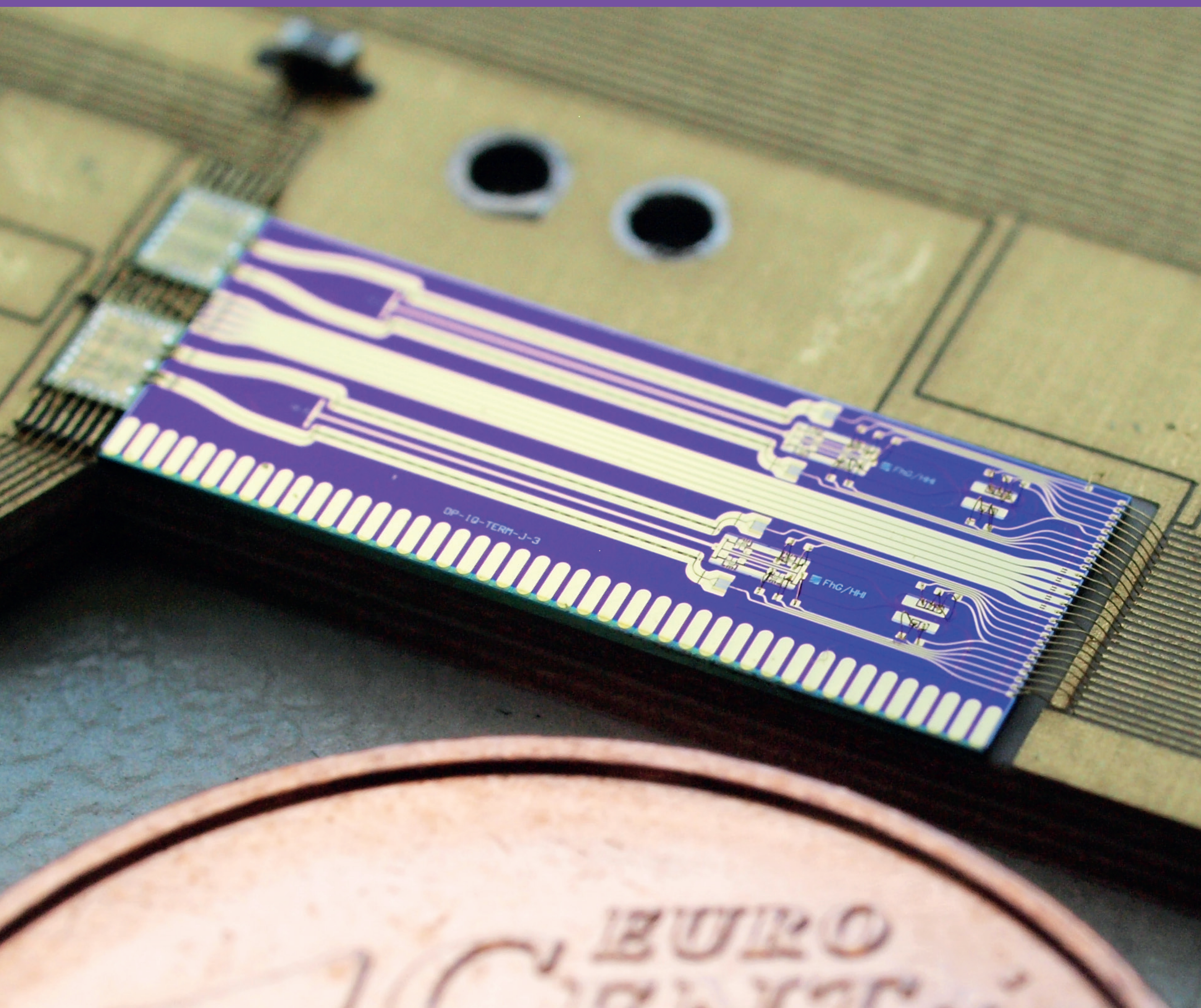
Forschungsfabrik Mikroelektronik Deutschland

RESEARCH FAB MICROELECTRONICS GERMANY

FRAUNHOFER GROUP FOR MICROELECTRONICS IN COOPERATION WITH LEIBNIZ INSTITUTES FBH AND IHP

Optoelectronic Systems

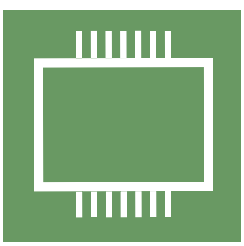


Research Fab Microelectronics Germany: Benefit from the Largest R&D Cooperation for Micro and Nanoelectronics in Europe

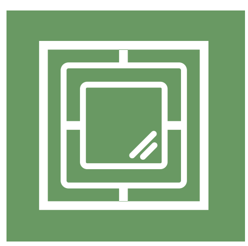
The Research Fab Microelectronics Germany (FMD) is a multisite cooperation advancing micro- and nanoelectronics research and development and comprises eleven institutes of the Fraunhofer Group for Microelectronics, as well as the two Leibniz institutes FBH and IHP. We are a one-stop shop for cutting-edge R&D services, application solutions and new technologies for a wide range of industrial customers.

By joining forces, we are able to provide tailor-made technology and system solutions from a single source. Drawing on FMD's broad technology portfolio, we have established six technology platforms: Microwave and Terahertz, Power Electronics, Extended CMOS, Optoelectronic Systems, Sensor Systems, and MEMS Actuators. Together these bundle the necessary individual expertise – from system design to testing and reliability assessment – to meet customer needs. Apart from leveraging synergies between technological know-how and the development of technological innovation, the platforms prioritize close cooperation with customers throughout the development process and the bundling of technological competencies along the entire value chain.

Our Technology Portfolio

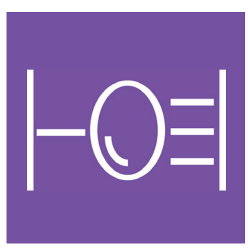


Microwave and Terahertz
Cutting-edge devices and circuits for frequencies up to and including the THz range.

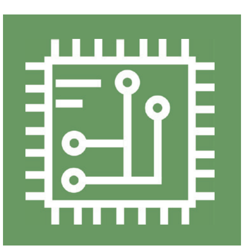


Extended CMOS
Design, fabrication and system integration of CMOS circuits.

Power Electronics
Design and fabrication of power electronic devices, including integration in modules and systems.



Optoelectronic Systems
Fully integrated optoelectronic systems for image acquisition and processing, and communication up to Tbit/s speed.



Sensor Systems
Sensor design, fabrication, integration, characterization, and testing within systems.

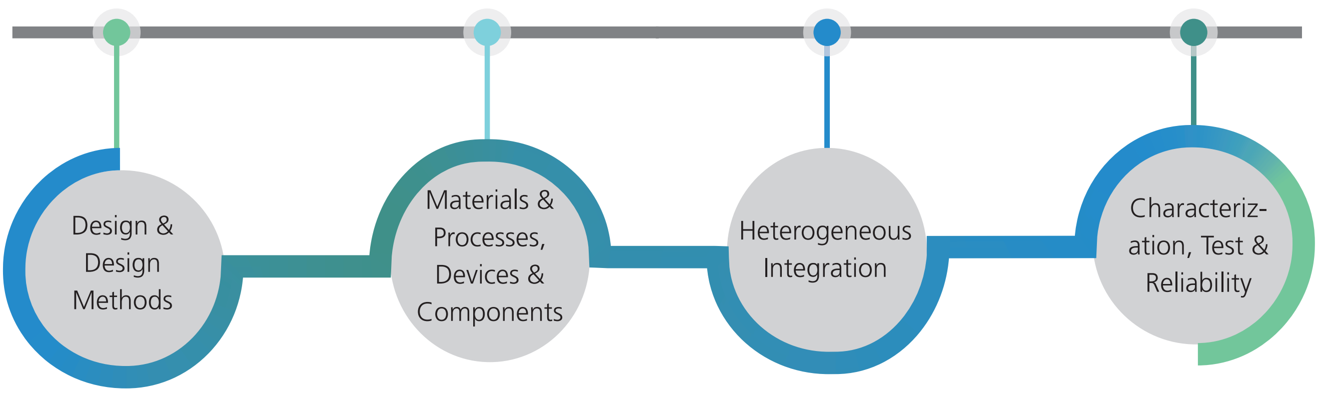
MEMS Actuators
Design and fabrication, as well as characterization, testing and system integration of MEMS actuators.

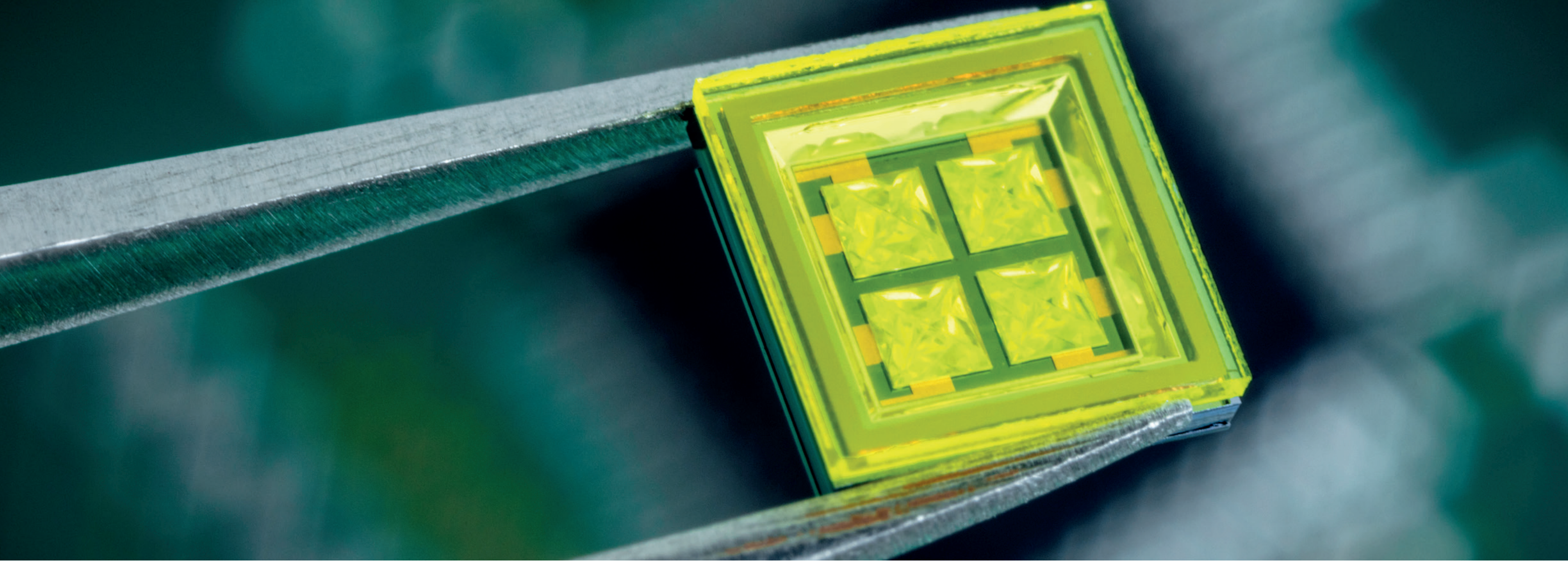
Technology Platform: Optoelectronic Systems

The technology platform Optoelectronic Systems combines the broad, interdisciplinary engineering expertise of Research Fab Microelectronics Germany (FMD) to achieve leading-edge optoelectronic devices and systems. Applications include imaging acquisition and processing, communication up to Tbit/s speed, and optical sensing applications. Our one-stop shop covers the complete component and technology chain for optical communication, from emitter, to modulator and receiver, through to fully integrated optoelectronic systems.

Starting with the specification and design of single devices, we integrate optoelectronic circuits and even design and realize complete hybrid-integrated systems. We lend our long-term experience and comprehensive know-how to the processing of a variety of materials – from Si to compound semiconductors and polymers – in our cleanroom facilities, as well as using the wide range of heterogeneous integration technologies required to realize even the most complex systems. Our Si-, III-V-, and polymer-based technologies allow the manufacturing of active and passive structures, like optical filters and multiplexers or lasers, semiconductor optical amplifiers (SOAs), and gain chips. We have a wide-ranging portfolio of active devices for different operation wavelengths, such as GaAs-based devices (wavelength between 626 nm and 1180 nm), InP-based devices (~ 1.25 – 1.7 µm), and quantum cascade devices (~ 2 – 11 µm). To reach all wavelengths from the yellow to the UV region of the optical spectrum non-linear frequency conversion can be harnessed. All the components and heterogeneous integration technologies – from emitters to fully-integrated modulators through to receivers – are available to design customized optoelectronic systems.

Our expertise in heterogeneous integration technologies illustrates the multitude of technological solutions at our disposal: systems-on-chip (SoC), advanced packaging, wafer level capping, and advanced substrate/interposer technologies. Furthermore, the hybrid integration of active III-V materials in polymer- and Si-based technology, including wafer-level atomic layer deposition for encapsulation, plays a significant role in achieving complete hybrid photonic integrated circuits (hybrid PICs). We perform in-depth characterization of the electro-optic performance of the designed, manufactured, and assembled optoelectronic systems and test the latter using multiple stress scenarios (thermal and mechanical stress), as well as performing reliability and degradation assessments. Finally, we also make customized solutions for specific applications possible by identifying the optimal materials and technologies required.





Our Competencies in Optoelectronic Systems along the Value Chain

Design & Design Methods

Component Design

- Vision systems-on-chip (VSoC), CMOS-integrated multispectral and polarization filters, MEMS-based optical systems
- Design for wafer level opto-packaging, for passive fiber-to-chip coupling in polymer-based optoelectronic circuits

Package & System Design

- Optical electronic-packaging co-design, mathematical modeling, physics-based numerical simulation, fitting of experimental data
- Libraries and tools for software-defined vision sensors, e.g. based on VSoCs

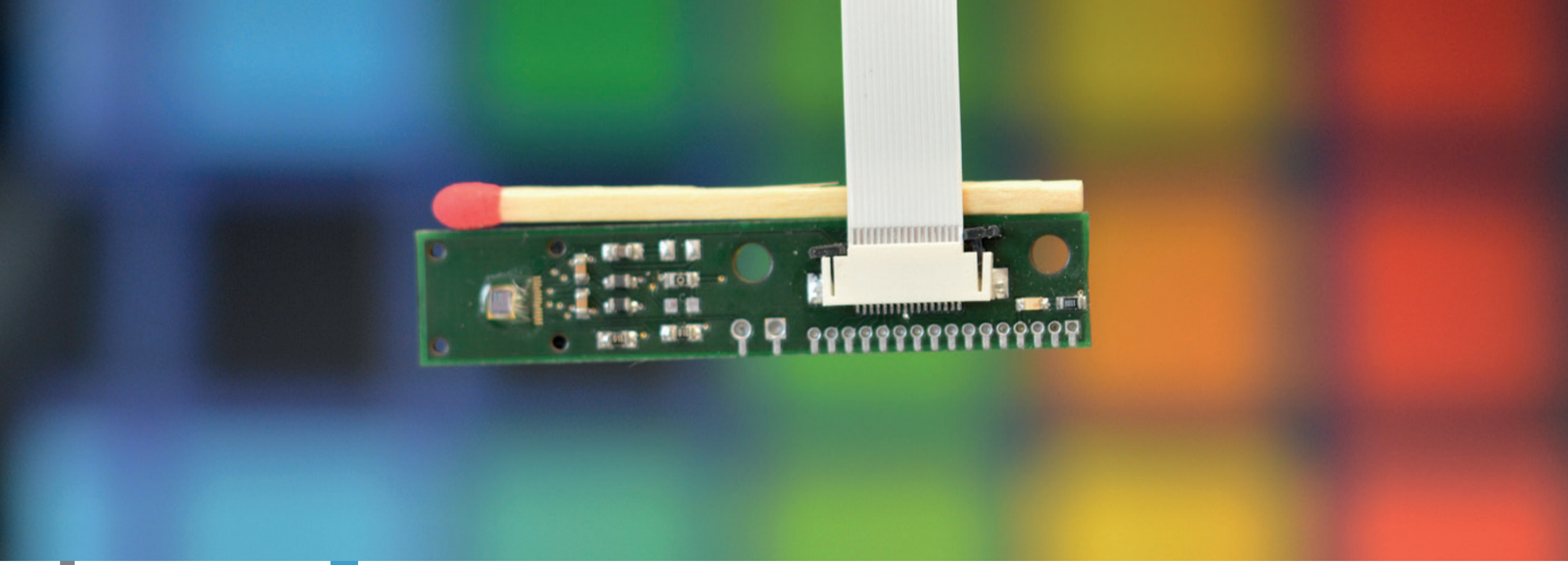
Materials & Processes, Devices & Components

Material Development

- Si, SiC, Ga_2O_3, InP, AlGaInN, AlGaInP, GaInAsP, GaSb, type II superlattices, glas, polymer, graphene

Process Development

- Epitaxial growth of customized III-V stacks on substrates from 1″ to 8″
- Distributed Bragg reflectors (DBR) by electron beam, optical or holographic lithography, laser facet passivation and coating
- Wafer level frontend processing of optoelectronic devices, e.g. complete InP fabrication including epitaxy and e-beam lithography
- Wafer level backend processes for photonic and optoelectronic packaging, 3D glass wafer forming for optics & opto-packaging



Heterogeneous System Integration

Devices & Components Realization

- Photoconductors, photodiodes, LED, laser
- Laser diodes (DFB, FP, EML), semiconductor optical amplifier (SOA, RSOA), gain chips and photonic integrated circuits (PIC)
- Modulators, MEMS scanner and mirrors, polymer couplers, AWGs, multi-plexers, switches, optical isolators, non-linear optics

Component Packaging

- Wafer level backend processing for photonic components
- Hermetic housing on wafer level, e.g. hermetic encapsulation of LASER diodes
- Glass opto-packages with various window orientations

Module & System Packaging

- Ultra-high precision adhesive bonding
- Silicon and glass interposers with electrical feedthroughs
- Microbumping and thin-film wiring for HF-compliant signal routing
- 3D integration of active electronic and photonic components
- High-precision flux-free assembly
- Automated active alignment of package components
- Aligning and gluing of optical elements in packages with sub-µm accuracy for optimal free-space beam formation from laser diodes
- Automated assembly of polymer-based optoelectronic circuits for small to medium volumes
- 3D multilayer integration and chip embedding in polymer, ceramics and silicon substrates

Characterization, Test & Reliability

Material Characterization

- Characterization of optical materials used for both passive and active components, such as complex layer stacks

Process Characterization

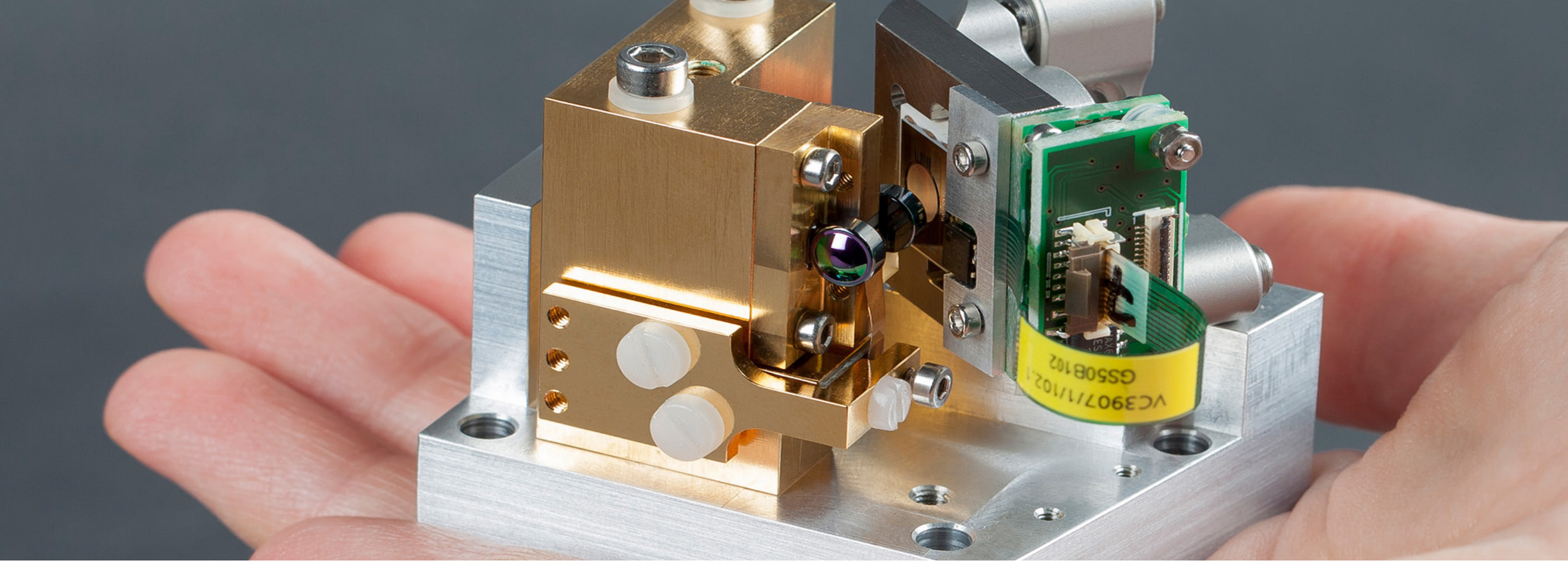
- Analysis of gluing strategies and geometries (UV and thermal epoxies)
- Design of laser-based processing and fusing of glass components
- In-line process monitoring and SPC for InP-based device processing

Devices & Components Characterization & Test

- Full characterization of optoelectronic devices
- In-depth characterization of application-specific performance parameters for optical and optoelectronic components and systems
- Measurement of spectral and propagation properties of diverse light sources
- Inspection of coupling interfaces to photonic integrated circuits
- Characterization of micro-optical components with wave front sensors
- Characterization of spectral and polarization properties of image sensors down to pixel level
- High-resolution and time-resolved characterization of pixel cells
- Accelerated lifetime testing and failure analysis

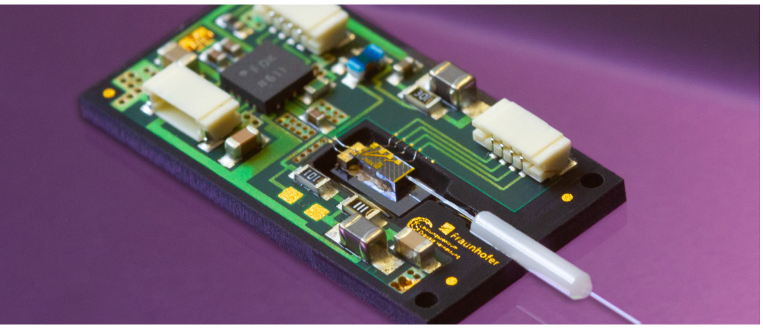
System Test & Reliability

- Reliability testing (thermal cycling, thermal storage)
- System test beds for optoelectronic components



Technology Example: Tunable Laser Module

The combined expertise of Fraunhofer HHI and IZM makes customer-specific miniaturized optoelectronic systems available for a broad range of application fields. The example board shown in the image below was developed for the German telecommunication vendor ADVA Optical Networking SE and comprises an integrated tunable laser chip based on Fraunhofer HHI's photonic integration technology. The integrated tunable laser combines an InP-based active section, which allows 10 Gb/s direct modulation for data transmission, and a polymer-based passive section featuring a phase shifter and a tunable Bragg grating, which achieve a wavelength tunability of 20 nm in the C band. The integrated tunable laser was assembled on an electronic board designed and fabricated by Fraunhofer IZM.



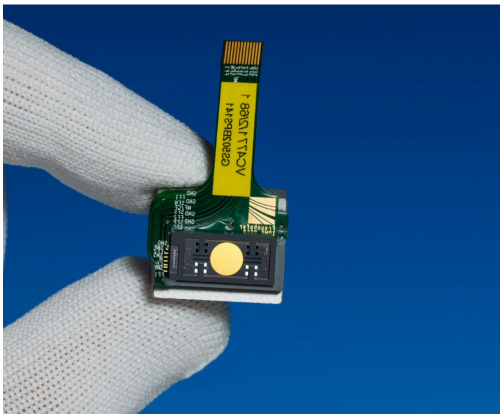
With novel technologies developed by Fraunhofer IZM, fabricating a robust 3D substrate, as well as integrating SMD and optoelectronic components, is achievable. The silica-filled epoxy resin board is manufactured using compression molding and is compatible with standard SMT processes, allowing it to be processed like a common PCB.

Integrated tunable laser chip employing Fraunhofer HHI's photonic integration technology and assembled on an electronic board designed and fabricated by Fraunhofer IZM.

Technology Example: External Cavitiy Quantum Cascade Lasers

Quantum cascade laser (QCLs) harness intersubband transitions in the conduction band of a semiconductor layer structure. Such laser sources are used in real-time spectroscopy, which facilitates fast quality and process control and the development of mobile or even hand-held devices. With sophisticated layer design, they can be optimized for performance or wide wavelength tunability. The emission wavelength of the chip material can be adjusted in external resonators using a diffraction grating. Micro-opto-electro-mechanical systems (MOEMS) grating scanners are used for this purpose.

Resonant grating scanners track a sinusoidal trajectory and allow very for high spectral scanning speeds of up to 1 kHz. With quasi-static grating scanners, individual wavelengths can be specifically targeted and almost any desired trajectory can be traced, thus enabling arbitrary spectral scanning speeds with repetition rates of up to several 10 hertz. They can replace conventional external cavity (EC) QCLs in many applications, with the added advantages of significantly smaller size and increased functionality. Fraunhofer IAF builds highly integrated EC QCLs for the mid-infrared wavelength regime that combine unique spectral scanning speeds with the small footprint mentioned above.



Scanning MOEMS grating module.

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