RESEARCH FAB MICROELECTRONICS GERMANY (FMD)

The Virtual Institute for Combined Microelectronic Research and Development

Forschungsfabrik Mikroelektronik Deutschland

Fraunhofer Group for Microelectronics in cooperation with Leibniz institutes FBH and IHP

Fraunhofer MIKROELEKTRONIK

Leibniz Ferdinand Braun Institut

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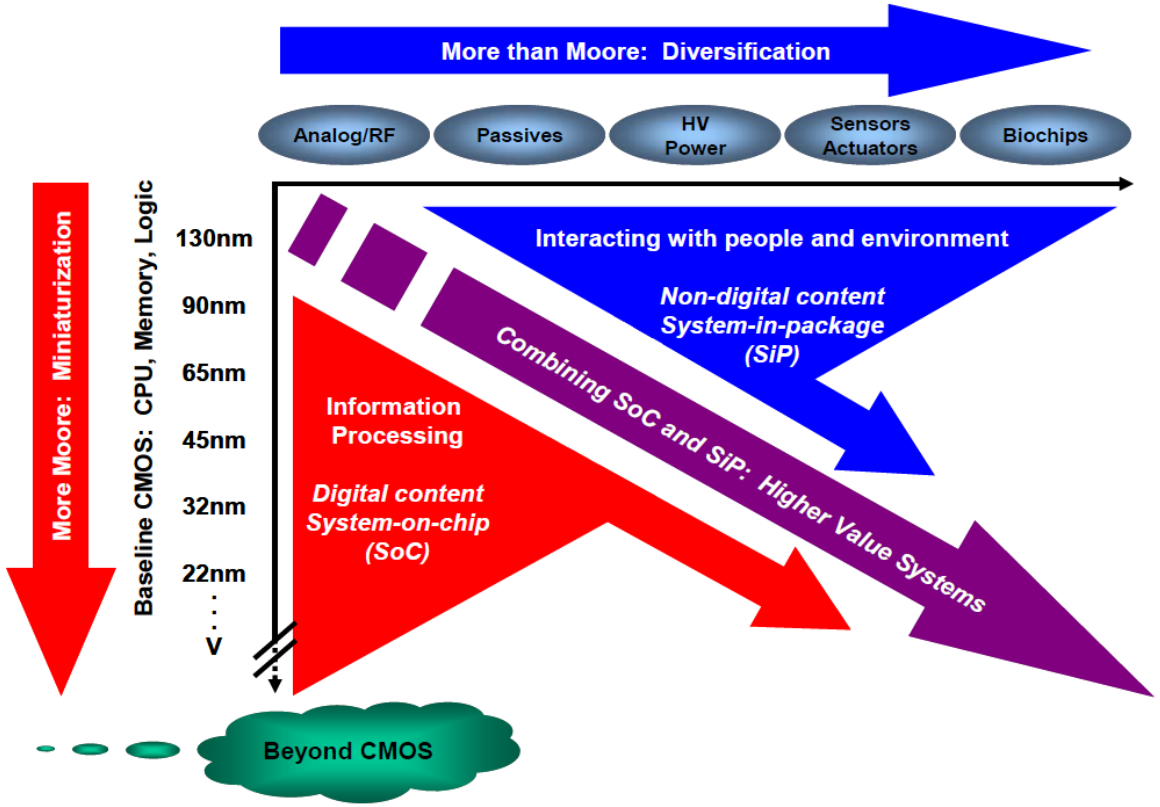
Mircoelectronic development trends

- **Micro- and Nanoelectronics** are key enabling technologies for all major industrial areas in Germany and Europe

- The development cycles are decreasing rapidly in the area of leading-edge technologies (»More Moore«) as well as in the field of microsystems (»More than Moore«)

- **New development and solutions for the Internet-of-Things could be generated only by strong cooperation efforts between different expertises**



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After handing over the grant approvals issued by the Federal Ministry of Education and Research, April 6, 2017 in Berlin

- Project volume 348,1 Mio. Eur
  - Fraunhofer 279,6 Mio. Eur
  - Leibniz 68,5 Mio. Eur
- Duration 4 years (2017-20)

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Project Research Fab Microelectronics Germany

- Largest Federal Ministry of Education and Research Project in the area of Microelectronics
- Targets
  - Setup of a virtual institute for the coordination of the cooperation partners inside the technology parks
- Investments in new machinery across the four technology parks:
  - Silicon-based technologies
  - Compound semiconductors
  - Heterointegration
  - Design, testing and reliability

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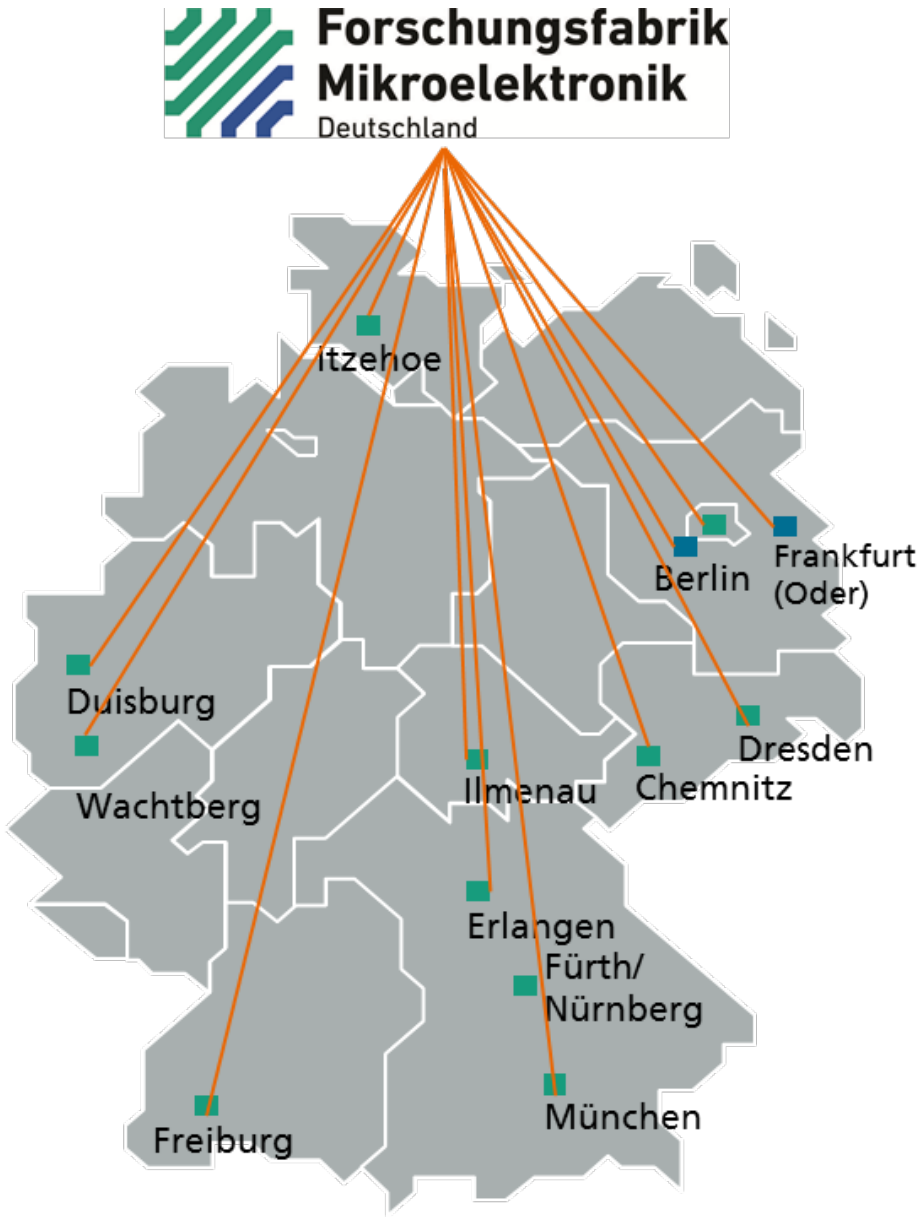
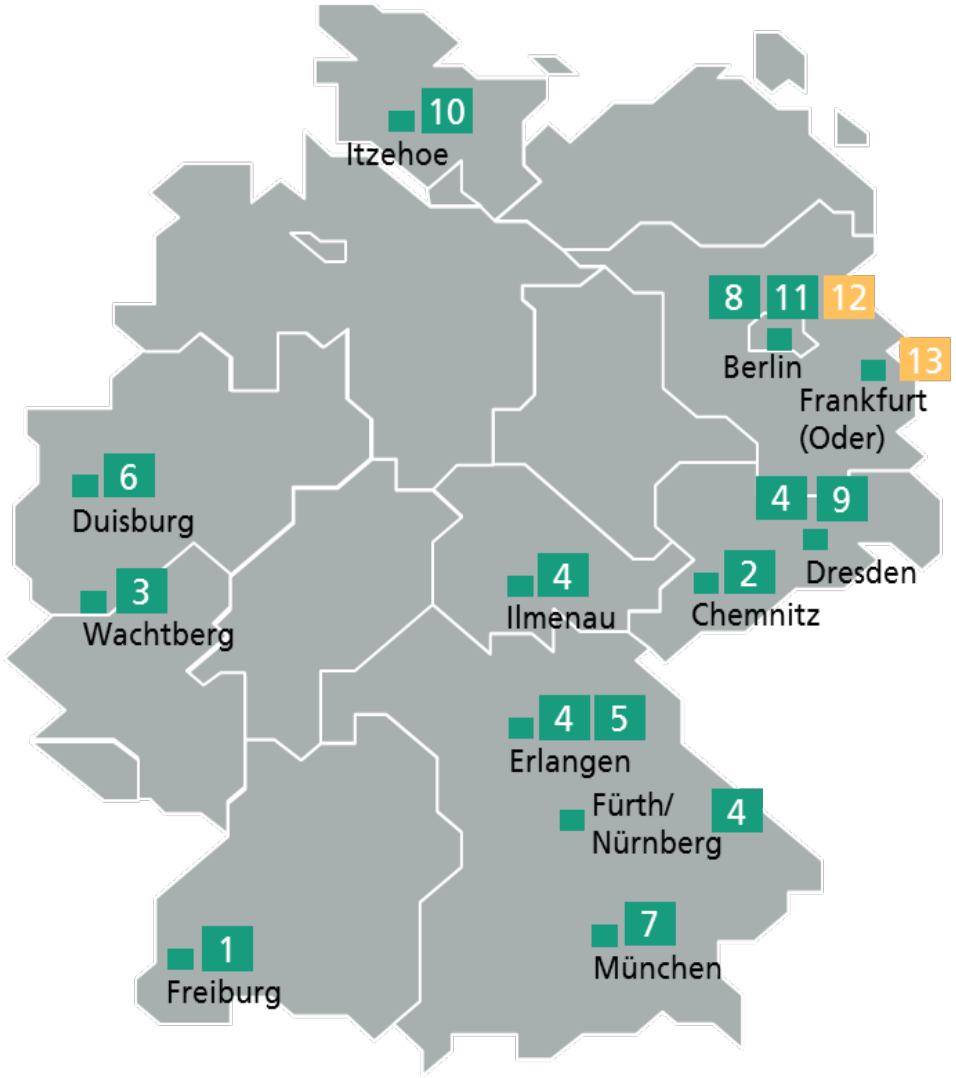


One-Stop-Shop for developments from wafer technologies to complete systems

- The FMD combines the expertise and infrastructure of 13 Research Institutes to deliver complete developments out of one hand
- The FMD will represent a reorganization of more than 2000 scientists and the necessary equipment for technological research and development under a single, virtual roof
- To prepare the FMD for future developments additional infrastructure investment of 350 Mio. € is planned

Research Fab Microelectronics Germany – Founding Participants



Fraunhofer Institute for

1 Applied Solid State Physics **IAF**
2 Electronic Nano Systems **ENAS**
3 High Frequency Physics and Radar Techniques **FHR**
4 Integrated Circuits **IIS**
5 Integrated Systems and Device Technology **IISB**
6 Microelectronic Circuits and Systems **IMS**
7 Microsystems and Solid State Technologies **EMFT**
8 Telecommunications, Heinrich Hertz Institute **HHI**
9 Photonic Microsystems **IPMS**
10 Silicon Technology **ISIT**
11 Reliability and Microintegration **IZM**

Leibniz Institute for

12 Hoechstfrequenztechnik, Ferdinand-Braun-Institut, **FBH**
13 Innovations for High Performance Microelectronics **IHP**

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FMD One-Stop-Shop

FMD One-Stop-Shop

Technology Park 1

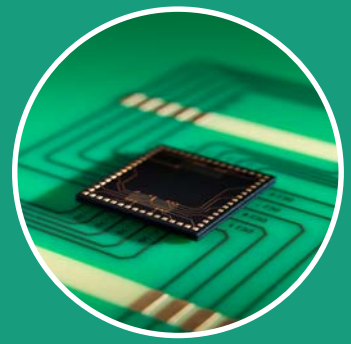
Investment
140,6 Million Euro

Silicon-based technologies

Technology Park 2

Investment
73,3 Million Euro

Compound semiconductors



Technology Park 3

Investment
43 Million Euro

Heterointegration

Technology Park 4

Investment
83,8 Million Euro

Design, testing and reliability

Research Fab Microelectronics Germany

Competencies alongside the value chain

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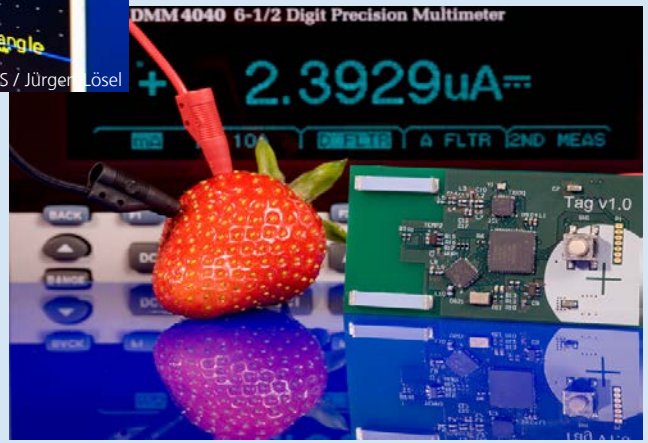
Research Fab Microelectronics Germany

Competencies alongside the value chain

Design & Design Methods	Materials and processes Devices and components	Heterogeneous Integration / SiP	Characterization, Test & Reliability

- Design Methods
  - Modeling and simulation
  - Function verification
- Design
  - System design
  - Component design and IP
- Prototyping
  - Hardware-in-the-loop concepts
  - Emulation



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Technology Park 4 »Design, testing and reliability«
Design methods and prototyping

- Functional Safety
  - verifiable design safeness, particularly regarding system integrity already in early design phases
  - integrated verification environment from concept via implementation to prototyping
  - Hardware-in-the-Loop
- Low-Power
  - development of analog and digital ultra-low-power circuits ("zero power design")
  - characterization and evaluation e.g. of future energy-efficient storage concepts
- Extension of design capabilities to FDSOI and FinFET technologies
- Focus of applications on: mobility, industry 4.0, IoT

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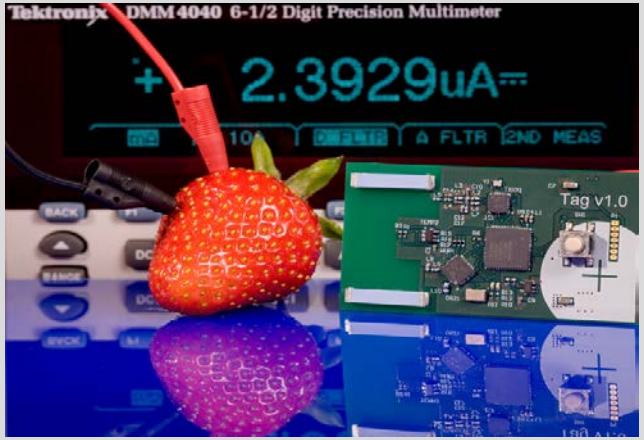

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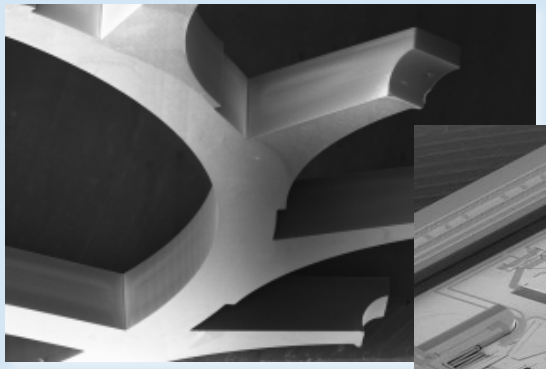
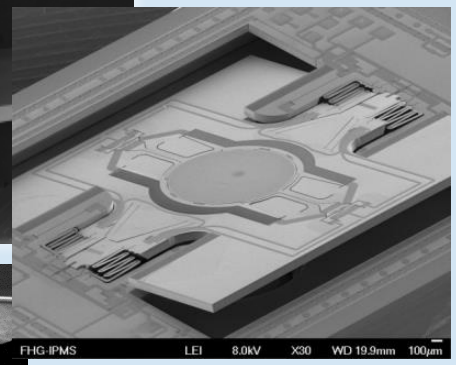
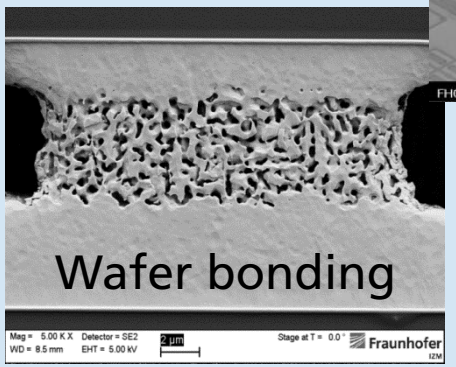
Competencies alongside the value chain

Design & Design Methods | Materials and processes Devices and components | Heterogeneous Integration / SiP | Characterization, Test & Reliability



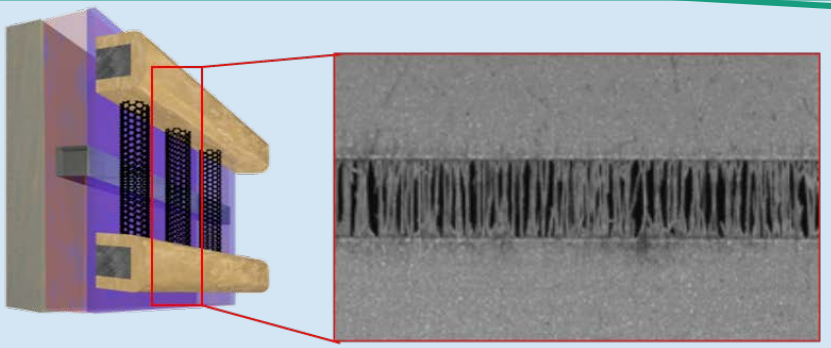
Bulk micromachining

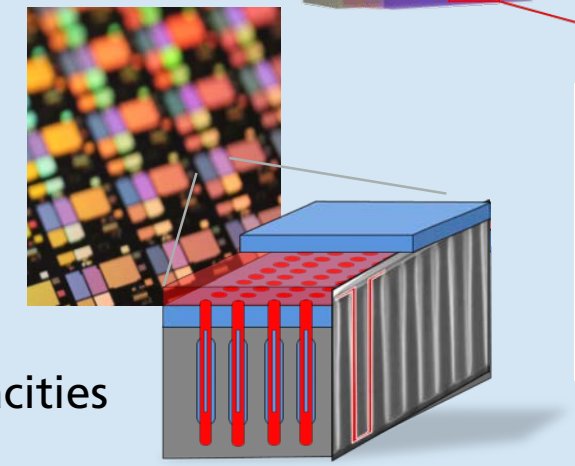




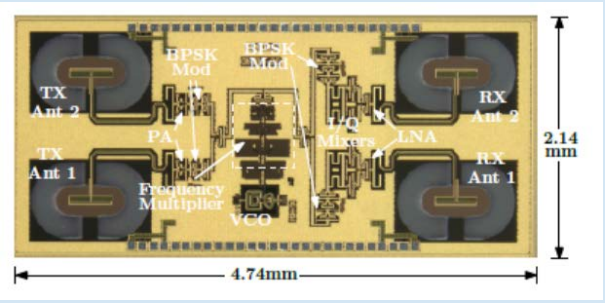
Wafer bonding

CNT based FETs





Silicon capacities



BiCMOS integrated THz antenna

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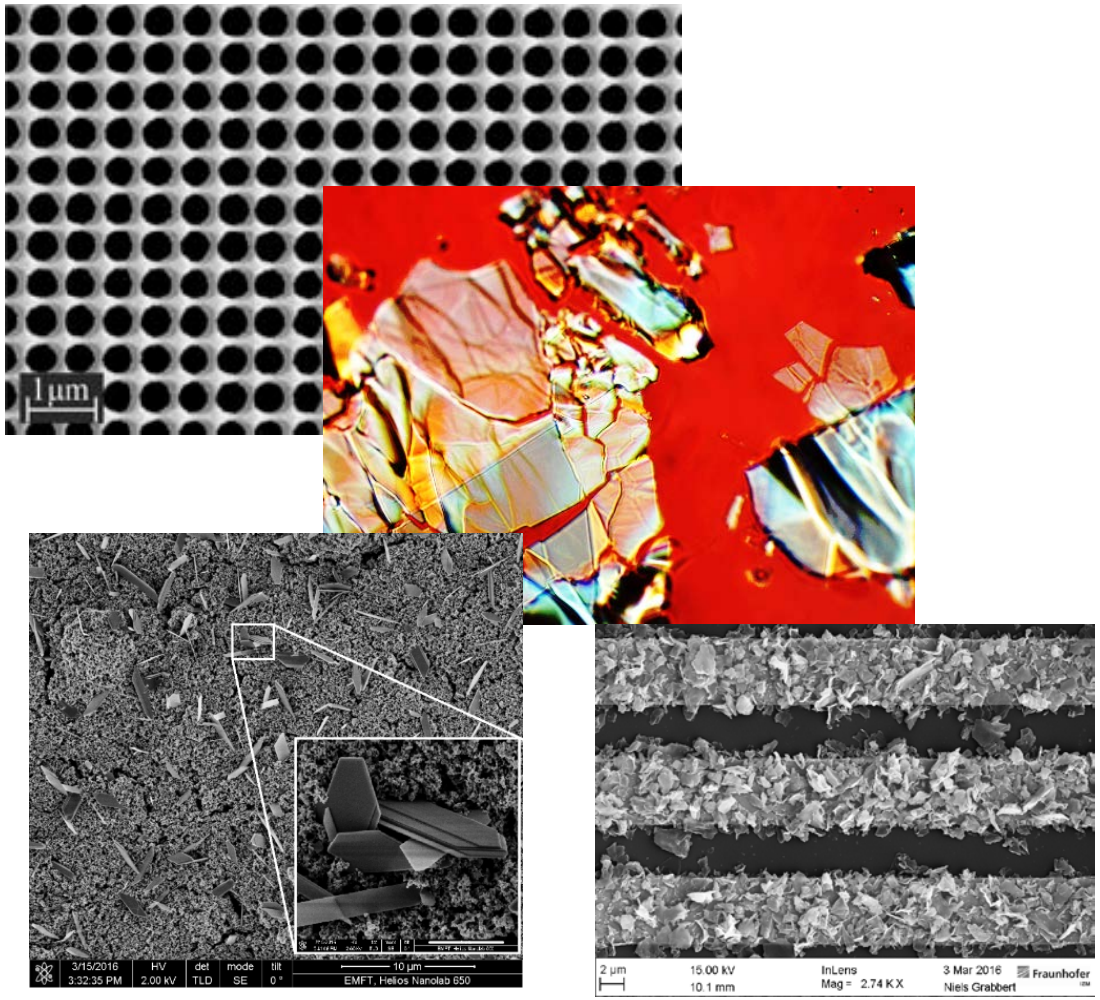
Technology Park 1 »Silicon-based technologies«

Novel material systems for chemical and physical sensors/actuators



- Plasmonic structures
  - Nano-antenna for THz/mid-infrared sensors
  - Spectroscopic anti-reflexion layer and reflection layers
  - Bio-sensors
- Novel Materials for physical/chemical sensors
  - Metal-Dichalcogenides
  - Carbon Nano-Tubes, Fullerene, Organic molecules and Layers
  - Nanoparticle systems
- CMOS compatible piezoelectric materials

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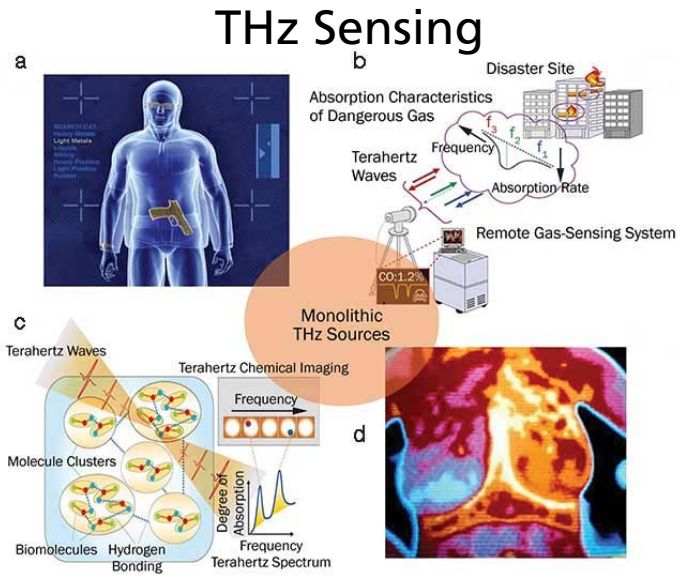
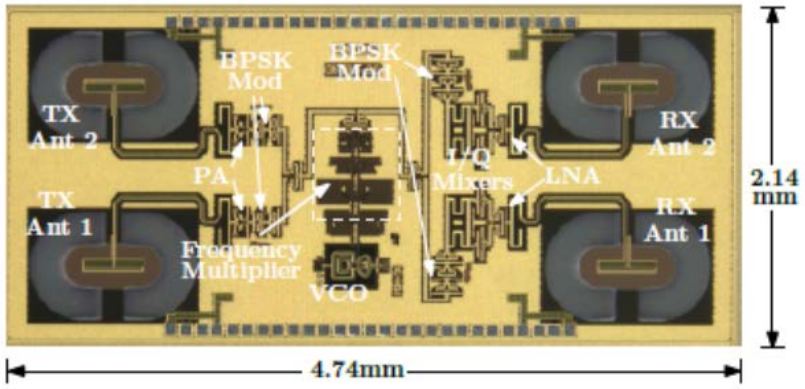
Technology Park 1 »Silicon-based technologies«

SiGe based high frequency and sensor devices

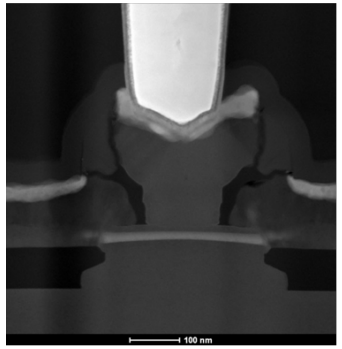




BiCMOS integrated THz antenna

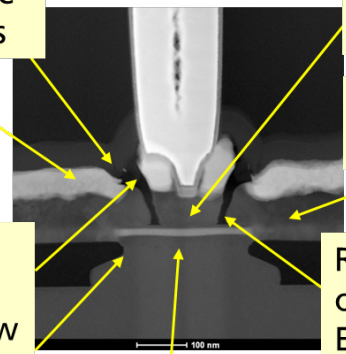
- MEMS based devices for Terahertz sensors
- Terahertz antennas
- BiCMOS High frequency devices

Starting Point SG13G2



Final Status (D7)

[Heinemann, IEDM 2016]



Narrower Silicide Blocking Spacers

Emitter Deposition

Ni Silicide

External Base Formation

Scaled Emitter-Poly Width & Collector Window

Reduced Width of Emitter & Emitter-Base Spacer

Millisecond Flash Annealing & Low-Temperature Backend

SiGe Base Profile & Adjacent Low-Doped Emitter & Collector Region

Hard-Mask for Selectively Implanted Collector (SIC)

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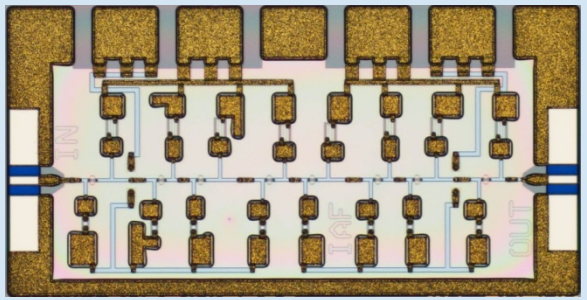
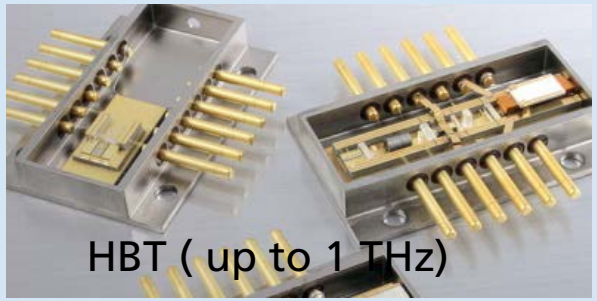
Competencies alongside the value chain

Design & Design Methods | Materials and processes Devices and components | Heterogeneous Integration / SiP | Characterization, Test & Reliability

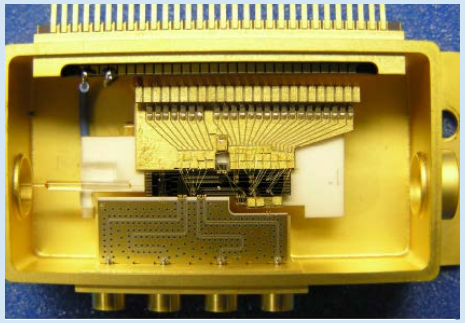
Highest Frequency Devices and Circuits



mHEMT (up to 1 THz)



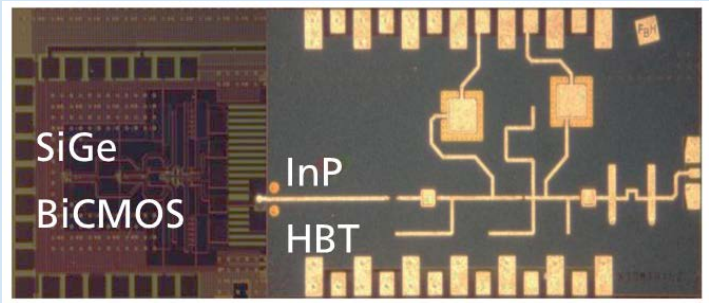
HBT (up to 1 THz)



InP based optoelectronics

Wide Bandgap Power Electronics

SiC 3300V MOSFET



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Technology Park 2 »Compound semiconductors«

Highest Frequency Devices and Circuits

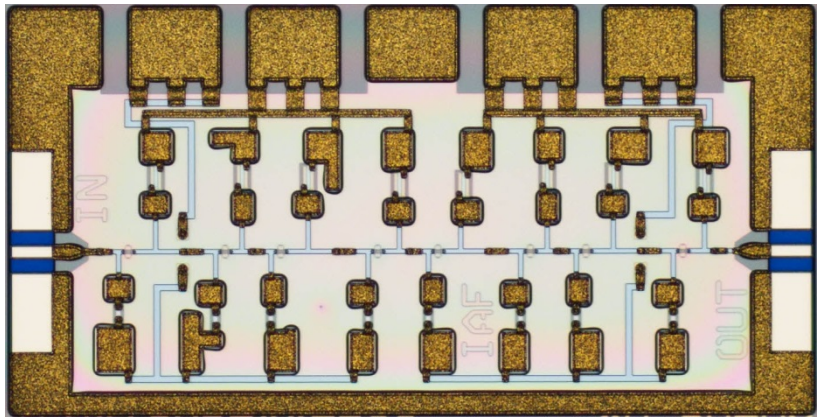
IAF Freiburg, FBH Berlin

Highest frequency technologies up to 1 THz

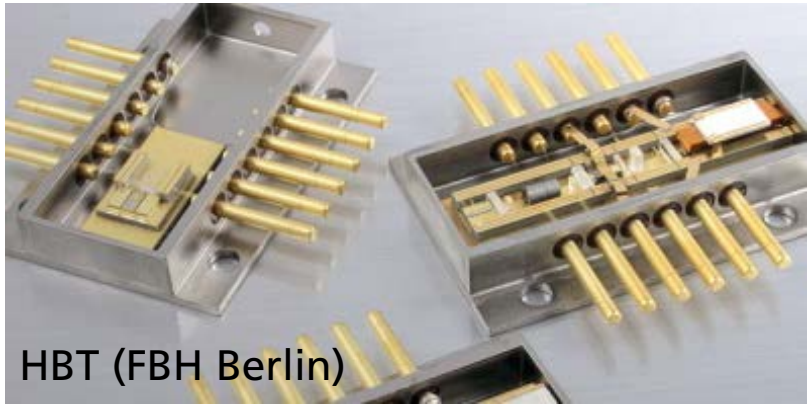
- InGaAs-on-GaAs metamorphic HEMT (mHEMT) technology for extremely low noise broadband amplifiers (esp. receivers)
- InGaAs-on-InP Heterojunction Bipolar Transistor (HBT) technology for transmitter with extremely high power density

Applications

- Electronic circuits up to 1 THz for
  - High-resolution Radar sensors and 3D cameras
  - Radiometers with highest sensitivity for satellite-based earth observation
  - mm-wave (~300GHz) wireless communication with highest bandwidths
    → 300 GHz directional radio link demonstator "Terranova"



mHEMT (IAF Freiburg)



HBT (FBH Berlin)

Purely electronic access to so-called "Teraherz gap"

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Technology Park 2 »Compound semiconductors«

Optoelectronics for Data Communication and Generation of THz Radiation

HHI Berlin

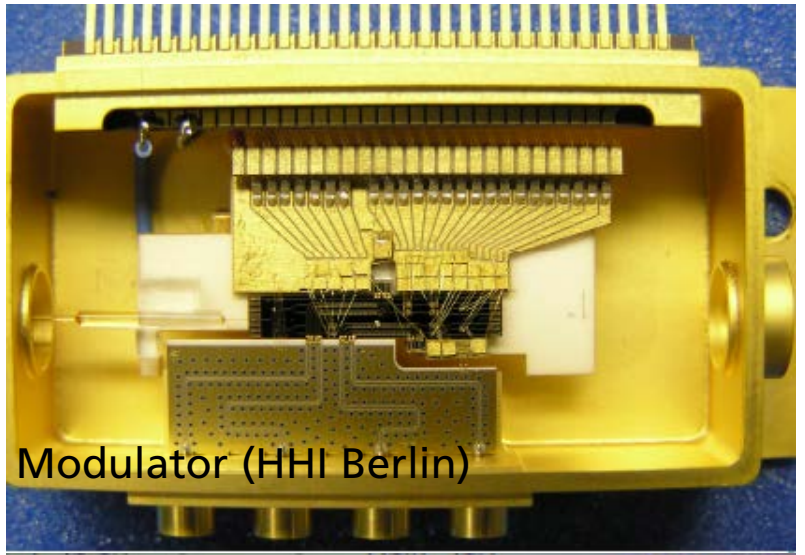
Glas fibre-based optoelectronics for data communication

- InP-based optoelectronics (modulators, detectors, lasers, THz-photoemitters) at 1310 nm and 1550 nm
- Integrated Photonic Circuits (PICs): completely on InP substrates, or as InP chips for integration with Si photonics or polymer photonics

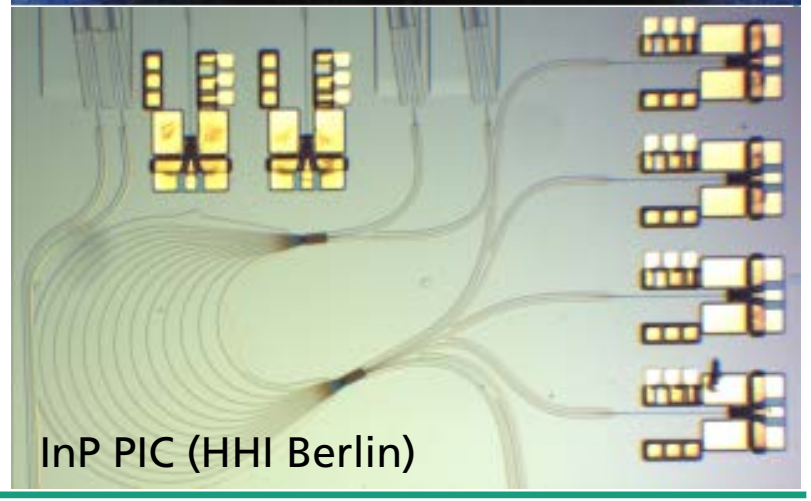
Applications

- Transmitter and receiver chips with data rates up to 1 Tb/s for optical fibre networks (intenet backbone)
- Integrable InP transmitter chips for Si photonics and polymer photonics in optical interconnecs (e.g. rack-to-rack in server rooms)
- InP transmitter und receiver chips for THz measurement systems with 0.1-6 THz for nondestructive material analysis

Highly efficient industry standard for fibre-optic communication



Modulator (HHI Berlin)



InP PIC (HHI Berlin)

Technology Park 2 »Compound semiconductors«

Wide Bandgap Power Electronics

IISB Erlagen, IAF Freiburg, FBH Berlin, ISIT Itzehoe

SiC based Power and High Temperature Electronics

- Novel voltage classes up to 10 kV
- Permanent operating temperatures > 250°C
- Vertical diodes and MOSFETS, bipolar high voltage switches, compensation devices

GaN based power switches, converters and amplifiers

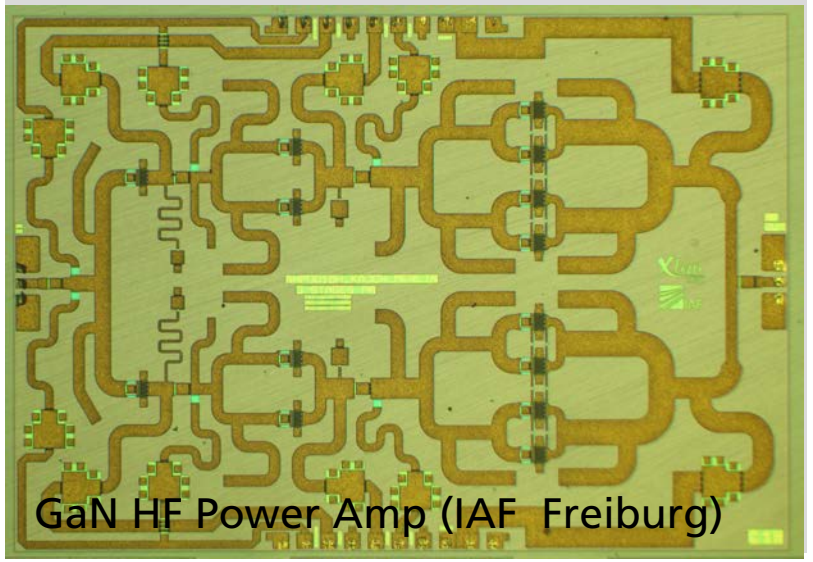
- Power conversion from kHz up to 100 MHz for switching power supplies
- RF power amps for mobile communication and radar up to 300 GHz
- Novel vertical diodes and MOSFETs up to 1.2 kV
- Fabrication on SiC (up to 100 mm) and Si (up to 200 mm) substrates

Novel semiconductors with very large bandgap

- Evaluating the potential of AlN (6 eV), Ga_2O_3 (4.8 eV)

Excellent electric strength, temperature stability, and cooling

SiC 3300V MOSFET (IISB Erlangen)



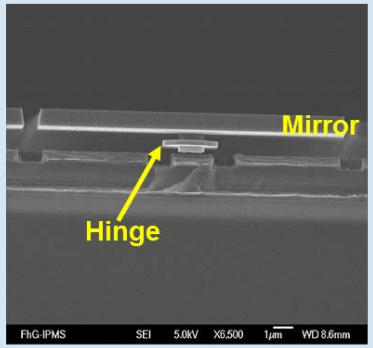
GaN HF Power Amp (IAF Freiburg)

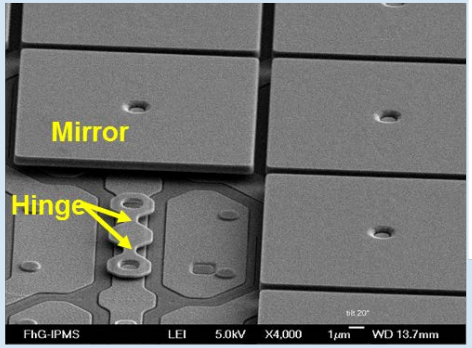
Research Fab Microelectronics Germany

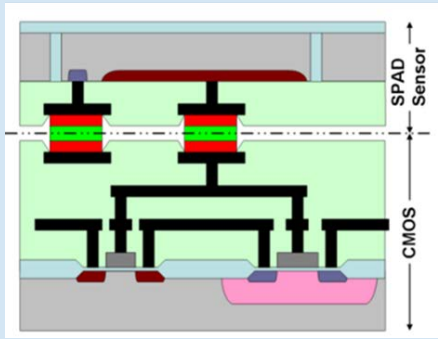
Competencies alongside the value chain

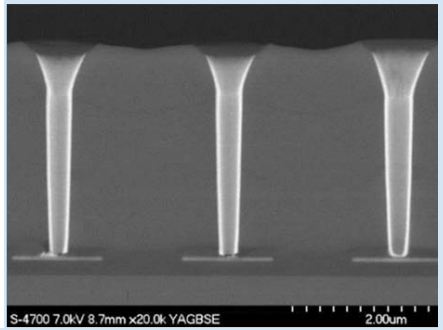
Design & Design Methods | Materials and processes Devices and components | Heterogeneous Integration / SiP | Characterization, Test & Reliability

- Post-CMOS integration technologies for sensors and actuators
  - SPADs
  - Pressure sensors
  - CMUTs
  - Chemical and biosensors
  - IR-Microbolometer-Arrays
  - Spatial light modulatora









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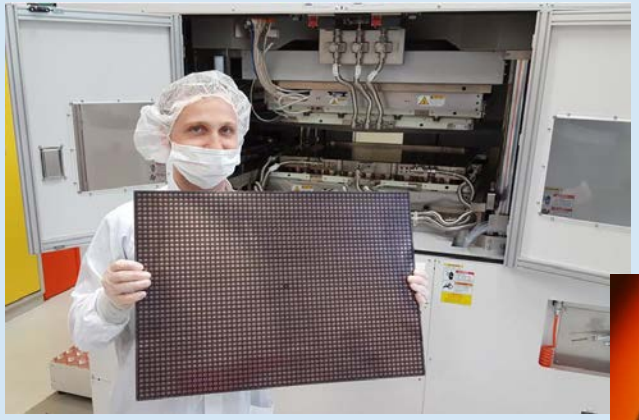
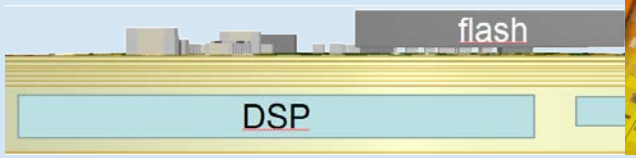
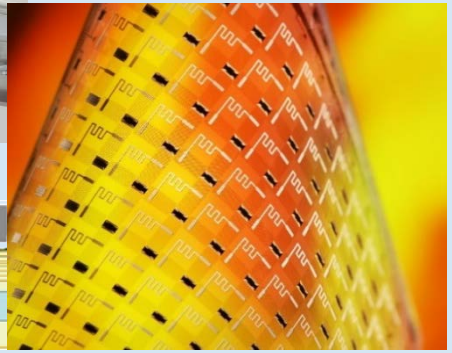
Competencies alongside the value chain

Design & Design Methods | Materials and processes Devices and components | Heterogeneous Integration / SiP | Characterization, Test & Reliability

- Memory, CPU, FPGA – (Single- & Multi Chip) Packaging
- MEMS, Sensor, Actuator
- Optoelectronic/Photonic
- Integrated Power Device
- Display/RFID/Flex
- RF and Analog Mixed Signal
- Advanced Substrate / Interposer







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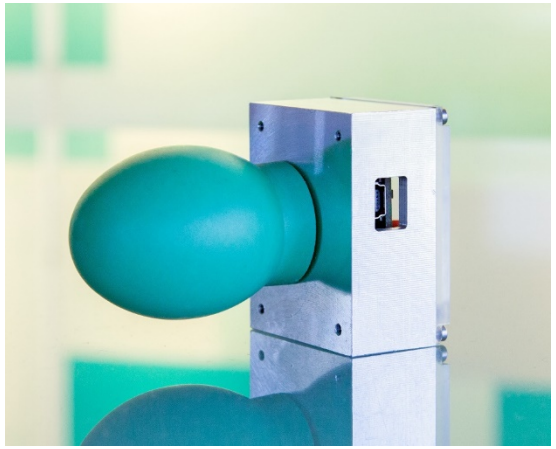
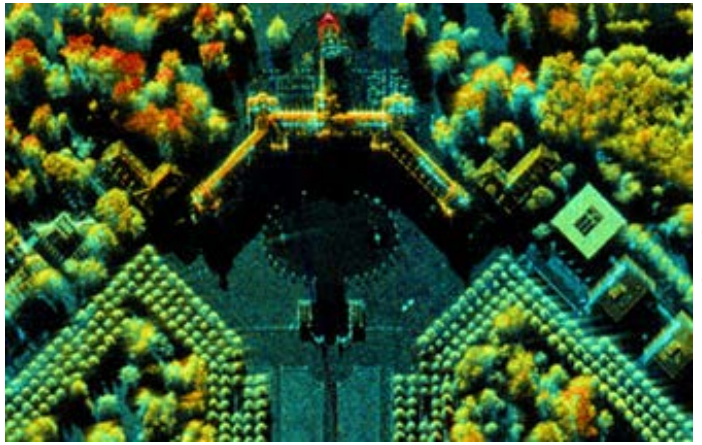
Technology Park 3 »Heterogeneous Integration«
MicroWave & TeraHertz Integration Line

- Radar Applications
  - Space to In-line-AOI
  - Security to Spectroscopy
- Ultra-high Bandwidth up to 300 GHz Radar
  - Highest achievable level of integration by integrating many components in one single SiGe-Chip
  - Very large applicable temperature range from -40 C up to +85 C.





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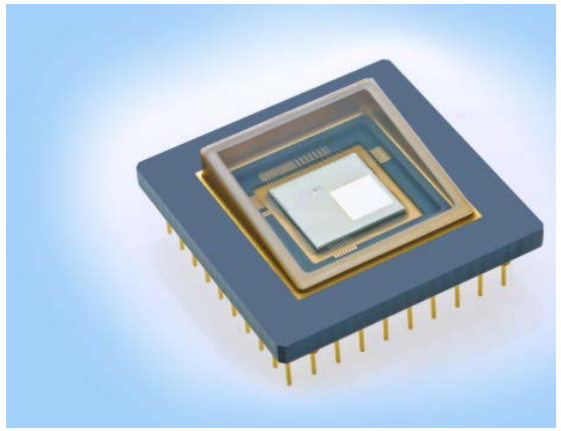
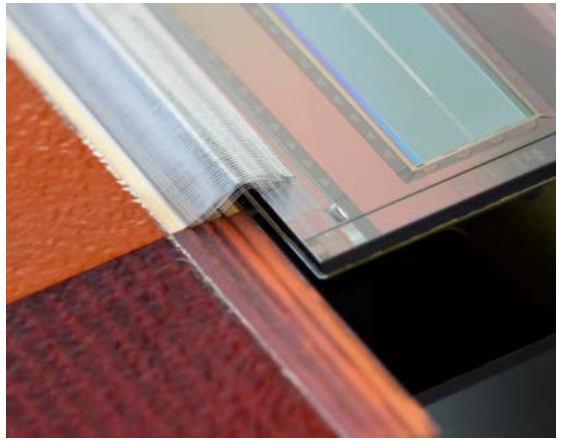
Technology Park 3 »Heterogeneous Integration«
NEMS/MEMS Packaging Integration Line

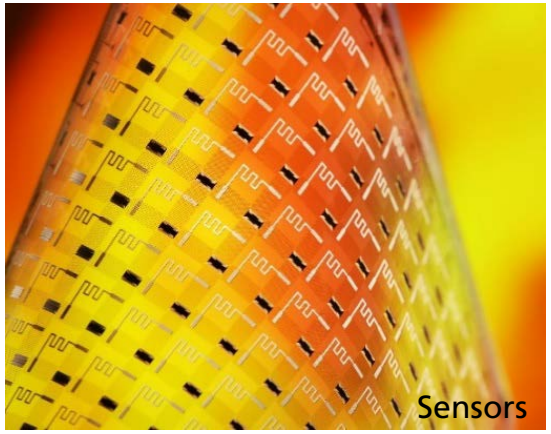
- Full Services Offer
  - Device and packaging construction (3D CAD)
  - Material selection (Package, Protection, …)
  - Simulation (thermal, optical, electrical)
  - Methodology evaluation
  - Chip Integration on Foil Sheets
- Technology Prospects
  - Extreme planar packaging technologies for several millions micro mirrors per chip
  - MEMS Packaging within clean room class ISO4 [US-Kl.10 – fully automated assembly



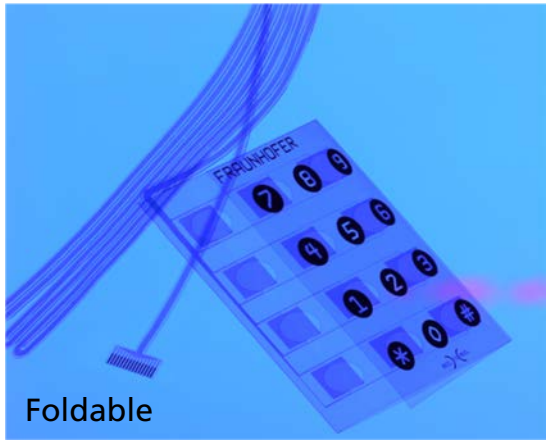


Technology Park 3 »Heterogeneous Integration«
Flex Substrate Integration Line

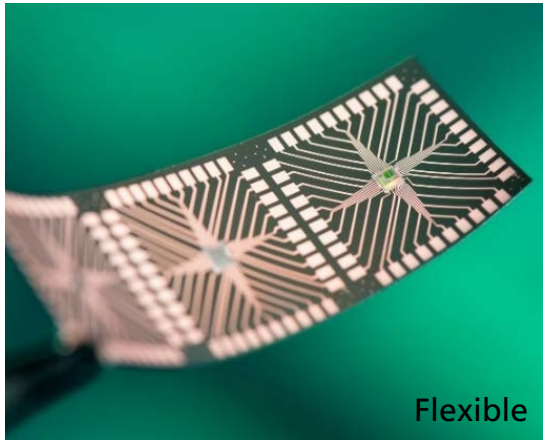
- Current Technology State
  - Production of high density redistribution layer on foils in Reel-to-Reel (RzR)
  - Chip Integration on Foil Sheets
- Technology Improvement
  - Integration of adaptive lithography for inline correction of the Foil Distortions within the Reel-to-Reel-process (RtR)
  - Extremely thin and foldable Chip-Foil-Packages in RtR
  - Module-based integration von multi-functional foil systems


Sensors


MEMS-IC



Foldable


Flexible

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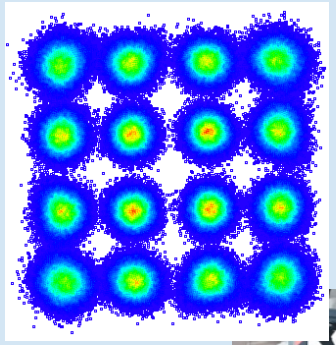
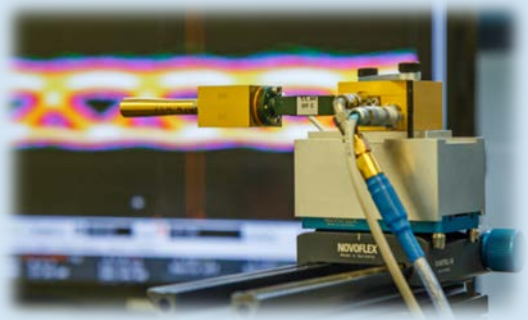
Competencies alongside the value chain

Design & Design Methods | Materials and processes Devices and components | Heterogeneous Integration / SiP | Characterization, Test & Reliability

- Characterization of materials and devices
- Measurement and analysis of circuits and systems
- Reliability assessment





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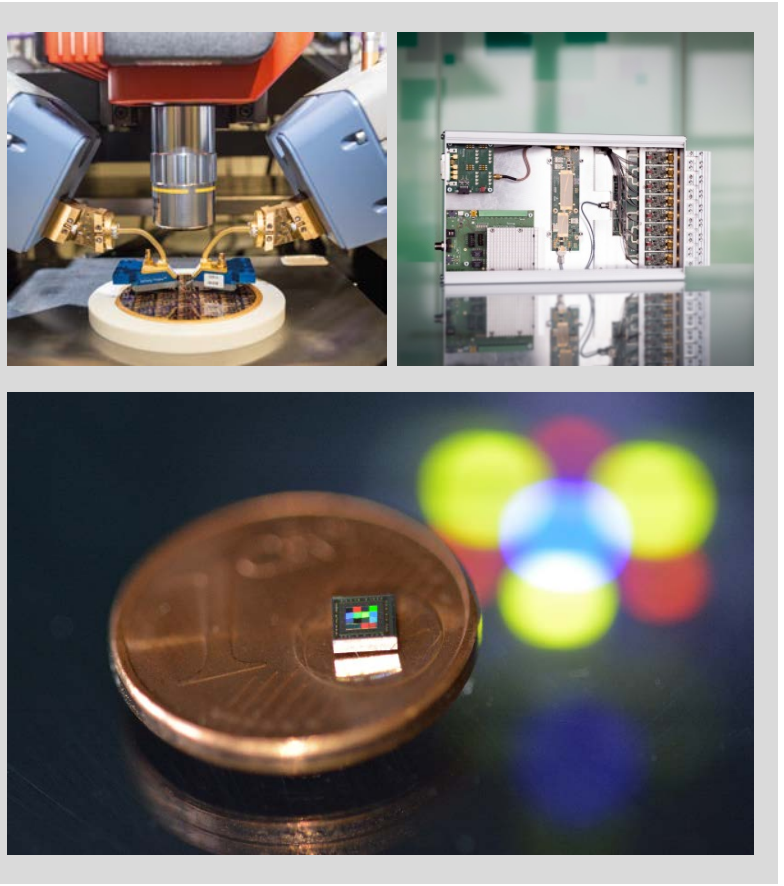
Technology Park 4 »Design, testing and reliability«
Characterization, measurement, and analysis

Characterization of materials and components

- General analysis and measurement equipment in almost all technological areas of FMD
- Special focus on
  - NEMS, MEMS, MOEMS
  - power-electronic devices

Measurement and analysis of circuits and systems

- Optoelectronic sensors
- Ultra-high frequency circuits and systems
- Digitalization of HF functions
- Novel sensor concepts



Technology Park 4 »Design, testing and reliability«

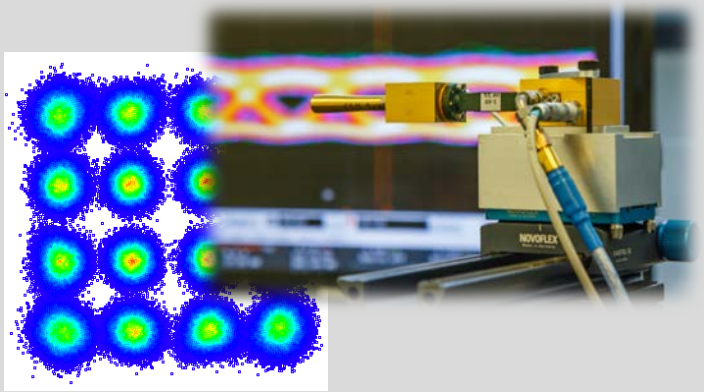
System test, test methods, and reliability

System test under realistic conditions

- New concepts of information processing
- Broadband data transmission
- New antenna concepts and integration technologies

Test methods and reliability assessment

- Test and analysis at component level with focus on complex structures
- Analysis technologies for evaluation of complex stress scenarios
- Design for reliability with focus on harsh environment



Contact

Jörg Amelung

+49 351 8823-339

joerg.amelung@mikroelektronik.fraunhofer.de

Stephan Guttowski

+49 30 46403-632

stephan.guttowski@mikroelektronik.fraunhofer.de

Forschungsfabrik Mikroelektronik Deutschland
c/o Fraunhofer-Verbund Mikroelektronik
Anna-Louisa-Karsch-Straße 2
10178 Berlin

www.forschungsfabrik-mikroelektronik.de

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