Fraunhofer Group for Microelectronics in Cooperation with Leibniz Institutes FBH and IHP
FMD Facts – A Short Overview

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.

SPONSORED BY THE

Federal Ministry of Education and Research

A cooperation of

Forschungsfabrik Mikroelektronik Deutschland

FMD Facts
–
A Short Overview

15.11.2019
Christoph Galle
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
# LiDAR Expertise along the entire value chain

<table>
<thead>
<tr>
<th>Laser sources</th>
<th>Sending optics</th>
<th>Beam steering</th>
<th>Receiving optics</th>
<th>Detectors</th>
<th>Signal processing / Sensor data fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>FBH</td>
<td>ISIT</td>
<td>IPMS</td>
<td>IOF</td>
<td>IMS</td>
<td>FHR</td>
</tr>
<tr>
<td>905 nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHI</td>
<td>ILT</td>
<td>ISIT</td>
<td>ILT</td>
<td>IAF</td>
<td>IPM</td>
</tr>
<tr>
<td>1550 nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

15.11.2019

Christoph Galle
LiDAR @ Component Level

Laser sources

- **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


## Laser sources at 905 nm

<table>
<thead>
<tr>
<th></th>
<th>1 emitter</th>
<th>3 emitter (beams combinable)</th>
<th>8 emitter (bar)</th>
<th>48 emitter (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>repetition frequency / kHz</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>pulse width / ns</td>
<td>5</td>
<td>5</td>
<td>2, 5</td>
<td>2, 5</td>
</tr>
<tr>
<td>temperature / °C</td>
<td>25</td>
<td>85</td>
<td>25, 85</td>
<td>25, 25</td>
</tr>
<tr>
<td>max. pulse current / A</td>
<td>110</td>
<td>110</td>
<td>190, 190</td>
<td>170, 410</td>
</tr>
<tr>
<td>max. peak power / W</td>
<td>40</td>
<td>35</td>
<td>100, 85</td>
<td>120, 180</td>
</tr>
<tr>
<td>pulse energy / nJ</td>
<td>200</td>
<td>175</td>
<td>500, 425</td>
<td>240, 900</td>
</tr>
<tr>
<td>wavelength / nm</td>
<td>905</td>
<td>909</td>
<td>905, 909</td>
<td>905, 905</td>
</tr>
</tbody>
</table>
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
LiDAR @ Component Level
Silicon detectors

- **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-amplification and small arrays of SiPMs
LiDAR @ Component Level
III/V semiconductor detectors

- **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

© Fraunhofer IAF
Complementary Competencies: Sensor Data Fusion

- 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)
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

© Fraunhofer IMS, ILT

15.11.2019
Christoph Galle
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
LiDAR
New approaches

- **Single Photon Avalanche Diodes**
  - Wafer-2-Wafer-Bonding → 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
Our Invitation to Cooperate: Services of FMD

- 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

▪ 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

© Fraunhofer FHR
▪ 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