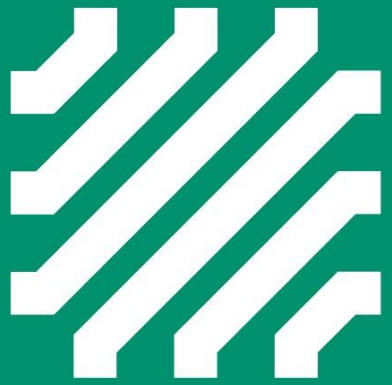

Forschungsfabrik Mikroelektronik Deutschland

Fraunhofer Group for Microelectronics in Cooperation with Leibniz Institutes FBH and IHP

Forschungsfabrik Mikroelektronik Deutschland

Solid-State LiDAR : Umgebungssensorik für sicheres autonomes Fahren

Jörg Amelung, Christoph Galle
Forschungsfabrik Mikroelektronik Deutschland

MikroSystemTechnik KONGRESS 2019

A cooperation of
Fraunhofer MIKROELEKTRONIK
Leibniz Ferdinand Braun Institut
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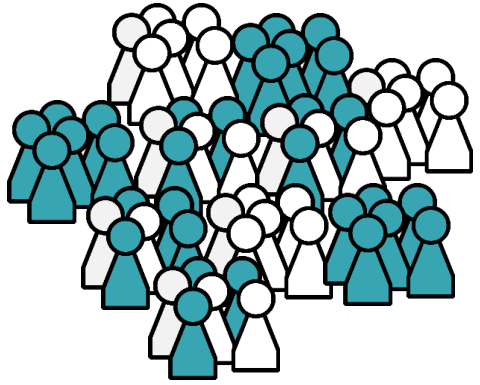
FMD Facts – A Short Overview

Forschungsfabrik Mikroelektronik Deutschland

The FMD combines the expertise and infrastructure of **13 research institutes** all over Germany to deliver complete developments in an **One-Stop-Shop**.



Within the FMD more than 2.000 scientists work together under a single, virtual roof, **3.500 employees** in total.

Total **investment of 350 Mio. EUR** for additional infrastructure and future developments.

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Federal Ministry of Education and Research

International Establishment of the FMD and Cooperation with **European Partners** (e.g. NGC Alliance)

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FMD Offer for Customers

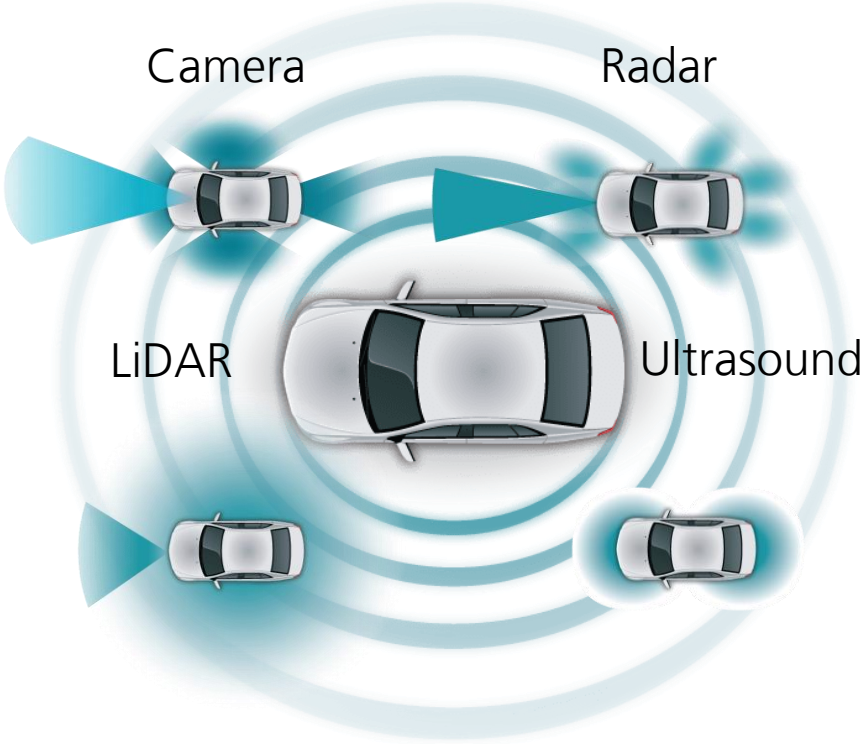
Forschungsfabrik Mikroelektronik Deutschland

Application Specific Solutions	**Solid-State LiDAR: Umgebungssensorik für sicheres autonomes Fahren**
Technology Platforms	▪ 6 Technology platforms along the value chain ▪ 2 Design platforms
FMD as a strong Fundament	▪ 13 Member institutes of the Fraunhofer-Gesellschaft and Leibniz-Gemeinschaft all over Germany

Vehicle Environmental Recognition

Forschungsfabrik Mikroelektronik Deutschland

- Safe Vehicle Environmental Recognition is the key technology for autonomous driving
- Solutions & Technologies for Detection
  - Camera
  - LiDAR
  - RADAR
  - Ultrasound



Source: www.ti.com

Vehicle Environmental Recognition

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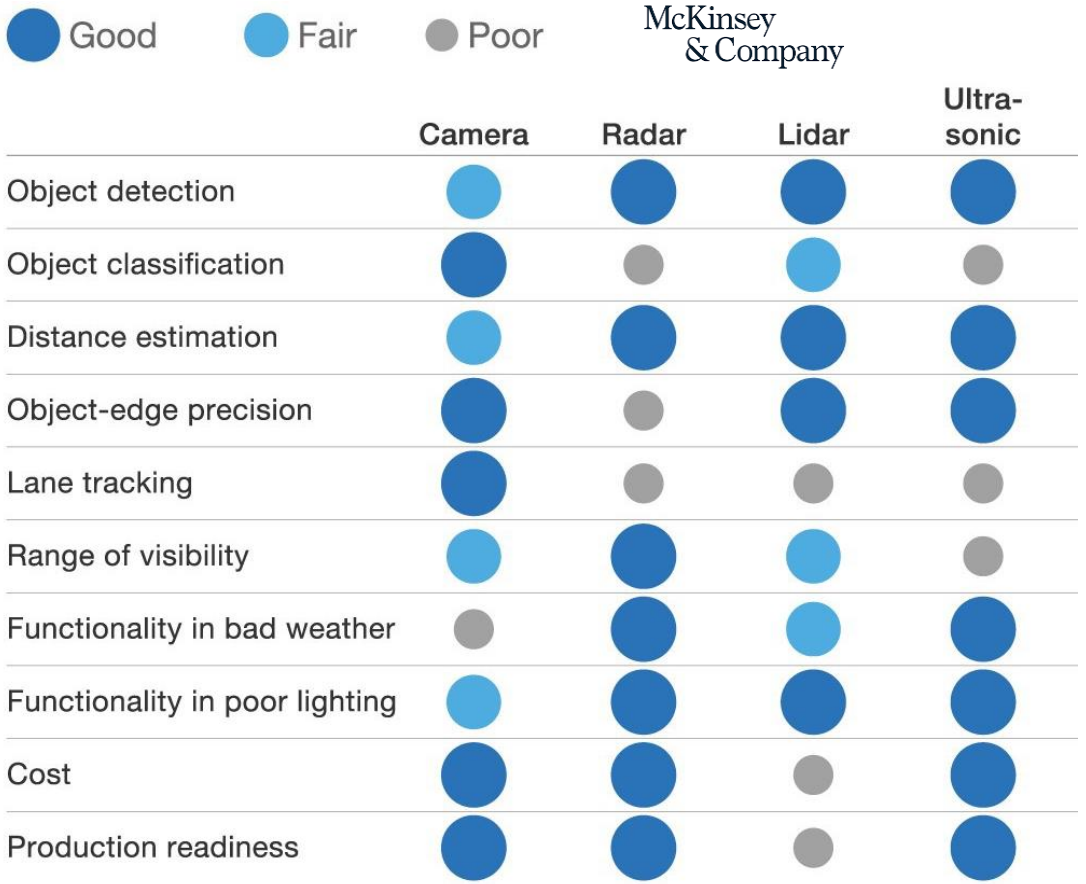
- Only the the combination of at least two different physical detection methods allows safe autonomous driving
- Main challenges for LiDAR are
  - Cost reduction
  - Range
  - Dimension



Solid State LiDAR

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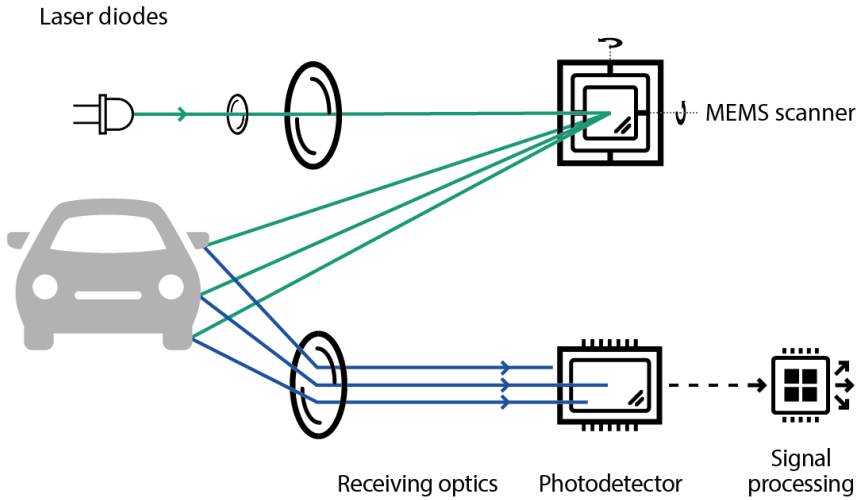
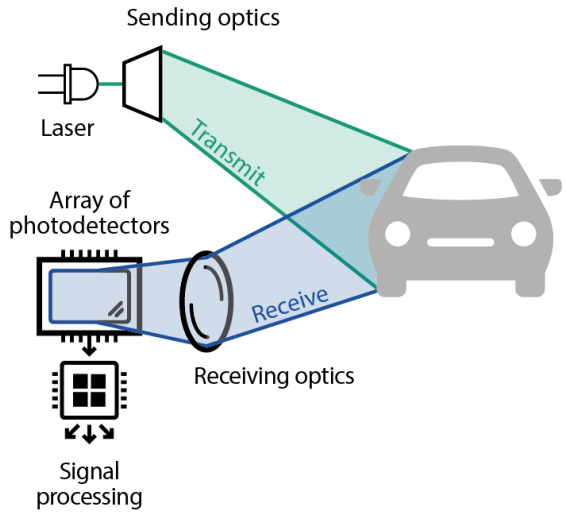
- Solid State LiDAR systems allows the cost efficient solution for the safe detection in autonomous vehicles

- LiDAR system approaches
  - MEMS-based scanning LiDAR
  - Flash LiDAR
  - OPA
- Optical Wavelengths
  - 905nm as well as 1550nm



MEMS based scanning LiDAR



Flash LiDAR

LiDAR - Elements along the entire value chain

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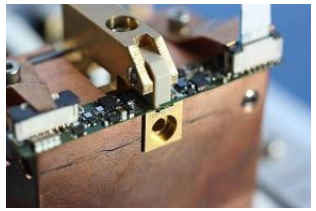
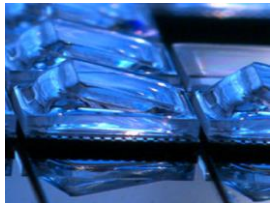
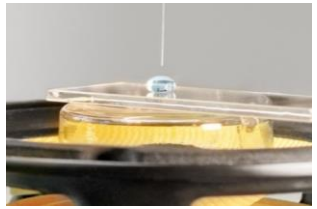
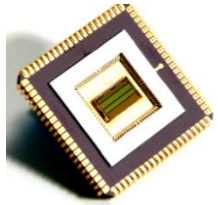
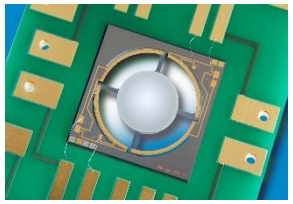
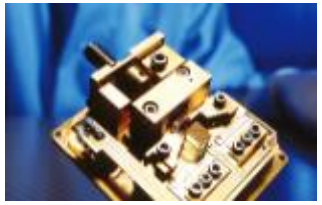
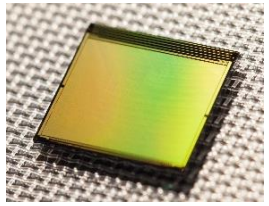
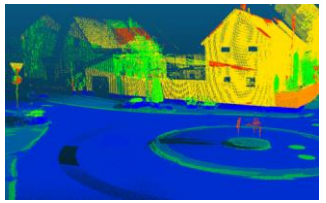
	Laser Sources	Sending Optics	Beam Steering	Receiving optics	Detectors	Signal processing / Sensor data fusion
	FBH	ISIT	IPMS	IOF	IMS	FHR
905 nm						
	HHI	ILT	ISIT	ILT	IAF	IPM
1550 nm						

Design and Test (IIS), Advanced System Integration (IZM)

LiDAR - Components
Laser sources

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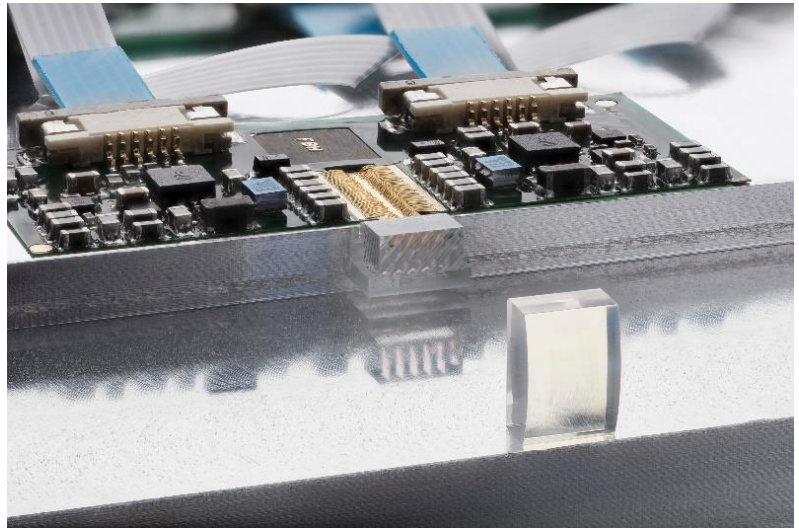
- **905 nm: GaAs-based diode lasers**
  - Distributed Bragg reflector (DBR) broad area (BA) laser
  - Optical pulse lengths 3 … 10 ns
  - Emission wavelength 904 nm @ T = 25°C
  - Wavelength shift < 10 nm
    between temperatures of –40°C and +85°C
  - Pulse power 100 W @ 85°C (3-emitter chip)
  - Spot of combined beam 90 cm x 56 cm at distance of 180 m
- **1500 nm: InP diode lasers at 1500 nm**
  - BA-lasers: cw operation: 5 W; pulsed operation: 16 W (300 ns)
  - Coherent light source and tunable lasers for beam steering for FMCW LiDAR
  - Higher eye safety power limit



LiDAR - Components
MEMS Scanners

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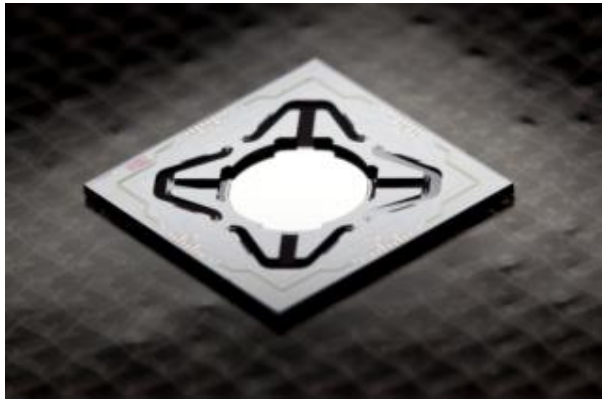
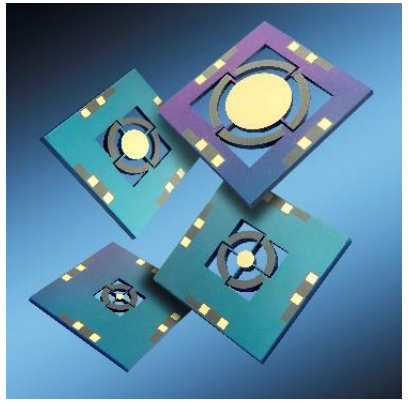
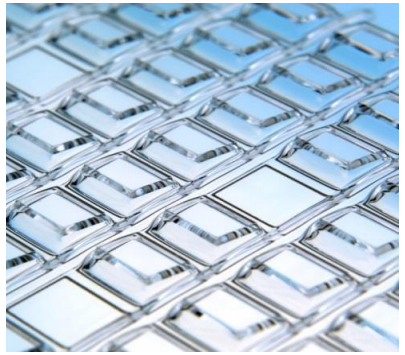
- 1D and 2D scanning devices (arrays possible)
- Resonant and quasistatic deflections
- Drive mechanisms are designed application-specific:
  - Electrostatic
  - Piezoelectric
  - Magnetic
- Scan ranges from 0.1° up to 180°
- Mirror diameters: 0.5 mm - 50 mm
- Scan frequency: 0.1 Hz - 100 kHz
- Fatigue free, high temperature resistant, highly reflective coatings (R>99%)







LiDAR - Components
Silicon detecotors

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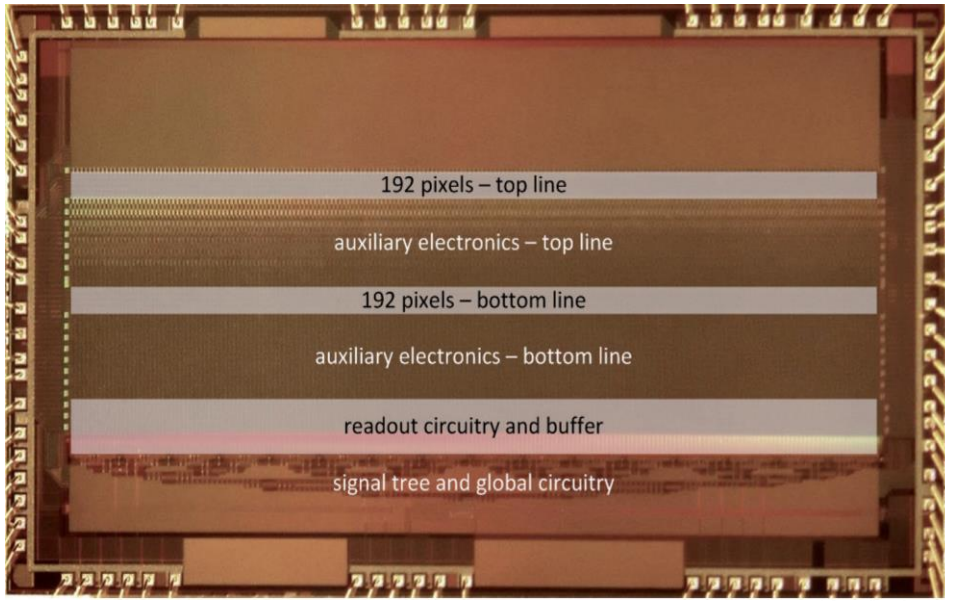
- **Single Photon Avalanche Diode (SPAD)**
- **arrays at 905 nm**
  - Avalanche photodiode operated in Geiger-Mode
  - High spatial resolution and on-chip signal processing (AI on chip)
  - No analog signal processing needed
  - Compatible to CMOS process technology
  - High volume production at low cost
  - Background light suppression



SPADeye2 Sensor, 192x2 Pixel, 9 x 5.2 mm²

LiDAR - Components
III/V Semiconductor Detectors

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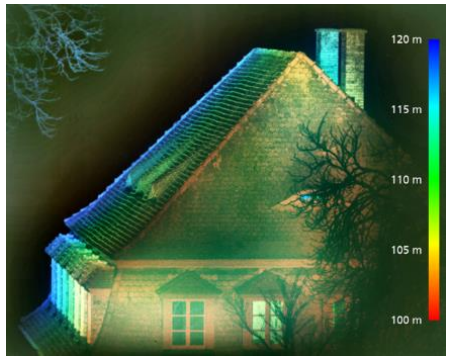
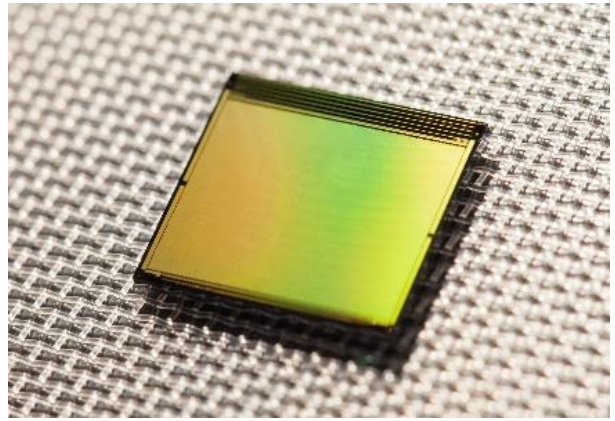
- **InGaAs-based APDs (SWIR) at 1550 nm**
  - High-resolution InGaAs APD focal plane arrays with 640 x 512 pixels
  - Spectral sensitivity up to 1650 nm
  - Operation in proportional mode
  - Internal signal amplification (gain)
  - Design of coherent photodetectors, needed for FMCW or phase shift LiDAR systems
  - Monolithic integration of SWIR detectors and the corresponding laser source can be realized
  - Laser gated viewing systems (Flash LiDAR)
    - Maximum Range > 1 km
    - Distance resolution < 1 m
    - Lateral resolution > VGA





LiDAR - Systems Integration Technologies

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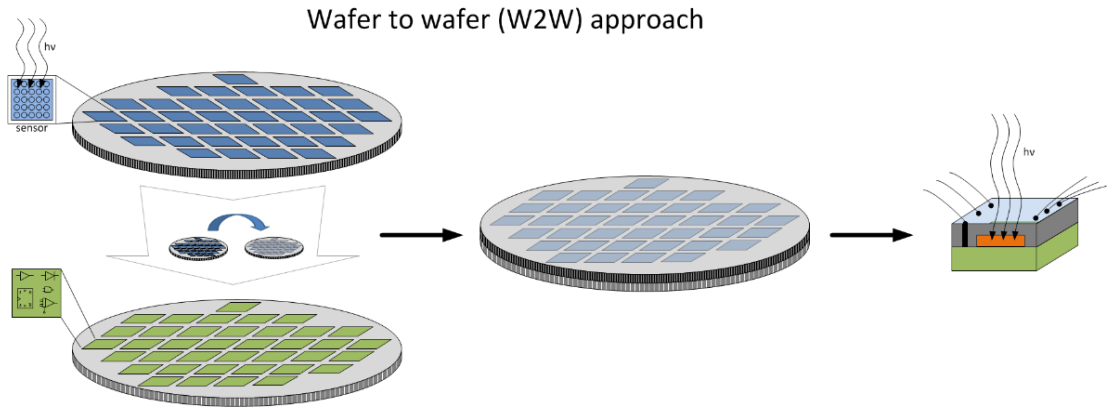
- 3D integration technologies for LIDAR
  - 3D IC Technology with TSV and RDL
  - Wafer Level Packaging & Assembly
- SPAD on CMOS integration
  - 3D-SPAD with 40 µm pitch
  - Wafer processing with TSVs, RDL, bumping and flip chip assembly of thin SPADs
- SiPM integration
  - Edgeless design with high voltage isolation
- Optical and thermal design, simulation and measurement techniques
- Wafer Level Optics Integration
  - Vacuum packaging by hermetic encapsulation with inclined glass caps



LiDAR - Systems
Sensor Data Fusion

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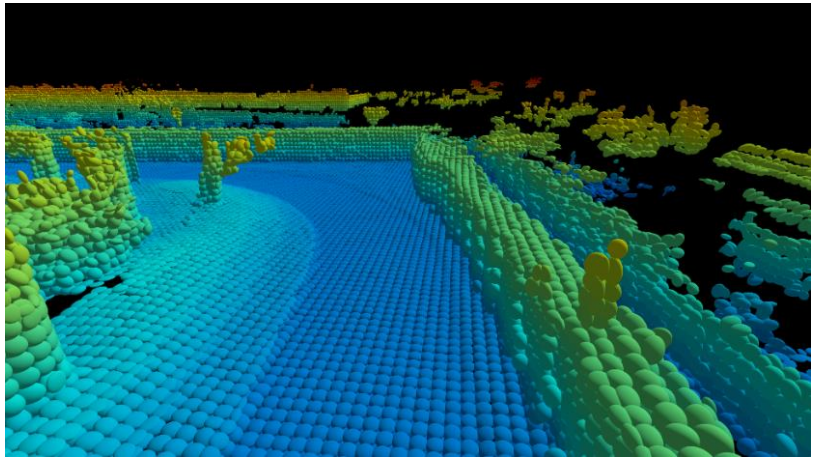
- Multi-Sensor Fusion (LiDAR, RADAR, Camera,…)
- Environment perception for autonomous vehicles
- Sensor Cloud (BDC Web)
  - Storage and management of position- and time-synchronous data
  - Automated algorithms for data analysis and data elevation
- FLLT Labeling Toolchain:
  - Automated labeling of point clouds and training data for AI
  - The larger the data pool, the better the computer system can learn → automated labeling
  - Web-based solution for the labeling process (data overview, data review, data labeling)



Conclusion

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- The safe, cost effective and robust enviromental detection is the key parameter for autonomous driving
- Solid State LiDAR systems are important for the safe optical detection of the surrounding

- The FMD offers all parts of solid-state LiDAR solutions along the whole value chain for the autonomous driving of the future

DANKE

Das dieser Veröffentlichung zugrunde liegende Vorhaben wurde zum Teil mit Mitteln des Bundesministeriums für Bildung und Forschung unter den Förderkennzeichen 16FMD01K, 16FMD02 und 16FMD03 gefördert.

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