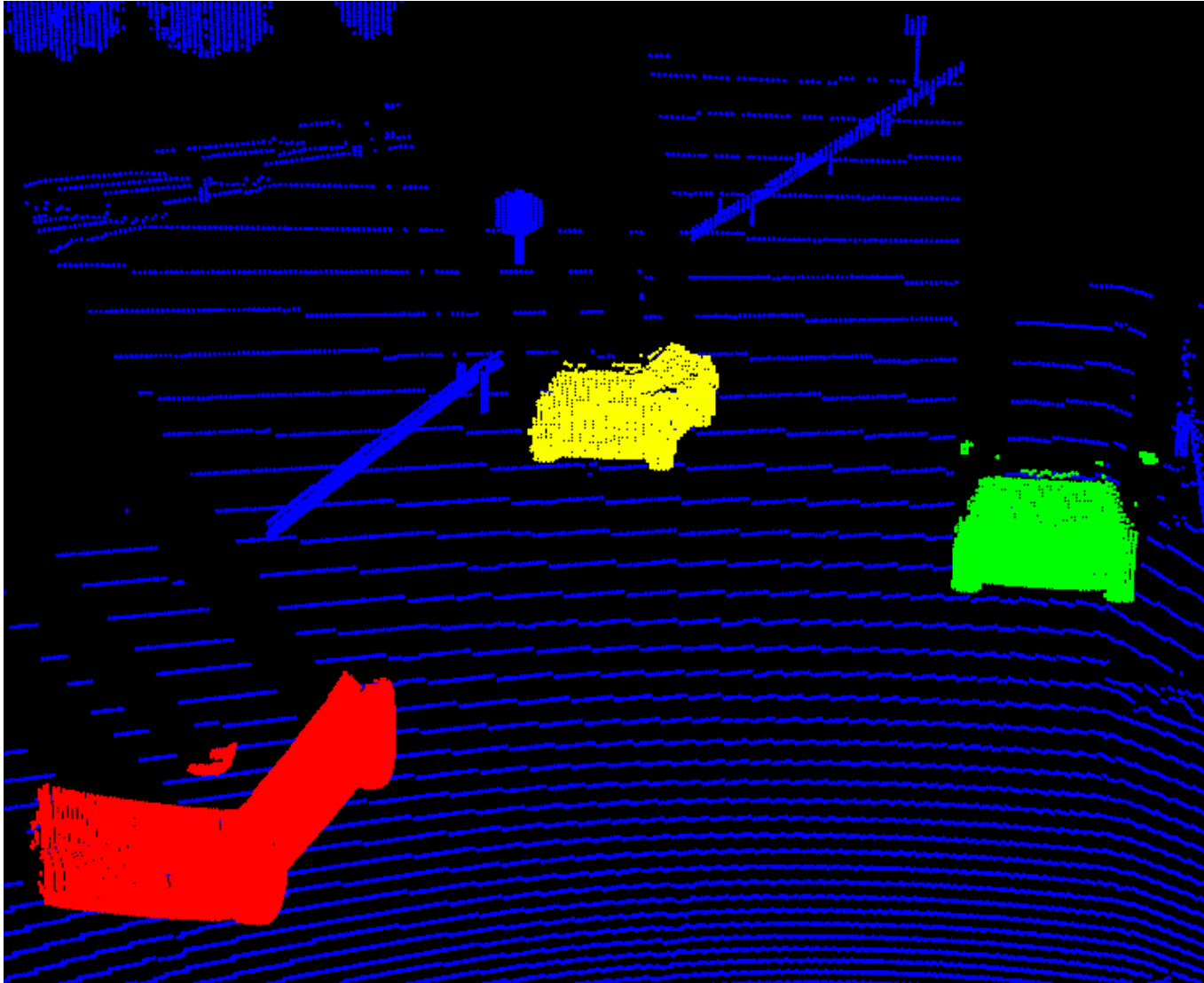
Object ID gets lost during waveform generation but can be retrieved to produce realistic segmented data.

Applications:
➤ Training of neural networks
➤ Validation of segmentation algorithms
➤ General object detection analysis

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Conclusions:
- CarMaker FSS+ provides a suitable platform for detailed LiDAR simulations
- Various effects of signal generation can be considered: waveform, illumination and sensitivity profiles, scanning patterns
- Automatic annotation is possible

Limitations:
- It is difficult to achieve real-time due to the GPU-CPU bottleneck
- No secondary reflections, no transparency

Open questions or sugestions?
- Contact me at ivan.stepanov@valeo.com

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SMART TECHNOLOGY
FOR SMARTER CARS