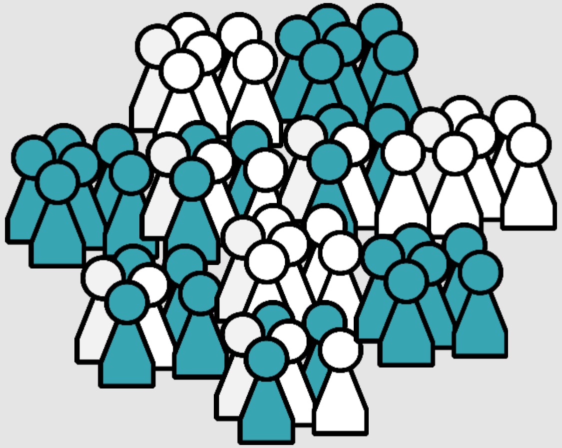
Forschungsfabrik Mikroelektronik Deutschland

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

FMD Facts – A Short Overview

Forschungsfabrik Mikroelektronik Deutschland

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



Within the FMD more than 2.000 scientists work together under a single, virtual roof.

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

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FBH Leibniz Ferdinand Braun Institut

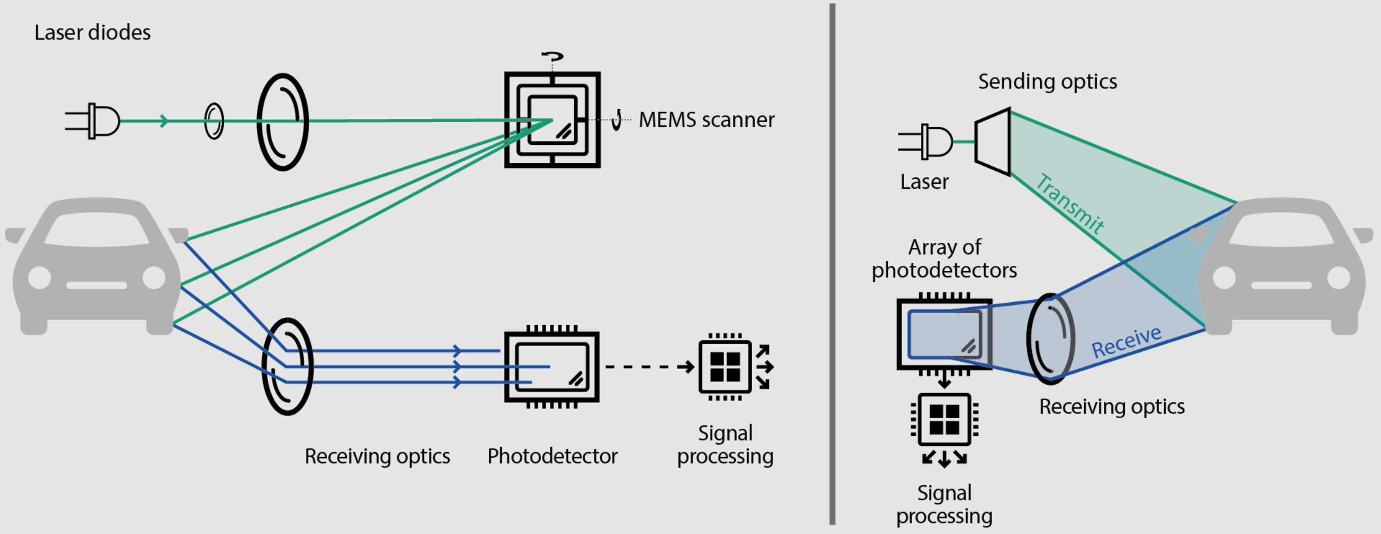
ihp

Vehicle Environment Recognition

- **LiDAR**
- RADAR
- Camera
- Sensor Data Fusion
- Integration Technologies

LiDAR
R&D activities of FMD

- Expertise along the entire value chain of a LiDAR system, especially components:
  - Laser sources
  - Sending and receiving Optics
  - Micromirrors
  - Detectors
- LiDAR system approaches
  - MEMS-based scanning LiDAR
  - Flash LiDAR
  - OPA
- Wavelengths
  - 905nm as well as 1550nm



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LiDAR
Expertise along the entire value chain

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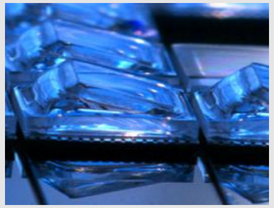
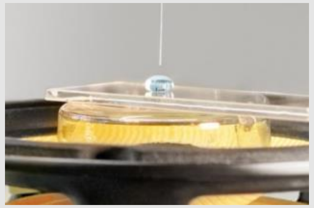
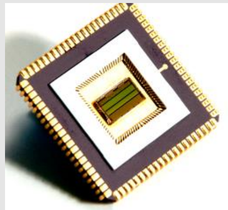
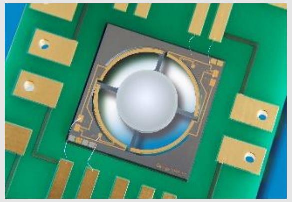
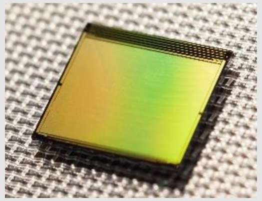
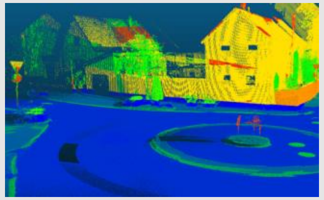
	Laser sources	Sending optics	Beam steering	Receiving optics	Detectors	Signal processing / Sensor data fusion
	FBH	ISIT	IPMS	IOF	IMS	FHR
905 nm						
	HHI	ILT	ISIT	ILT	IAF	IPM
1550 nm						

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

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LiDAR @ Component Level
Laser sources

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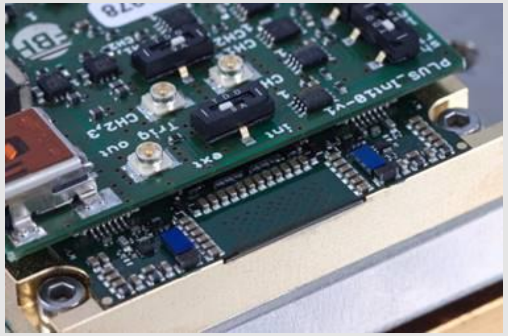
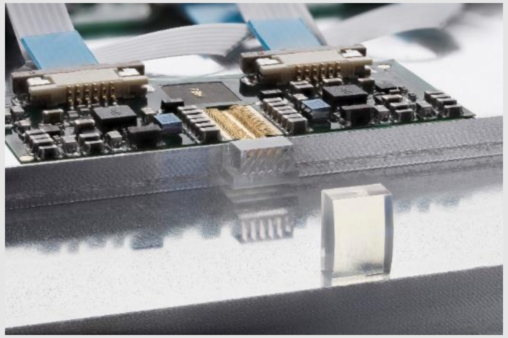
- **Next generation LiDAR laser source for line scanners at 905 nm**
  - 600 W LiDAR module
  - high pulse power laser source with a 48-emitter diode laser bar
  - 4-10 ns pulses with >600 W pulse peak power at 905 nm
  - wavelength shifts with temperature by 0.06 nm/K only
  - bar is electrically driven by a new in-house developed high-speed GaN driver providing current pulses of up to 800 A
  - wavelength is stabilized by integrating distributed Bragg reflectors

- **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
  - 3 ns pulses and 50W optical power/single BA device expected
  - Vertically stacked active layers will enable even higher optical powers





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LiDAR @ Component Level
Laser sources

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- **Laser sources at 905 nm**

	1 emitter		3 emitter (beams combinable)		8 emitter (bar)		48 emitter (bar)	
repetition frequency / kHz	10		10		10		10	
pulse width / ns	5		5		2	5	2	5
temperature / °C	25	85	25	85	25		25	
max. pulse current / A	110	110	190	190	170	410	600	900
max. peak power / W	40	35	100	85	120	180	400	600
pulse energy / nJ	200	175	500	425	240	900	800	3000
wavelength / nm	905	909	905	909	905		905	

LiDAR @ Component Level
MEMS scanners

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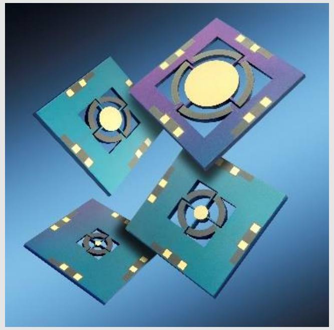
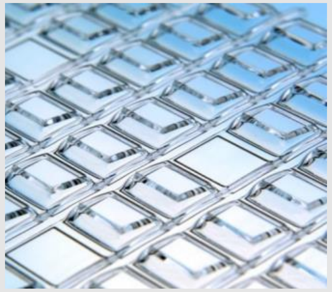
- **1D and 2D scanning devices (arrays possible)**
  - Resonant and quasistatic deflections
  - Drive mechanisms are designed application-specific:
    - Electrostatic, piezoelectric, magnetic
  - Optical scan ranges: 0.1° up to 180°
  - Mirror diameters: 0.5 mm - 50 mm
  - Scan frequency: 0.1 Hz - 100 kHz
  - Fatigue free, high temperature resistant, highly reflective coatings (R>99%)
  - Fabrication: qualified, fully CMOS-compatible bulk micromachining process suitable for mass fabrication
  - Scanners can be vacuum packaged at the wafer level by hermetic encapsulation with inclined glass caps





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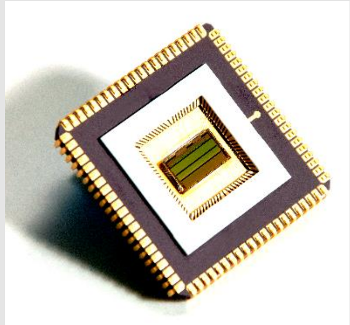
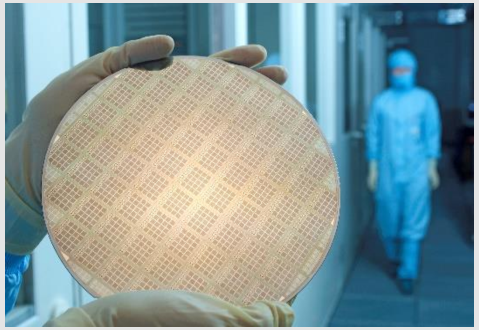
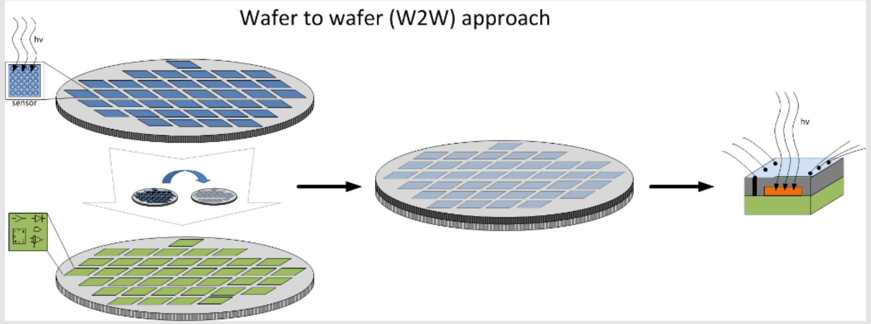
LiDAR @ Component Level
Silicon detecotors

- **Single Photon Avalanche Diode (SPAD) arrays at 905 nm**
  - Avalanche photodiode operated in Geiger-Mode
  - Very few photons can be detected
  - High spatial resolution and on-chip signal processing (AI on chip)
  - High volume production at low cost (CMOS)
  - Background light suppression
  - Backside Illuminated SPAD arrays:
    - High density CMOS readout circuit
    - Wafer to wafer bonding process for high volumes
- **Silicon Photomultiplier (SiPM) at 905 nm**
  - Avalanche photodiodes in Geiger mode
  - High gain and single-photon resolution
  - CMOS integration allows on-chip pre-amplificaton and small arrays of SiPMs







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LiDAR @ Component Level
III/V semiconductor detectors

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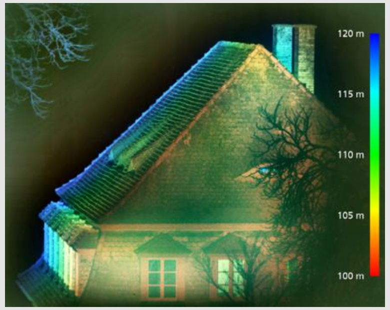
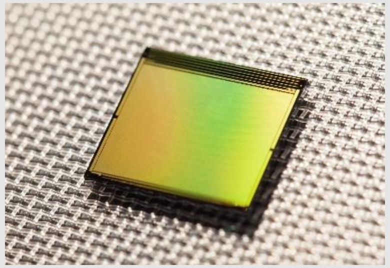
- **InGaAs-based APDs (SWIR) at 1550 nm**
  - High-resolution InGaAs APD focal plane arrays
  - 640 x 512 pixels
  - Spectral sensitivity up to 1650 nm
  - Operation in proportional mode
  - Internal signal amplification (gain)
  - Design of coherent photodetectors, needed for FMCW or phase shift LiDAR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





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Complementary Competencies: Sensor Data Fusion

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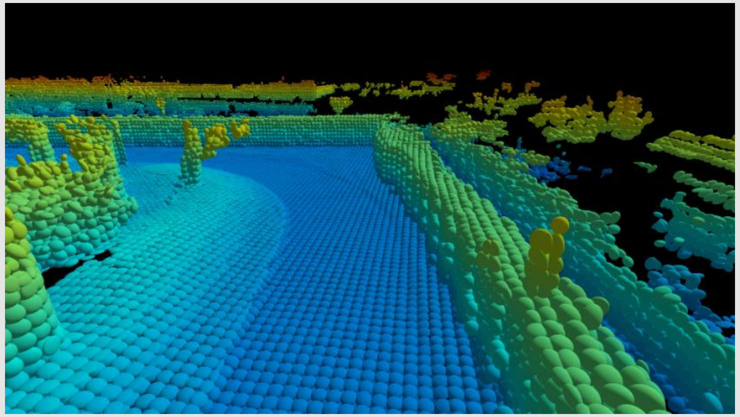
- Multi-Sensor Fusion (LiDAR, RADAR, Camera,…)
- Environment perception for autonomous vehicles
- Sensor Cloud (BDC Web)
  - Storage and management of position- and time-synchronous data
  - Automated algorithms for data analysis and data elevation
- FLLT LabelingToolchain:
  - Automated labeling of 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)



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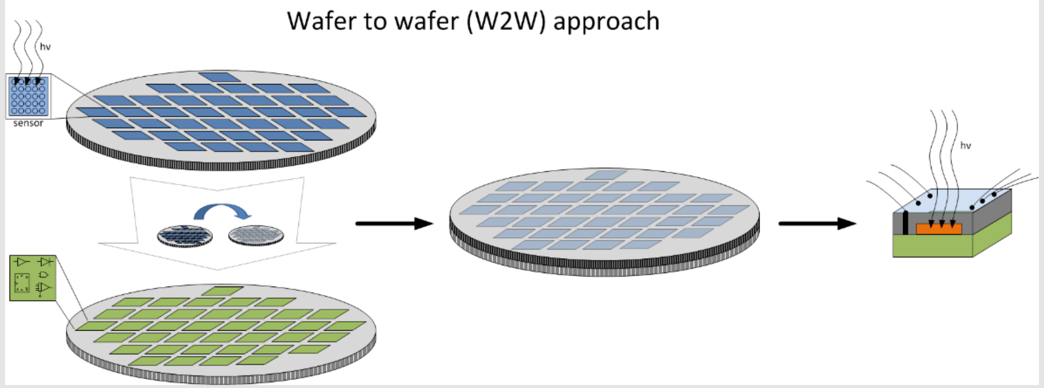
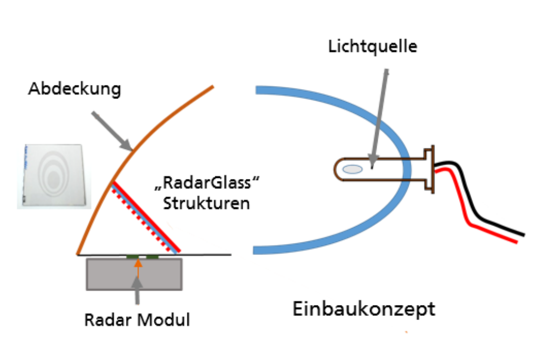
Complementary Competencies: Integration Technologies

- 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
- Thermo-mechanical design, simulation and measurement techniques
- Wafer Level Optics Integration
  - Vacuum packaging by hermetic encapsulation with inclined glass caps





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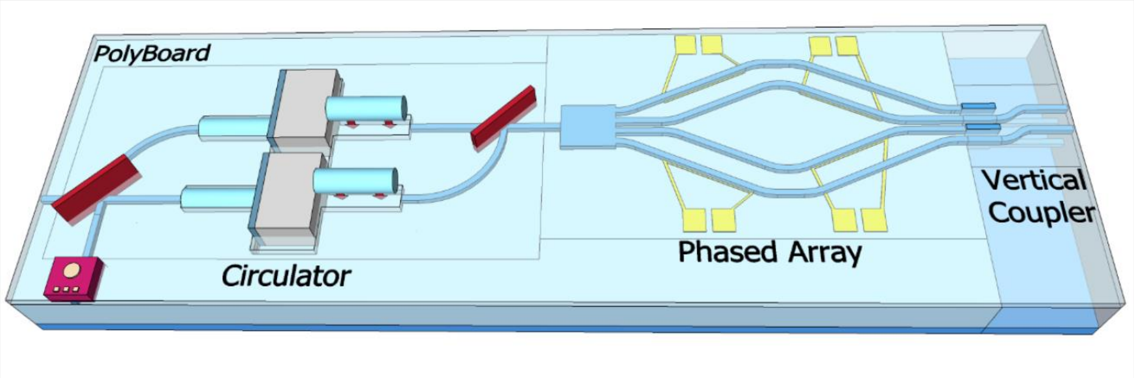
LiDAR
New approaches

- **Scanning-LiDAR - Hybrid Integration Concept**
  - Based on Hybrid Photonic Integrated Circuits (Hybrid PICs)
  - Strength: Low upfront development effort, short iteration cycles
  - Optical circulator: separation of emitted and received light
  - Phased array: non-mechanical beam steering
  - Vertical coupler: non-mechanical beam steering



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LiDAR
New approaches

- **Single Photon Avalanche Diodes**
  - Wafer-2-Wafer-Bondig → separate manufacturing of SPAD and ROIC + higher fill factor
    - Advantage: separate optimization of SPAD and ROIC
  - 2D Focal-Plane Arrays
- **MEMS scanners**
  - Improvement of drive mechanisms (piezo, magnetic) → quasistatic modules with high precision
  - High optical scan angles → 180°
- **Miniaturized & hybrid sensor module**
  - 79 GHz Radar & Camera

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Our Invitation to Cooperate: Services of FMD

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- Industrial contract research
  - R&D-Projects
  - Feasibility studies
  - Technology and process development
  - Pilot fabrication
- Services for manufacturers
  - Demonstrators and prototypes
  - Technology services
- Technology transfer
  - Licensing of technologies and processes
- Cooperative projects
  - R&D projects jointly funded by public and industrial sources

RADAR
Testing of Radar Systems

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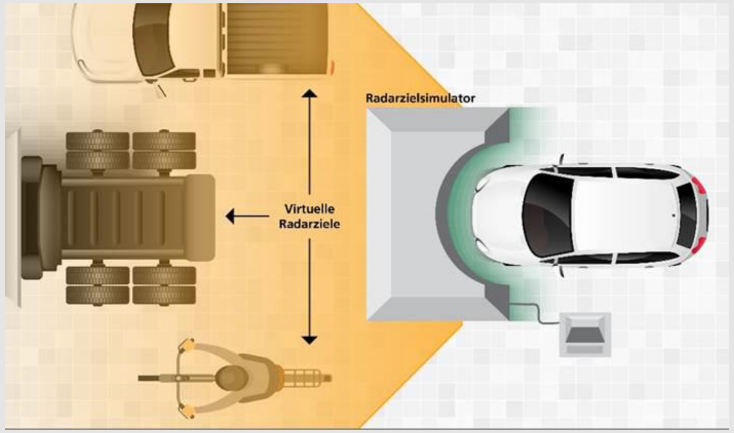
- ATRIUM
  - Automotive test environment for radar in-the-loop testing and measurements
  - Radar target simulator in the E-band
  - Full simulation of critical traffic scenarios
  - Testing of mounted automotive radar sensors:
    - New radar technologies and sensor concepts can be tested
    - Effects from long-term use of a vehicle or damage
    - Designed for a high throughput of automotive radar sensors and can therefore be used by technical inspection organizations damage to the vehicle
  - Reliable qualification of automobile radars
  - Facilitating the control of the functionality of the next generation of automotive radar sensors



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Camera

- Goals of R&D project „KameRad“
  - Development of a miniaturized & hybrid sensor module
  - Combined Camera and Radar module: 79 GHz Radar & Camera
  - Sensor fusion (hardware & software)
  - Decentralized computing platform with sufficient computing power for deep learning
  - Interface for Car-2-X- communications and GPS
  - Unit size: no bigger than a smartphone
  - Reaction time of less than 10 milliseconds
  - Integrated signal processing capacity allowing all processing to take place directly within the module

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