

Fraunhofer Group for Microelectronics in Cooperation with the Leibniz Institutes FBH und IHP

Microwave and Terahertz

Research Fab Microelectronics Germany: Benefit from Europe's Largest R&D Cooperation for Micro- and Nanoelectronics

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.

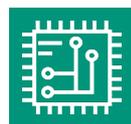
By joining forces, we are able to provide tailor made technology and system solutions from a single source. Drawing on FMD's broad technology portfolio, we have established six technology

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.

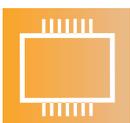
Our Technology Portfolio



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



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



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



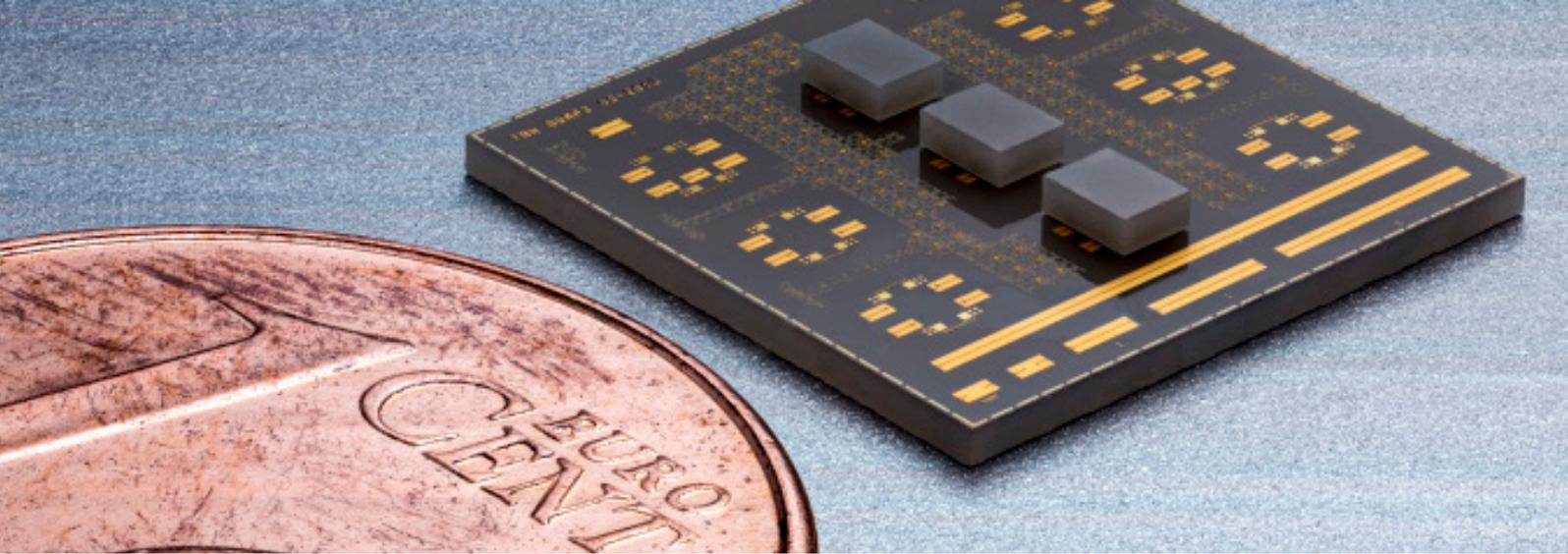
Optoelectronic Systems
Fully integrated optoelectronic systems for image acquisition and processing, and communication up to Tbit/s speed.



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



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



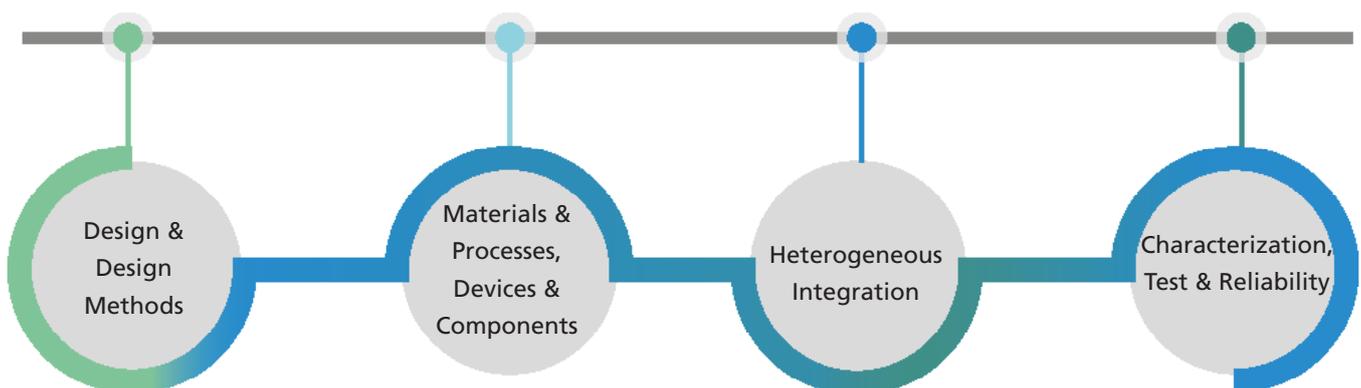
Technology Platform: Microwave and Terahertz

As part of Research Fab Microelectronics Germany (FMD), the technology platform Microwave & Terahertz makes microelectronic development accessible to industry and research by providing consulting services, development, and access to infrastructure. We cover the complete value chain, from design, materials selection, processing, system integration, materials characterization, device testing and reliability assessment. Our technology platform specializes in turn-key and custom solutions for the design, manufacturing, packaging, characterization and testing of cost-effective, high-performance and reliable devices, integrated circuits and systems for applications up to the THz-regime. Your specifications are top priority throughout the development process, from modeling and design, to fabrication using advanced manufacturing techniques. Application-specific requirements and boundary conditions are factored in at the very beginning of the design process. This allows us to focus on future and emerging applications, especially applications related to communication and sensing (e.g., 5G mm-wave or radar sensing for autonomous vehicles).

We are uniquely equipped for rapid prototyping and manufacturing of devices, circuits and systems for applications up to THz range. For this our cleanrooms for silicon (200 mm and 300 mm) and for compound-semiconductors (up to 6") are the basis. We fabricate and process a variety of devices, including HBTs, HEMTs, passive structures and mm-wave integrated

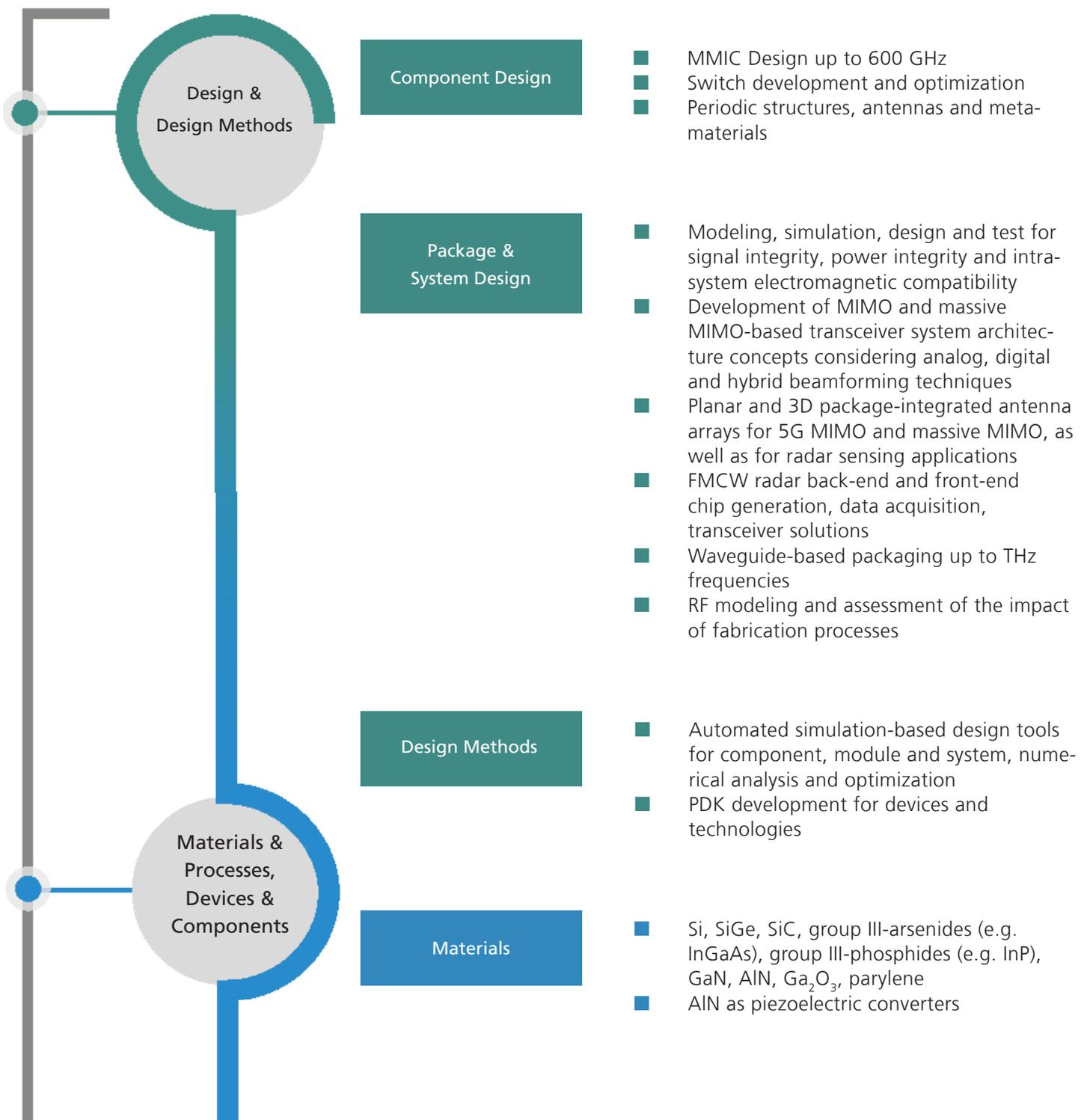
circuits (MMICs) using a wide range of ultra-fast technologies, such as Si, SiGe, InP, GaN/SiC, InGaAs/GaAs. In addition to our in-house processes, we apply standard CMOS processes of external foundries to prototype and design CMOS MMICs for our customers or partners. Furthermore, we research and develop the integration of III-V materials into Si-based technologies, successfully demonstrated with a transfer-substrate process for integration of an InP-based HBT with SiGe:C BICMOS technology in a single chip.

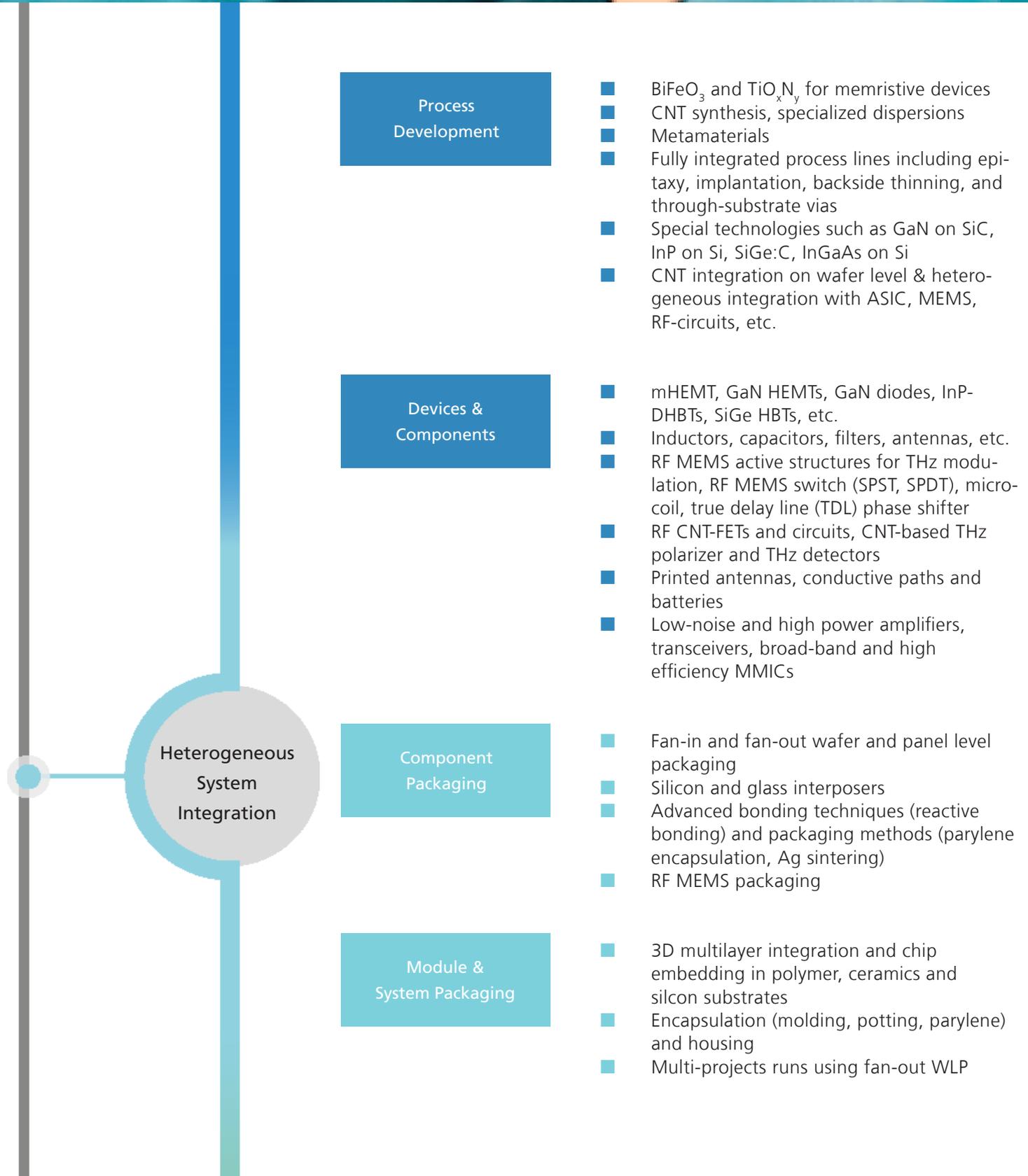
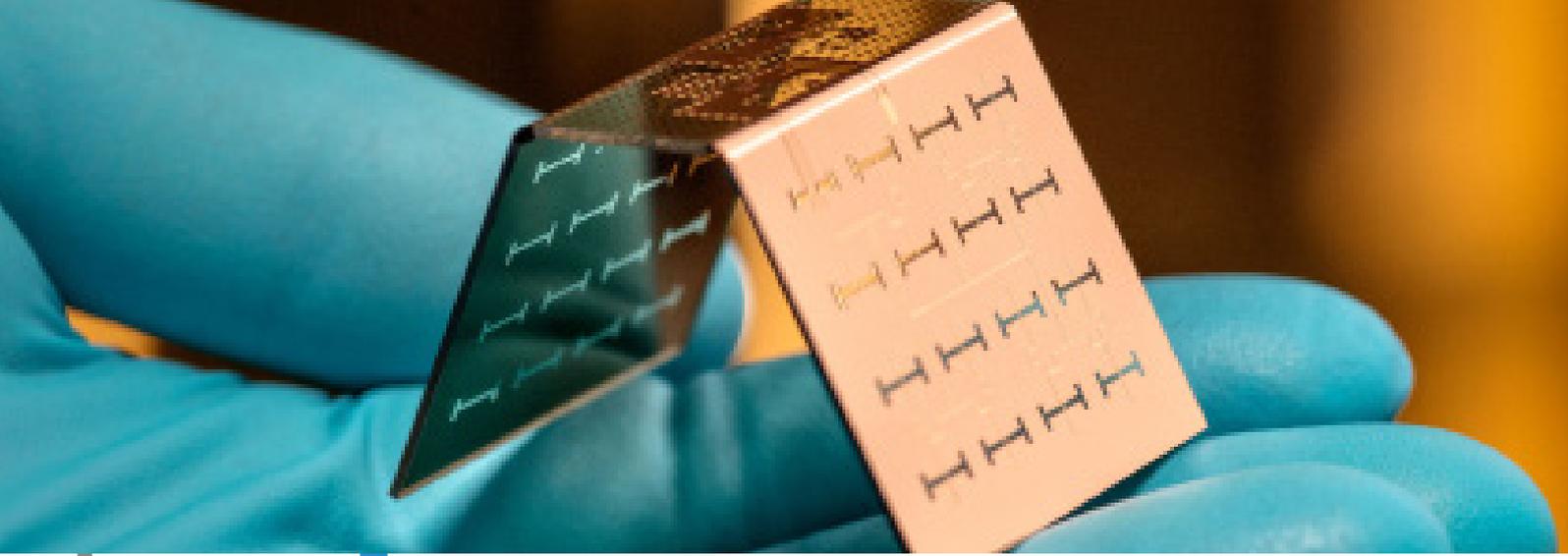
The technology platform is expert in all aspects of package-integrated antennas and the packaging and heterointegration of high frequency SiP applications. We apply our advanced assembly, packaging and system-integration technologies at wafer and board levels for the development of miniaturized mm-wave and terahertz components, modules and systems. We can characterize and test the functionality of already designed, manufactured and assembled systems, including under harsh environments, and perform reliability assessments. To top it off, several of the FMD team are also members of Europractice consortium, which allows us to offer our partners advance access with minimum fuss to novel Microwave & Terahertz modules and technologies.

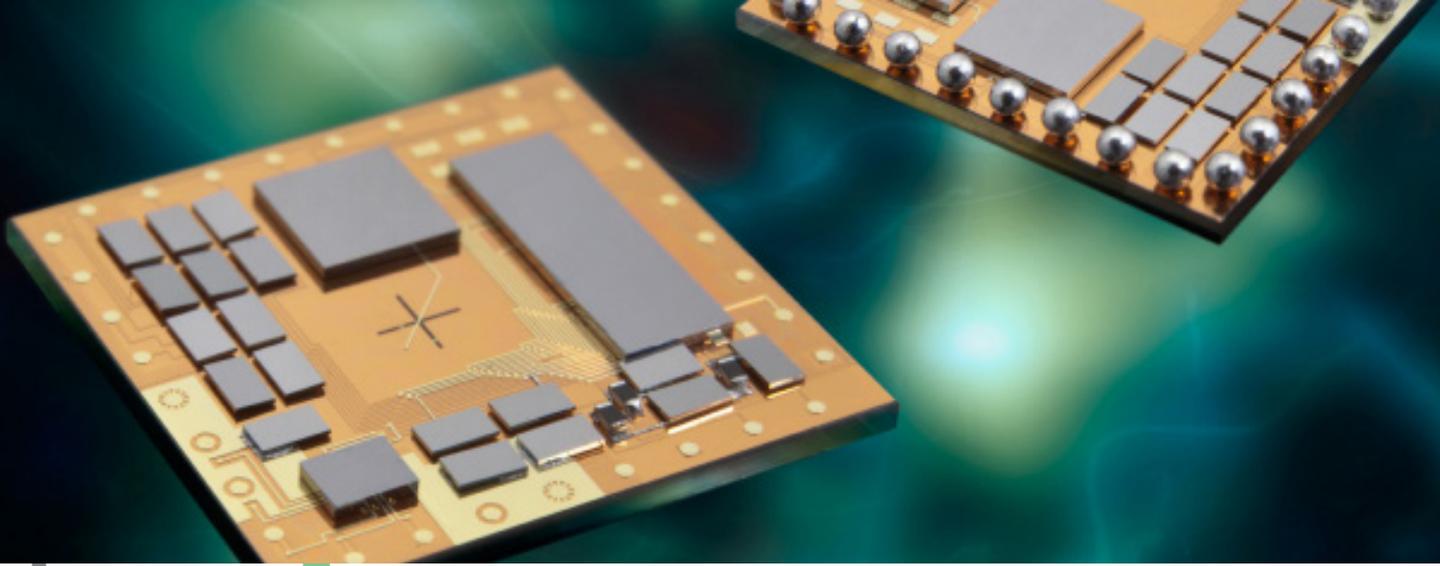




Our Competencies in Microwave and Terahertz along the Value Chain







Characterization, Test & Reliability

Materials & Devices Test

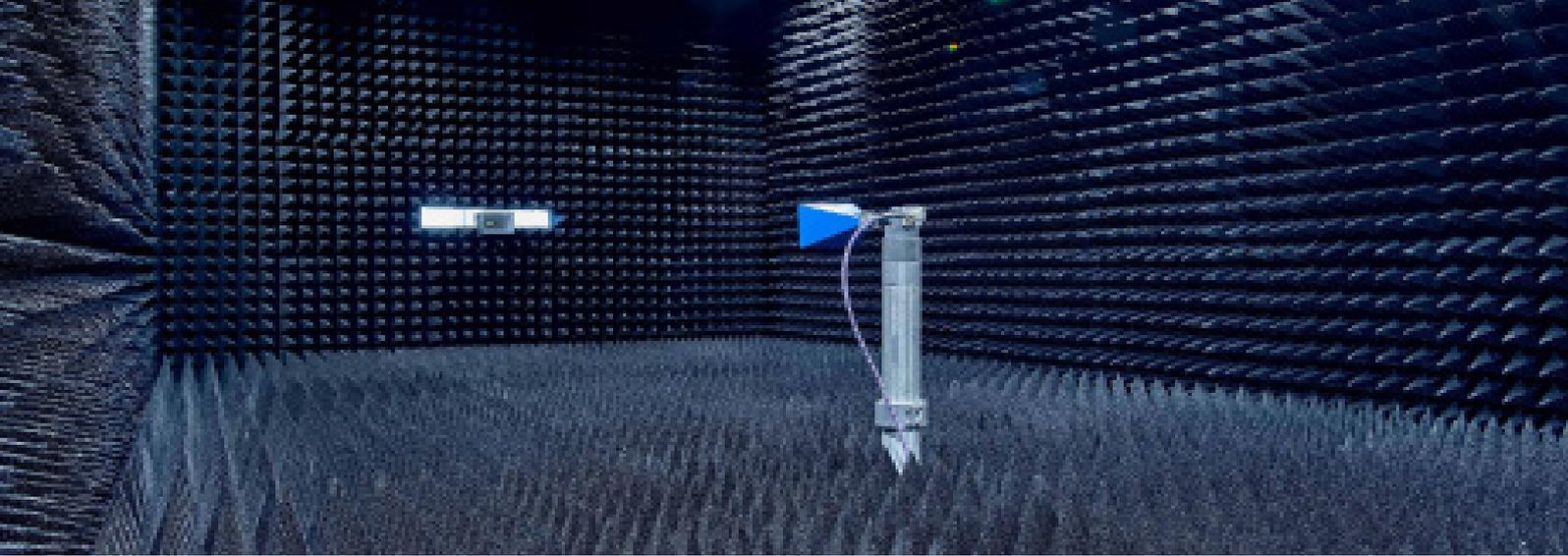
- RF measurement, characterization and test of dielectric materials, interconnects and packaging technologies, RF spectroscopy

Devices & Components Char- acterization & Test

- Wafer level characterization (current-, capacitance-voltage, biased temperature stress, TSV measurement, mercury probe)
- On-wafer small- and large-signal characterization (from DC to THz)
- In-circuit measurements of mm-wave components and modules up to 1.1 THz
- Antenna measurement and characterization, EM near-field characterization, beamforming and functional tests
- Functional and layout verification, electromagnetic modeling, simulation and testing, real-time time-domain dynamic analysis
- Pulsed isothermal S-parameter measurements
- Load-pull, noise, power and DC measurements
- Digital PA-based MIMO characterization

System Test & Reliability

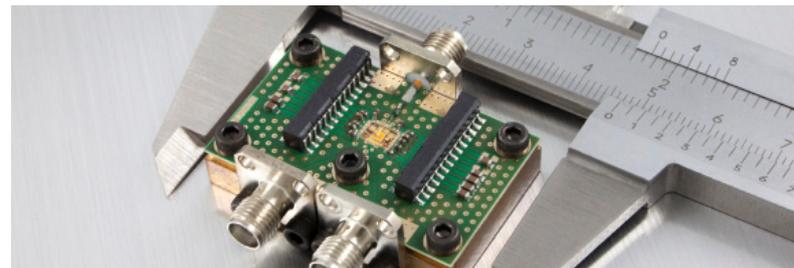
- Power capability, third-order intercept point (IIP3), 1 dB compression point
- Wideband power amplifier measurements with DPD
- Supply and load modulation systems (MISO) with DPD
- THz imaging and spectrometer setup
- System analysis, environmental assessment and eco-design for RF systems



Technology Example: 5G Infrastructure for Future Wireless Communication

The increased data rates of 5G mobile communication will meet user demands in urban areas and make efficient use of today's limited bandwidth. However, the technologies required for 5G communication will differ vastly in terms of energy efficiency, agility, bandwidth, RF output power, frequency usage, and latency. The extremely efficient, flexible solutions developed at Leibniz FBH are a crucial step toward meeting the requirements of future 5G systems up to the mm-wave range. The semiconductor technologies applied in their development are based on in-house GaN and InP processes for highest output power in the mm-wave range. Two main strategies are pursued: (1) improving back-off efficiency with GaN-based envelope tracking systems and a fully digital transmitter; (2) developing InP-based components for a mm-wave 5G infrastructure with unprecedented perfor-

mance. The first approach requires very efficient GaN switching stages, the design and fabrication of which Leibniz FBH now specializes in. Game-changing results have been achieved, including back-off efficiencies superior to established solutions. The second main strategy has also yielded results, including the realization of front-end components for future 140 GHz 5G wireless networks.



Fully digital transmitter chain for base station application.

Technology Example: MIRANDA-94 – High Resolution Real Time SAR Imaging

FMD member institutes Fraunhofer FHR and IAF joined forces to develop an advanced, real-time synthetic aperture radar (SAR) – known as MIRANDA-94. The mm-wave system is a miniaturized radar sensor optimized for use in ultralight aircrafts. The radar is backed on the aircraft by a mechanical beam stabilization - using a programmable gimbal that allows linear and nonlinear trajectories to perform SAR imaging for various applications. The real-time evaluation for the MIRANDA-94 SAR images was developed in a multinational EU project. The SAR image depicts the compound of Fraunhofer FHR. MIRANDA-94 operates at a center frequency of 94 GHz at a resolution of less than 15 cm. To achieve such high resolution, the system has to work with a bandwidth larger than 1 GHz. The high operational frequency and large bandwidth place great demands on the components of the RF transceiver, signal generation, and signal processing.

Fraunhofer IAF drew on their sophisticated III-V semiconductor technologies to construct the mm-wave components for the transceiver module, while Fraunhofer FHR took responsibility for the system integration and applied its long-standing experience in measurement campaigns of airborne radar systems to the project.



SAR image of the compound of Fraunhofer FHR measured with MIRANDA-94 with 94 GHz operational frequency and 2 GHz bandwidth. The resulting image resolution is 7.5 cm.

Research Fab Microelectronics Germany (FMD)

The Research Fab Microelectronics Germany (FMD) as a cooperation of the Fraunhofer Group for Microelectronics with the Leibniz Institutes FBH and IHP is your central contact for all questions concerning micro- and nanoelectronics in Germany and Europe. As a One-Stop-Shop, FMD combines the scientifically excellent technologies, applications and system solutions of the cooperating institutes into a combined overall offer in order to actively address the current and future challenges of electronics research. Under the virtual roof of FMD, Europe's largest R&D cooperation has been created, which, with its 2,000 researchers and its unique diversity of competencies and infrastructures, provides customers and partners with easy access to new applications and high technologies at different technical levels of maturity. The FMD offers a comprehensive and Europe-wide unique range of services for companies, especially for small and medium-sized enterprises (SMEs) but also start-ups, and is an important innovation driver and strategic dialog partner.

In this way, the Research Fab Microelectronics Germany strengthens the competitiveness of Germany as a microelectronics location and ensures further technological sovereignty along the entire value chain. Together with its international partners from science and industry, FMD also actively contributes to the German and European research agenda, thereby providing important impetus for the development of elementary innovations for the world of tomorrow – to the benefit of society and the strengthening of the German and European economy.

A cooperation of



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