FRAUNHOFER IN INDIA

NEWSLETTER ISSUE 1 – 2025

MICROELECTRONICS - Carving a better future with precision technologies

Focus: Microwave & Terahertz, MEMS Actuators, Optoelectronics

CONTENT

FOREWORD

Ms Anandi Iyer
Director, Fraunhofer Office India

Dear Readers,

As we draw the curtains on 2024, we at the Fraunhofer Office in India look back at a year that was a great for Indo German Relations. India is steadily and surely gaining recognition in Germany, as witnessed by the several important German ministerial and business delegations between the two countries. It is not only due to the China + 1 policy. We believe that the incredible growth trajectory of India, as probably one of the very few countries with a projected GDP growth of over 7% in the post Covid VUCA world, the impressive, encouraging policies of the Indian Government that are spurring economic growth, unique innovations such as Digital Stack, the buzzing Start Up scenario and the dynamism of the entrepreneurial, qualified young workforce in India are all leading up to a powerful magnet that attracts world attention. Visitors from Germany have been struck by the energy, positivity, and vigour that India manifests in its interactions.

Whether Renewable Energy (ReInvest India), Semiconductors (SEMICON), the Asia Pacific Conference or the Indo German Bilateral Consultations, they all heralded the New India. And brought into sharp focus the opportunities and the commitment to address new horizons with vision and alacrity. We have had the privilege of being part of many of these initiatives and are delighted to have played a significant role in fostering R&D and Innovation cooperation between the two countries. Of particular significance is that this year also realised some lighthouse projects that we have been working on for some time. The Partnership with the Tamil Nadu Government in setting up a robust and collaborative innovation ecosystem kicked off in September 2024. We are excited about this partnership! The German Innovations, a new concept of bringing German companies together to "co-create and co-elevate" has been a great journey of collaboration, co-creation and co-innovation. We are extremely thrilled about this initiative and are working out the proof of concepts that address India specific challenges and seek to scale them up in partnership with Indian institutions. The Knowledge Paper on "How to transform India into a Technology and Innovation Hub" is a highlight of our cooperation, which we brought out in partnership with Mercedes Benz Research and Development Centre India. Special thanks to Mr Amitabh Kant for his valuable inputs and support. The next year promises to be even more exciting with some absolutely unique projects being rolled out. The Women-in-STEM exhibition and symposium, the partnership with C-DOT, the Energy Delegation to India, our cooperation with MeitY/CMET on Electronics, our collaboration on the German Innovations Initiative and of course the organisation of the 8th Fraunhofer Innovation and Technology Forum!

This edition showcases most of our highlights of 2024 and focuses on Semiconductors. In the current technological era, semiconductors are the bedrock of almost every modern device— from smartphones and laptops to electric vehicles and industrial machinery. These tiny yet mighty components power the digital world, facilitating advancements in artificial intelligence (AI), 5G, Internet of Things (IoT), and beyond. India, with its growing technological and economic footprint, stands at the crossroads of a semiconductor revolution, and its relevance in the country cannot be overstated. We have interviews with Mr Ajai Chowdhury, Chairperson - Quantum Mission India and Ex-Founder - HCL Ltd, as well as Prof Dr Albrecht Heuberger, Director of the Fraunhofer Institute for Integrated Systems and Chairperson of the Fraunhofer Microsystems Alliance. I am sure their insightful commentaries, the innovative technologies we have collated here, the highlights of 2024 will make for very interesting reading.

Wishing you all a wonderful season of happiness and cheer and a great start to 2025!

Anandi Iyer

An interview with
Prof. Dr. Albert Heuberger
Speaker of the Fraunhofer Research Fab Microelectronics Germany (FMD);
Executive Director, Fraunhofer Institute for Integrated Circuits (IIS)

1. How do you perceive the role of Germany's advanced R&D infrastructure in shaping the global innovation landscape in electronics design and manufacturing, particularly for optoelectronics and terahertz technologies?

In our digitalized high-tech living and working world, the availability of communication and data connections is a basic requirement. Due to the increasing mobility of users, the flexible use of broadband multimedia content (e.g. entertainment, medicine, and logistics) and future technologies, such as the Internet of Things (IOT) or autonomous driving, both data volume in mobile networks and demand on communication networks are growing. One promising option for increasing data capacity and usable bandwidth is the additional use of terahertz technologies. This forms the basis for innovation not only in the area of radio systems, but also in the area of non-destructive testing (NDT). Europe and especially Germany has a vibrant ecosystem of technology champions (sometime hidden) from traditional IDMs (integrated device manufacturer), foundries, material and equipment suppliers, design and test houses to integrators, OEMs (original equipment manufacturer) and vertical industries, including SMEs and start-ups. The competitive advantage of this ecosystem is based on superior semiconductor-based solutions. The R&D infrastructure is essential for the sovereignty and competitive advantage all these applications areas such as telecommunications, high-performance computing, Artificial Intelligence/Machine Learning, sensor systems, medical & scientific instrumentation and industrial manufacturing.

In RF and terahertz solutions, different frequency ranges have different requirement and opportunities for system integration. One basic reason for this is that there is not a single semiconductor technology, e.g. CMOS, which could meet all technical specs. Instead, one has a combination of technologies, typically CMOS with SiGe-BiCMOS and III-Vs (GaAs, InP, GaN-on-SiC or GaN-on-Si.) and, consequently, the typical RF module consists of several chips, with all the interconnect issues involved. Hence, in contrast to lower frequencies, when the chip integration approach is motivated by cost and yield aspects, in RF the additional benefit is that it allows for heterogeneous integration and facilitates use of chips in different technologies and from different fabs. High-frequency signals require therefore special packaging. The higher the frequency of operation the more critical the packaging. This is due to physical effects, since interconnect parasitics increase with frequency and parasitic modes etc. in the housing become an issue. While technical solutions are available on principle, in many cases they do not match the restrictions regarding volume scalability and fabrication cost. System-on-Chip (SoC) avoids most of the problems, but performance of SoC realizations degrades severely with increasing frequency so that SoC must be ruled out for many applications.

Photonics integration requires both optical and electrical connectivity. This significantly complicates the situation, which can be seen also from the fact that complexity and maturity of photonic integrated circuits (PICs) are much less developed than their electronic counterparts. Since the optical devices (light emitters, modulators, detectors) require wavelength-specific semiconductor processes, which are not suitable as optical interposers, heterogeneous integration is a must and the chiplet techniques is a logical advance from what is used for PICs so far. Novel back-end-of-line interface technologies will be used therefore for photonic chips based on InP and GaAs.

Brief profile of Prof. Dr. Albert Heuberger

Prof. Dr. Albert Heuberger is the spokesman of the Fraunhofer Microelectronics Group, the world's leading research group specializing in micro- and nano-electronic applications and systems. Additionally, he holds the position of Chairman of the Steering Committee of the Research Fab Microelectronics Germany (FMD). Prof. Heuberger's research focuses on communication technologies for IoT, 5G communication, as well as cognitive sensor technologies for mobility, industrial control, and health applications. Since 2011, Prof. Heuberger has been the Executive Director of the Fraunhofer Institute for Integrated Circuits (IIS) in Erlangen, Germany. Furthermore, he holds the Chair of Information Technology at the University of Erlangen-Nuremberg.

2. How has Germany's leadership in precision engineering and material science influenced the development of next-generation MEMS actuators for industrial and consumer applications?

Germany's expertise in precision engineering, combined with material development, forms the backbone of their advancements in machinery and precision product fabrication. The principles of MEMS and precision manufacturing are closely aligned, allowing for seamless transfer of techniques and materials between the two fields. This meticulous attention to detail and adherence to high standards have led to significant progress in micro-fabrication techniques, enabling the creation of exceptionally precise and reliable MEMS devices. German research institutions, like the Fraunhofer microelectronic institutes, and universities have been at the forefront of material innovation, developing novel materials that enhance the performance and durability of MEMS actuators. This synergy between precision engineering and material science has paved the way for MEMS actuators that are not only more efficient but also more adaptable to a wide range of applications, from industrial systems, like spatial-light-modulators or light scanning mirrors, to consumer devices, like all-silicon microphones and micro-speaker. Their efforts continue to inspire advancements that shape the future of MEMS technology.

3. What are the primary challenges in scaling these technologies from prototype to mass production, and how can applied research and international collaborations address these challenges?

In semiconductor sector, promising innovations often lack the necessary scaling options on the way to industrial maturity. Hence, the central function of prototyping is to provide a bridge from the laboratory to industrial production "From Lab to Fab". This helps to overcome the so-called "Valley of Death" in the transfer of semiconductor research to business, and hence facilitates not just keeping the industries in the cutting edge by faster development of new product generations, but also creating new businesses in the sector. The aim of the so-called System-Technology-Co-Design STCO design methodology ensures the necessary connectivity to the design platform and make the "From Lab to Fab"; process easier, more accessible, and efficient for companies, especially SMEs. Access to R&D pilot lines includes services for small volume prototyping, strategic collaboration, contract research, collaborative projects. Test kits lay the foundations for the services that include small volume prototyping, strategic collaboration with industry, contract research and innovative project design. This is typically supported alongside R&D contracts, providing a critical link between research and commercial scalability. The services include e.g. proof of concept, demonstrators with high TRL/ low volume production, prototype runs and small volume business, options to transfer high innovative products with volume forecast and support to expedite transfer of research results into applications.

One of the greatest strengths of research collaborations lies not only in achieving the project's specific goals but also in the dynamic exchange of ideas and expertise among partners during the project phase. These projects bring together diverse perspectives from academia, industry, RTOs, and others, fostering innovation through interdisciplinary teamwork. Early involvement of the key players necessary for scaling from lab to fab significantly strengthens the long-term success of a technology.

This advantage becomes even more pronounced in international collaborations, such as those within European frameworks. In Germany, we benefit from these well-established relationships with longstanding partners. However, expanding collaborations to countries like India offers an exciting opportunity to engage with entirely new partners who can contribute fresh ideas and business approaches, driving innovation processes to completely new levels.

4. What policies or frameworks have proven most effective in fostering innovation ecosystems in Germany, and how could these be adapted for a rapidly evolving technology landscape and a thriving market like India?

Electronic manufacturing currently involves partners for supply chains around the world: No local market or company has all the capabilities required for end-to-end semiconductor design and manufacturing.

Technological sovereignty and secure supply chains as well as energy efficiency and climate protection have become the defining topics of semiconductor technology. Therefore, green semiconductor manufacturing technologies take on a key climate protection task by ensuring the overall increasing energy requirements of the electronics industry is kept as low as possible over the long term. This requires implementing a systemic eco-design that generally minimizes the use of energy and resources, in particular the use of critical or strategic raw materials sparingly and reducing direct emissions from manufacturing processes to the absolute minimum.

Hardware technologies form the foundation of a growing number of business models across nearly all sectors. Despite their increasing relevance, specialized knowledge about semiconductor technologies often remains limited. This is where RTOs play a crucial role, acting as enablers of innovation from the earliest stages of development.

One of our most successful initiatives is the “space-projects” framework, designed to provide startups and SMEs with an easy access to cutting-edge infrastructure and technologies. These projects aim to collaboratively build prototypes with one or more FMD partner institutes. The resulting prototypes serve as proof-of-concept, empowering businesses to secure funding and elevate their products to the next stage of development.

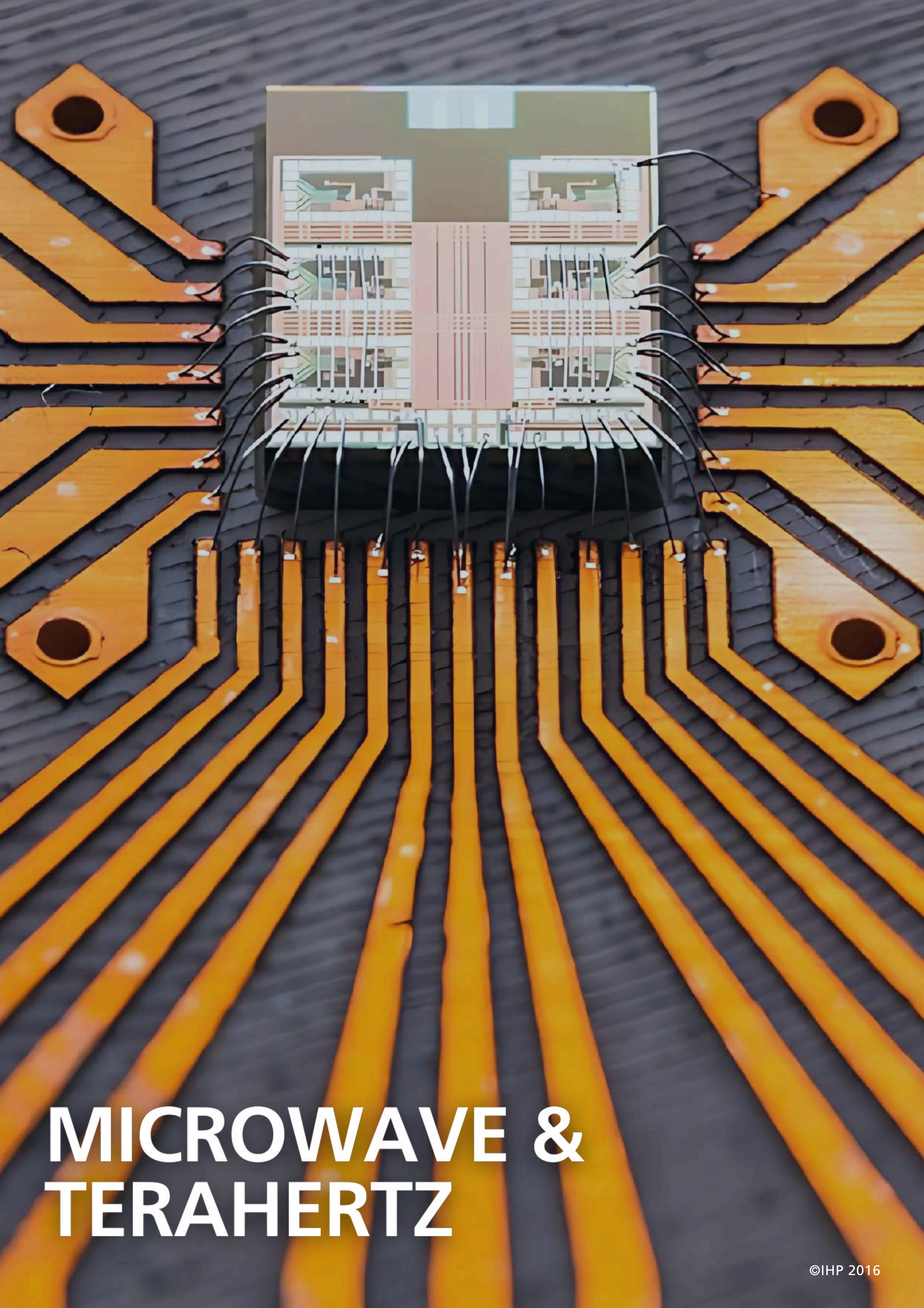
A key advantage of this program is its low barrier to entry. Businesses simply need to submit their idea for initial evaluation. Once a suitable partner institute is identified, they pitch their concept to an expert jury. Successful applicants can join the project immediately – fully funded by the German Ministry of Education and Research. This streamlined process ensures participants save both time and resources, which is particularly critical in dynamic and fast-growing markets like India.

5. What strategic collaborations between Fraunhofer and India could accelerate the adoption and commercialization of optoelectronic and terahertz solutions across critical sectors?

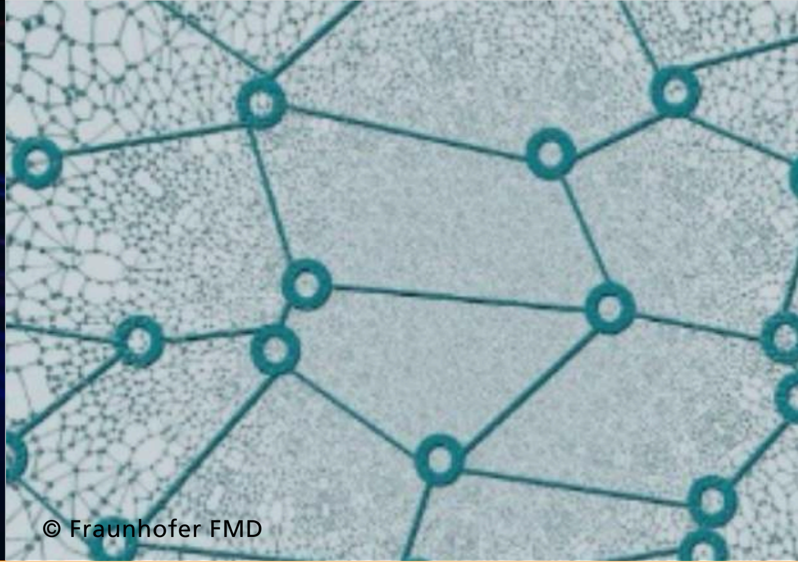
Although terahertz radiation is predestined for a wide range of applications, such as in security technology, quality assurance or materials testing, its industrial introduction has so far failed due to the lack of availability of inexpensive, fast, and high-resolution systems with optimized, AI-based image recognition algorithms. There are multiple connecting points with Researchers and Industrial Partners from India to booster optoelectronic and terahertz solutions.

FMD offers a multidisciplinary expertise and multiple areas of technology, bringing together researchers from different institutes to work towards a common goal, pooling resources and knowledge and to achieve synergistic outcomes. The institutes collaborate and work together both internally and with external partners through various mechanisms and approaches to leverage their expertise, resources, and capabilities effectively, e.g. joint projects, inter-institute cooperation, expert exchange, shared infrastructure/facilities, or technology transfer. The forms of collaboration include e.g. formal cooperation agreements or networks established enabling knowledge sharing, technology transfer, and joint initiatives across institutes, fostering innovation and efficiency. By sharing access to specialized infrastructure, laboratories, and equipment, Fraunhofer Institutes maximize resource utilization and enable access to state-of-the-art facilities for research and development activities. Summarizing, Fraunhofer institutes have wide experience, strong culture, and well-tested practices for intense collaboration.

In particular, after selection of a project proposal and implementation plan, the FMD will organize the implementation process and help optimize the project execution.



MICROWAVE & TERAHERTZ



Terahertz technologies for visionary innovations in communications and sensor technology

In our digitized, high-tech living and working world, the availability of communication and data connections is a basic requirement. Due to the increasing mobility of users, the flexible use of broadband multimedia content (e.g., entertainment, medicine, and logistics), and future technologies, such as the Internet of Things (IOT) or autonomous driving, both data volume in mobile networks and demand on communication networks are growing. One promising option for increasing data capacity and usable bandwidth is the additional use of terahertz technologies. This forms the basis for innovation not only in the area of radio systems, but also in the area of non-destructive testing (NDT). Terahertz waves can penetrate most electrically non-conductive materials, such as ceramics or plastics, in a manner analogous to ultrasound and X-ray, but can be significantly more advantageous, because, for example, they do not require a coupling medium or radiation protection measures.

Although terahertz radiation is predestined for a wide range of applications, such as security technology, quality assurance, or materials testing, its industrial introduction has so far failed due to the lack of availability of inexpensive, fast, and high-resolution systems with optimized, AI-based image recognition algorithms. The "T-KOS" project, initiated by the Forschungsfabrik Mikroelektronik Deutschland (FMD) and funded with 10 million euros by the Federal Ministry of Education and Research, addresses this issue.

Project goals

The T-KOS project aims to develop terahertz technology synergistically for the first time in the fields of communication and sensor technology for industry. The Forschungsfabrik Mikroelektronik Deutschland (FMD) combines its technological competences for communication and sensor technology with the expertise of the Fraunhofer ITWM for this purpose. The researchers are studying terahertz radiation for its potential applications in industry. Our team is pursuing three overarching project goals:

- Industrially suitable terahertz communication and sensor technology by combining scalable electronic and photonic concepts.
- Inline monitoring of production processes with AI-based, real-time imaging processing for resource-efficient production.
- Application of terahertz communication in industrial production

Terahertz Photonics - for broadband, spatially and depth resolved sensing and imaging

In this development path, terahertz photonic systems with a bandwidth of 300 GHz - 2.5 THz are being developed for non-destructive, high-resolution industrial imaging. The basis is a photonic FMCW spectrometer. Within the framework of T-KOS, this will be further developed into a synthetic FMCW radar with eight distributed transmitter and receiver units each. At the end of the project, a depth-resolved, 3D terahertz imaging system in the frequency range of 300 GHz - 2.5 GHz with a lateral and a depth resolution of 0.3 mm will be demonstrated. The competences of the HHI in the field of

PROJECT INFORMATION

Project partners

- Fraunhofer FHR, Wachtberg (network coordinator)
- Fraunhofer ENAS, Chemnitz
- Fraunhofer HHI, Berlin
- Fraunhofer IAF, Freiburg
- Fraunhofer IMS, Duisburg
- Fraunhofer IPMS, Dresden
- Fraunhofer ITWM, Kaiserslautern
- Fraunhofer IZM, Berlin
- Research Fab Microelectronics Germany FMD, Berlin
- Ferdinand-Braun-Institut gGmbH/Leibniz-Institut für Höchstfrequenztechnik, Berlin
- IHP GmbH/Leibniz Institute for High Performance Microelectronics, Frankfurt/Oder

Project volume

EUR 10 million (of which 100% funded by BMBF)

Duration

May, 2021 - August, 2022

The project is funded by the German Federal Ministry of Research and Education (BMBF) (grant numbers 16KIS1404K, 16KIS1405 and 16KIS1406).

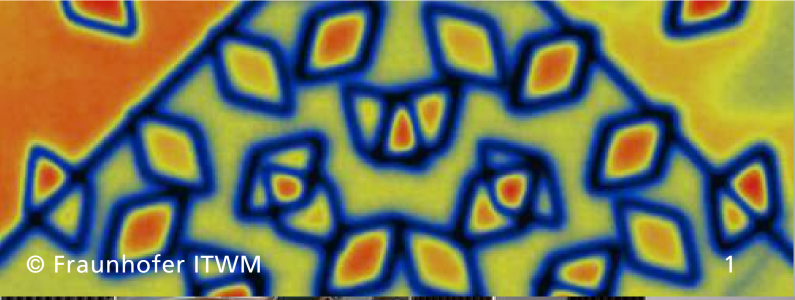
terahertz sensor systems, the competences of the ITWM in the field of terahertz signal processing and conditioning, and the competences of the FHR in the field of high-frequency radar will be combined. At the same time, concepts of hybrid photonic integration in the material platforms indium phosphide (InP) and polymer and silicon nitride (SiNx) are being developed in order to integrate the discrete components of the FMCW radar (lasers, phase modulators, optical amplifiers, and terahertz transmit and receive antennas) at chip level. Thus, by the end of the project, photonically integrated terahertz transmit and receive arrays with up to four4 individual elements will be demonstrated as phased array antennas. This highly scalable technology enables both dynamic beam steering, which can replace static sensor systems in the future, and the provision of cost-effective and compact terahertz sensor systems for measurement technology manufacturers.

Terahertz Line Scan Camera - for real-time industrial imaging

The goal of this development path is the scalable heterointegration of silicon germanium (SiGe) and indium phosphide (InP) chips. Together with real-time, capable AI-based signal processing, a high-speed inline measurement system for non-destructive monitoring of production processes with simultaneous high image quality will be developed. The technologies used will allow future use in production facilities with belt speeds of more than 10 m/s. The system demonstrator will provide proof of functionality for belt speeds of 1 m/s to 2 m/s. In order to ensure a high penetration depth into the components to be investigated while maintaining a high lateral resolution, frequencies around 300 GHz are used. The skills of FHR (radar systems and signal processing), FBH (InP electronics), IAF (terahertz front-ends), IHP (SiGe technology), IMS (AI-based signal processing), ENAS (functional tests and system analysis), IZM (industrial packaging), IPMS (Si-MMICs and low-power ASICS), and ITWM (terahertz measurement systems and fast radar imaging algorithms) are all brought together in this development path. The interface between signal processing and sensor hardware will be designed in such a way that the image reconstruction methods developed in terahertz photonics can also be used for this development path. Thus, a modular system concept for terahertz imaging for photonic and electronic components is created.

Terahertz Communication - High-bit-rate electronic and photonic radio links at carrier frequencies around 300 GHz and broadband channel characterization

The goal of this development path is to create radio systems in the terahertz band that can handle data rates of at least 100 Gbit/s. This will make it possible to use a point-to-multipoint radio network topology to build high-bit-rate, tightly meshed pico-cell radio networks for the first time. For this purpose, asymmetric solutions in the frequency range from 250 GHz to 320 GHz are investigated, which can achieve down-stream data rates per link in the range of ≥ 100 Gbit/s. In the upstream direction, data rates of 25 Gbit/s-100 Gbit/s are targeted. Either the TDMA or the FDMA method divides the available frequency spectrum. The resulting broadcasting transmitter capacities can thus be several 100 Gbit/s. Terahertz radio systems offer the possibility for applying very dense space multiplexing. These will be developed here for the first time as a functional demonstrator, especially for point-to-multipoint configurations with digital beam steering for SIMO broadcasting and MISO methods to distribute data streams in multiple spatial directions. The goal is to demonstrate bi-directional communication with at least two other terahertz transmit and receive units spaced 25 m to 100 m apart. Additionally, researchers are developing systems for over-the-air (OTA) testing and channel sounding to characterize the components of terahertz radio systems and precisely measure time-variant radio channels for future data transmission systems, covering frequencies up to 500 GHz. The skills of HHI in photonic terahertz source development, terahertz wireless communication systems, baseband signal processing, and radio channel characterization are brought together in this development path by IAF's skills in InP-based terahertz front ends.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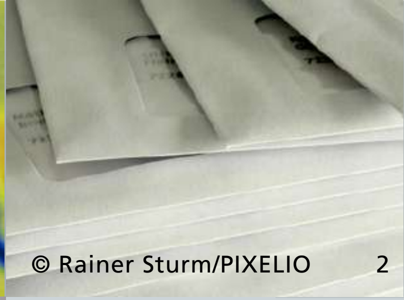
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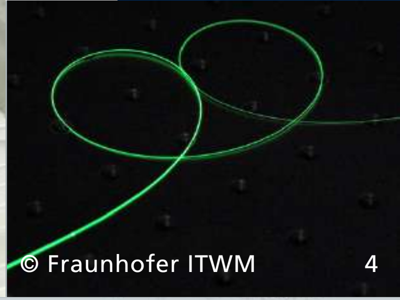
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Terahertz Spectroscopy and Terahertz Imaging

TERAHERTZ TIME-DOMAIN SPECTROSCOPY

One of the established measurement techniques in the terahertz spectral range is terahertz time domain spectroscopy (TDS). It uses ultrashort femtosecond (fs) laser pulses to make a wide range of electromagnetic radiation and the pump-probe principle to find things. The advantages here are a coherent detection of the terahertz waves and, thus, a high-resolution amplitude and phase recording of the terahertz electric field in the time domain. This measurement technique suppresses incoherent radiation, i.e., there is no interference from room temperature or ambient light.

Main Applications

Time-of-flight measurements focus on analyzing the time-of-flight of the reflected signals. Using this approach, one can determine distances and coating thicknesses with high accuracy. This approach underlies the industrially used paint thickness measurement.

Terahertz time-domain spectroscopy is a reliable method for the non-contact and non-destructive characterization of materials, e.g., powders, solids, or liquids, and gases. Many molecules show characteristic signatures in their absorption spectra in this spectral range–a chemical fingerprint.

Gases show rotational spectra with narrow absorption lines. Only crystalline solids show broad absorption bands due to the phonon vibrations of the crystal. Therefore, to identify powdery or solid substances using these absorption bands, they must contain at least a crystalline component. Liquids, therefore, do not show distinct absorption bands. Chemometric methods evaluate spectra for reliable substance identification under real operating conditions. The Postscanner is based on a combination of terahertz spectroscopy and chemometric evaluation for the identification of drugs and explosives in mail.

Unlike IR and Raman spectroscopy, which are sensitive to intramolecular vibrational and rotational motions, terahertz spectroscopy provides information on intermolecular motions. Thus, in addition to the mere detection of macromolecules, statements can be made about the state of aggregation, polymorphic structures, and the crystallinity of the substances.

TERAHERTZ IMAGING

Terahertz waves can penetrate many materials, making them ideal for non-destructive testing of objects. By means of terahertz imaging, similar to X-rays and ultrasound, images of the interior of the object can be generated. Terahertz imaging can detect manufacturing-related defects or weak points in the object during production. Terahertz technology thus makes an important contribution to industrial quality control and conserves resources.

Lateral Versus Axial Resolution

In terahertz imaging, lateral and axial resolutions must be distinguished. The wavelength used primarily dictates the lateral resolution. Due to the frequency range used, the wavelength of 3 mm (100 GHz) ranges from 100 µm (3 THz). Other factors that determine lateral resolution are the optics used and the imaging concept employed. The axial resolution is determined by the imaging technique used (TDS,

EXAMPLE PROJECTS

Flexible Pipe Inspection

Our measuring system allows direct testing of the pipe wall thickness at four freely selectable positions.

Terahertz Mail Scanner T-Cognition

The use of terahertz mail scanners in the postal logistics chain makes it possible to warn people at risk of letter or parcel bombs in good time without opening the mail items.

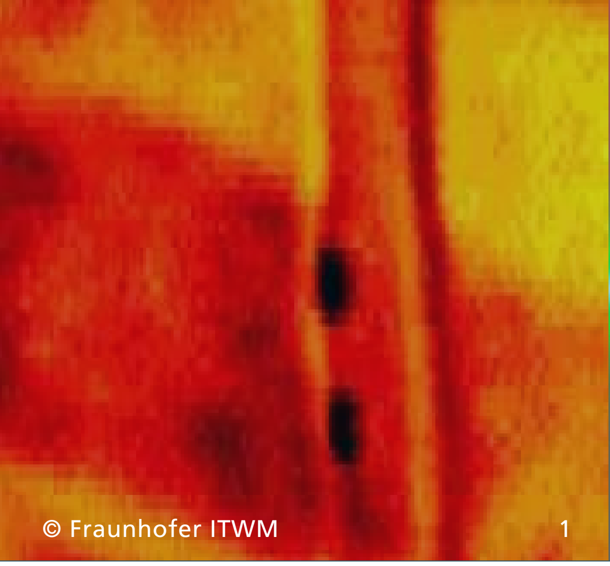
SLAPCOPS

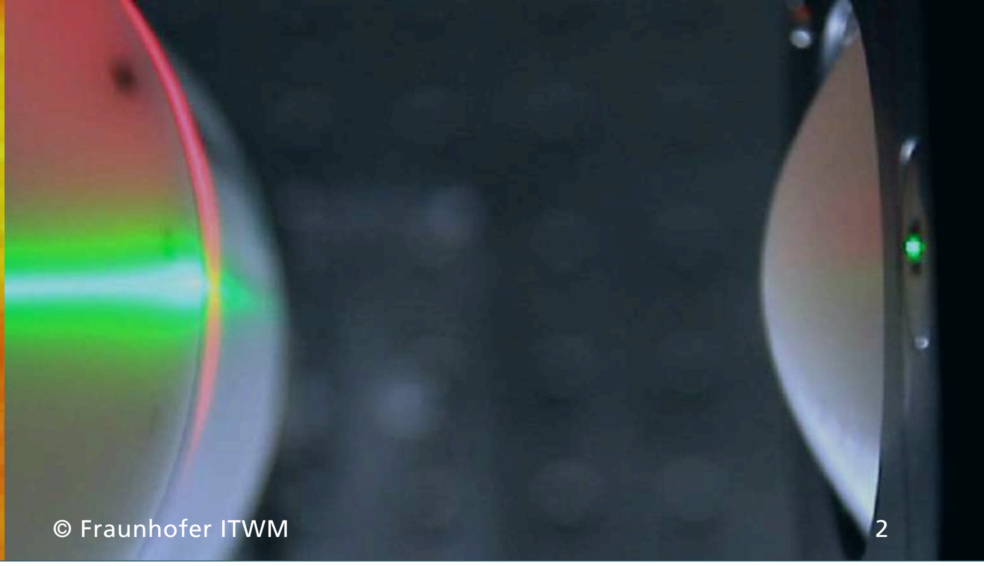
A Laser Concept for the Future of Terahertz Measurement Technology.

SelfPaint

In the project “SelfPaint”, we are working with the Fraunhofer Institutes IPA and FCC to develop a self-programming paint cell for unit numbers of one.

1. With the help of Terahertz time-domain spectroscopy (TDS) we can characterize materials such as dry chemicals, solids and liquids with a non-contact and non-destructive method.
2. In cooperation with Hübner GmbH & Co. KG we developed a mail scanner. Thanks to the harmless Terahertz waves the scanner can be used in virtually any location.
3. Multiphysical simulation of a high rotation atomizer with contact charger to calculate the droplet trajectories, in this example, to the chassis of Volvo V60.
4. Our SLAPCOPS laser system does not require a mechanical traversing unit and still uses only one laser. Active fibers are the key component of the system, which, as shown here in the picture, are characteristically green.





EXAMPLE PROJECTS

ASKIVIT
In the project “ASKIVIT”, we are working with partners on automated sorting to recover wood, wood-based materials and non-ferrous metals. Our experience in the field of terahertz imaging, among other things, is supporting here.

RADOM
A millimeter-wave terahertz system developed by our institute checks radar domes of planes (RADOM) for defects.

DOTNAC
Within the framework of the DOTNAC project we developed a terahertz scanner for testing aircraft components. The focus is on fiberglass compounds and paint coatings.

FMCW, or MIMO). These techniques allow time-of-flight measurement and, thus, depth-resolved imaging. The axial resolution here ranges from 10 µm to several mm, depending on the imaging technique.

Active terahertz imaging for non-destructive testing can be implemented using various concepts:
- Combination of terahertz source and planar detector
- Array of coherent emitters and receivers
- Mechanically scanning transmitters and receivers

Area detectors in the terahertz range are currently only power detectors, i.e., these detectors only detect the incident power but no phase of the incoming wave. Thus, no information on propagation time and the like is accessible. Transmission mainly implements this concept.

Typically, the arrays operate on coherent transmitters and receivers based on the MIMO (Multiple-Input -Multiple-Output) principle. The transmitters are usually switched individually, and the detectors are always active, capturing the amplitude and phase of the signals reflected from the target. In this way, the images are reconstructed. Here, the measurements are preferably made in the reflection.

Most terahertz detectors are point sensors. An object must be detected in a grid pattern to generate an image with this type of sensor. In this method, the transmitter and receiver are either moved relative to the object or the object is moved if the sensor is stationary. Here, measurements are made for both transmission and reflection.

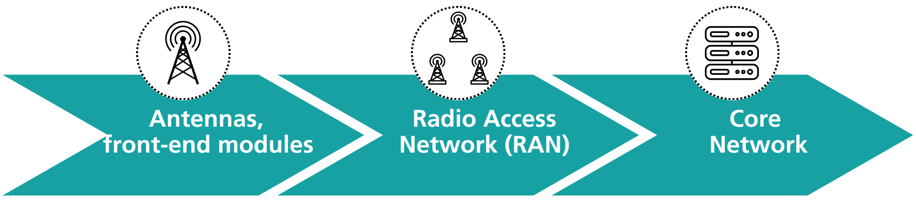
While the first method only allows a transmitted image, the two methods create a depth-resolved image of the object under investigation. Therefore, this is often referred to as tomography or 3D imaging, which is not quite correct. Since the refractive index of the object is not equal to one (=air), the images are distorted in the beam direction due to the different travel time.

1. The Terahertz FMCW radar system detects manufacturing defects or imperfections.
2. Terahertz imaging systems detect hidden material defects.

6G SENTINEL - Fraunhofer lighthouse project for 6G technologies

In the 6G SENTINEL project, the five participating Fraunhofer Institutes are developing key technologies for the impending 6G mobile communications standard. To this end, they are working on further improving the data rates, availability, accuracy, service quality, and reliability of mobile communications. 6G SENTINEL aims not only to push existing 5G technologies further, but also to develop brand new approaches that will help applications such as virtual reality, digital twins, and autonomous driving achieve a genuine breakthrough with 6G. The top priorities are to exploit terahertz frequencies and develop technology for more flexible networks, in particular by incorporating satellites and flying platforms.

6G SENTINEL pools technology expertise to deliver systems know-how in 6G



6G SENTINEL is targeting improvements to device antennas and front-end modules. It also seeks to optimize transmission technologies in the radio access network (RAN) and increase the flexibility of the core network. This means the project will help further develop all relevant components of a mobile communications network.

The participating institutes bring to the project complementary expertise from the fields of radio access networks, localization, core networks, semiconductor technologies for THz communication, and electronics packaging. This creates a unique combination of application know-how, technology expertise for individual aspects of a 6G network, and overall systems expertise.

Faster, more precise, more reliable and universally available
Mastering rapidly increasing performance requirements necessitates new answers. 6G SENTINEL is meeting the most urgent challenges of mobile communications with practical routes to effective solutions.

Terahertz technologies for ultra-high data rates

Mobile communications in the terahertz range offer great potential for vastly increasing data rates on account of the high bandwidth available.

Flexible networks for unlimited 6G availability

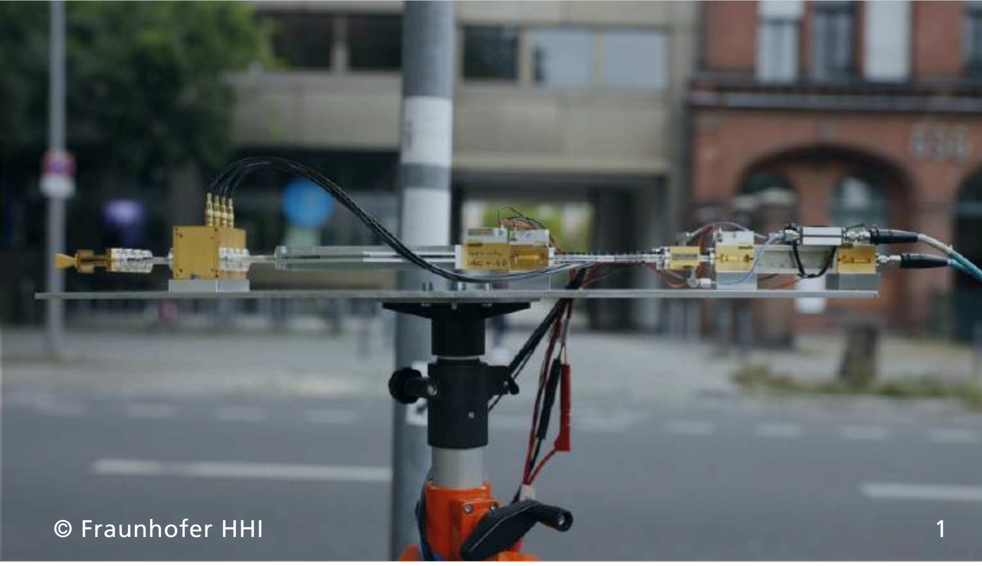
To improve the availability of mobile communications, flexible networks are essential. While AI-based network management can optimize use of the spectrum in a dynamic and demand-based fashion, the integration of satellites and flying platforms holds out the opportunity of expanding mobile communications coverage to an unlimited degree.

Fully integrated localization in 6G networks for greater accuracy

Using new localization approaches, information about the radio channel can be used to an increasingly systematic extent in order to improve the accuracy of positioning and enhance the user experience as well as precision in certain industrial and logistical applications.

Optimized 6G architecture for best service quality and reliability
er accuracy

A 6G system architecture conceived as an integral whole and based on a flexible network and open interfaces creates the conditions for equipping various communication applications with the requisite level of service quality and reliability in each case.



E-band transmitter module based on GaN for 6G mobile communications

6G mobile communications is expected to pave the way for innovative applications such as Artificial Intelligence, Virtual Reality and Internet of Things in everyday life from 2030. This will require a much higher performance capability than that of the current 5G mobile standard, involving new hardware solutions. At EuMW 2022, Fraunhofer IAF will therefore present an energy-efficient GaN-based transmitter module for the 6G-relevant frequency ranges above 70 GHz, which was developed jointly with Fraunhofer HHI. The high performance of the module has already been demonstrated at Fraunhofer HHI.

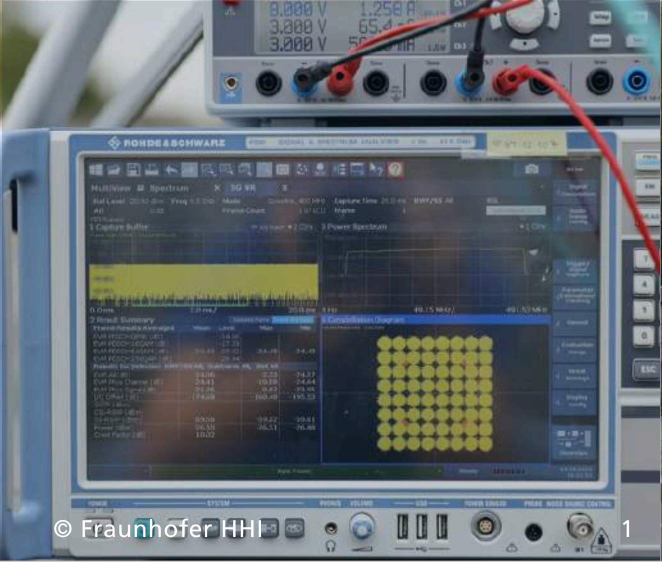
Self-driving cars, telemedicine, automated factories—promising future applications like these in transport, healthcare and industry depend on information and communications technology that exceeds the performance scope of the current fifth-generation mobile communications standard (5G). 6G mobile communications, which is expected to be introduced from 2030, promises the necessary high-speed networking for data volumes required in the future, with data rates exceeding 1 Tbit/s and latencies down to 100 µs.

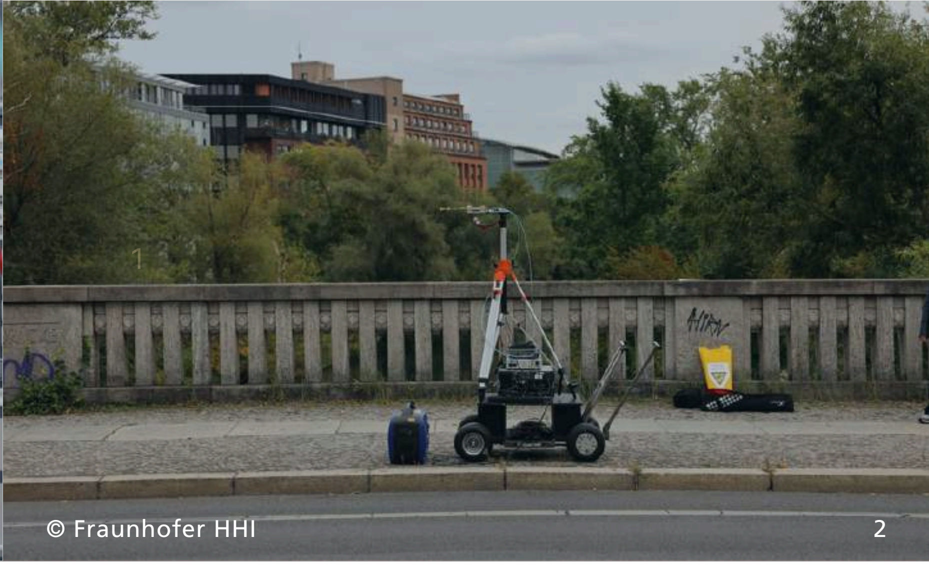
The Fraunhofer Institute for Applied Solid State Physics IAF and the Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, HHI have been working on the novel high-frequency components needed for 6G mobile communications since 2019 as part of the KONFEKT project ("Components for 6G Communications") funded by the Fraunhofer-Gesellschaft. The researchers have developed transmitter modules based on the power semiconductor gallium nitride (GaN), with which the frequency ranges around 80 GHz (E-band) and 140 GHz (D-band) can be tapped for the first time with this technology. The innovative E-band transmitter module, with its high performance that has already been successfully tested by Fraunhofer HHI, will be presented to the expert public at the European Microwave Week (EuMW) in Milan, Italy, from September 25 to 30, 2022.

Innovative hardware due to broadband compound semiconductors and SLM processes
"6G requires new types of hardware because of the high demands on performance and efficiency," explains Dr. Michael Mikulla from Fraunhofer IAF, who is coordinating the KONFEKT project: "Components at the current state of the art are reaching their limits. This applies in particular to the underlying semiconductor technology and the assembly and antenna technology. To achieve better results in output power, bandwidth and power efficiency, we use GaN-based monolithic integrated microwave circuits (MMICs) for our module instead of the silicon circuits currently in use. As a wide-bandgap semiconductor, GaN can process higher voltages and at the same time enables significantly lower-loss and more compact components. In addition, we are eliminating surface mount and planar packaging structures to design a lower-loss beamforming architecture with waveguides and inherent parallel circuitry."

Fraunhofer HHI is also heavily involved in the evaluation of 3D-printed waveguides.

1. E-band transmitter with GaN module, 3D-printed antenna and Rotman lens.
2. GaN-based E band module for broadband point-to-point data links over long distances in 6G mobile communications.





Several components, including power splitters, antennas and antenna feeders, have been designed, fabricated and characterized using the selective laser melting (SLM) process. This process also makes it possible to quickly and cost-effectively manufacture components that cannot be produced using conventional methods, paving the way for the development of 6G technology.

"Through these technical innovations, the Fraunhofer Institutes IAF and HHI are taking Germany and Europe a significant step forward towards the mobile communications of the future, while at the same time making an important contribution to domestic technological sovereignty," Mikulla emphasizes.

High-performance transmitter modules for future 6G frequency bands successfully demonstrated

The E-band module achieves a linear output power of 1 W in the frequency range from 81 GHz to 86 GHz by coupling the transmit power of four individual modules with extremely low-loss waveguide components. This makes it suitable for broadband point-to-point data links over long distances, which is a key capability for future 6G architectures.

Various transmission experiments conducted by Fraunhofer HHI have already demonstrated the performance of the jointly developed components: In different outdoor scenarios, signals corresponding to the current development specifications of 5G (5G-NR Release 16 of the global mobile communications standardization organization 3GPP) were transmitted at 85 GHz with a bandwidth of 400 MHz. With a clear line-of-sight, data was successfully transmitted over a distance of 600 meters in 64-symbol quadrature amplitude modulation (64-QAM), ensuring a high bandwidth efficiency of 6 bits/s/Hz. The Error Vector Magnitude (EVM) of the received signal was -24.43 dB, well below the 3GPP limit of -20.92 dB. With line-of-sight obstructed by trees and parked vehicles, 16QAM modulated data could be successfully transmitted over a distance of 150 meters. Even with a completely blocked line-of-sight between transmitter and receiver, it was still possible to transmit and successfully receive four-phase modulated data (Quaternary Phase-Shift Keying, QPSK) with an efficiency of 2 bits/s/Hz. The high signal-to-noise ratio of sometimes more than 20 dB in all scenarios is remarkable, especially considering the frequency range, and is only made possible by the high performance of the developed components.

In a second approach, a transmitter module for the frequency range around 140 GHz was developed, combining an output power of more than 100 mW with an extreme bandwidth of 20 GHz. Tests with this module are still pending. Both transmitter modules are ideal components for the development and testing of future 6G systems in the terahertz frequency range.

Fraunhofer IAF presents transmitter module at EuMW 2022

Researchers of Fraunhofer IAF present the transmitting module for the 6G-relevant frequency band around 80 GHz, developed together with Fraunhofer HHI, at EuMW 2022 in Milan from September 25 to 30.

1. Successful reception of 64QAM modulated data at a distance of 600 meters at 85 GHz.
2. E-band receiver in outdoor transmission experiment at 85 GHz.

6G-Health kick-off: Better healthcare with 6G networking

In addition to Fraunhofer HHI, the other partners include Charité Universitätsmedizin Berlin, Vodafone Group Services GmbH, Siemens AG, Infineon Technologies AG, NXP Semiconductors Germany GmbH, inomed Medizintechnik GmbH, SectorCon Ingenieurgesellschaft GmbH, SurgiTAIX AG, Berlin Heart GmbH, CTC advanced GmbH, Innovationszentrum für Computerassistierte Chirurgie (ICCAS), Institut der Medizinischen Fakultät der Universität Leipzig, Deutsches Forschungszentrum für Künstliche Intelligenz GmbH, ERNW Research GmbH, Martin-Luther-Universität Halle-Wittenberg, Interdisziplinäres Zentrum Medizin – Ethik – Recht, Smart Mobile Labs AG, Universität Bremen, Arbeitsbereich Nachrichtentechnik, Universität Rostock, Fakultät für Informatik und Elektrotechnik, Institut für Angewandte Mikroelektronik und Datentechnik.

Starting now, the Fraunhofer Heinrich-Hertz-Institut (HHI) is developing fundamental technology components for 6G-based medical applications in the research project "6G-Health" (Holistic Development of High-Performance 6G Networking for Distributed Medical Technology Systems). The goal is to incorporate the results into international 6G standardization. 6G-Health officially started in October 2022 and will run until October 2025. The team has now started its project work. 6G-Health is led by Vodafone and funded by the German Federal Ministry of Education and Research (BMBF) to the tune of 10 million euros. Of this, Fraunhofer HHI will receive one million euros.

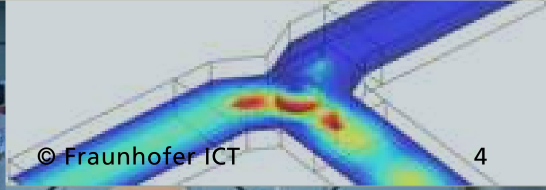
6G will unlock new opportunities to improve healthcare. For the first time, the next-generation mobile communications standard will be more than just a radio network: 6G will integrate sensing, mobile communications, and computing power to connect the virtual and real worlds in the best possible way.

In healthcare, for instance, this means that patients' vital parameters are sensed, processed, and transmitted directly via the 6G network. Doctors and nurses will benefit from new forms of collaboration through these enhanced network functionalities, for example, through augmented reality (AR) applications or telemedicine. In addition, secure communication will facilitate interaction between humans and machines, enabling, for example, support structures worn on the body (exoskeletons) to help patients walk or nurses push beds. This requires very low latencies. In addition, the use of AI in network technology will optimize energy efficiency.

In order to use these technologies extensively in medical care, the 6G-Health team is analyzing the performance requirements that are essential for the next generation of mobile communications. Based on this, the researchers will develop 6G components for future medical technology applications and evaluate them together with clinical partners. The researchers will ultimately incorporate their results into the international 6G standardization process.

Fraunhofer HHI is involved in the project with its "Wireless Communications and Networks" department. In 6G-Health, the team is developing concrete technology components for 6G-based, networked medical systems. To this end, they are extending the existing sensor technology for recording vital parameters with 6G technology components (e.g., through energy-efficient, AI-based preprocessing). In addition, the researchers are developing novel methods for vital parameter acquisition. For these procedures, the experts are working with so-called "Integrated Communication and Sensing" (ICAS). ICAS combines sensing and communication through the mobile radio system in order to exploit network resources efficiently and realize wide-area environmental sensing. Using this approach, physicians can monitor medically relevant (vital) parameters and contextual information from inside the hospital and from the patient’s home, e.g., before surgery.

The 6G Health project complements the work of Fraunhofer HHI researchers in the BMBF-funded Research Hub 6G-RIC. In this project, scientists have been working on the development of 6G since August 2021. They use the close collaboration in the 6G Health Consortium to coordinate requirements for the mobile communications standard and its future application in the medical field with clinical partners. This enables the experts to identify potential 6G applications at an early stage and lay the foundations for them in 6G standardization.



Microwave and plasma technology

Fraunhofer ICT's competences in the area of microwave and plasma technology go far beyond simple processing technologies. They include the development of production units and measurement technology, accompanied by numerical simulation of the electromagnetic field and the resulting heating or plasma formation. Particular attention is paid to the reproducible and controlled application of microwaves. Plasmas generated by microwaves can be used for the cleaning, modification, or coating of surfaces (PECVD).

HEATING OF PLASTICS WITH MICROWAVES

Microwaves are non-ionizing electromagnetic waves that are absorbed by polar, magnetic, or poorly electrically conductive materials throughout their entire volume. As a result, these materials can be heated regardless of their thermal conductivity.

Our offer
- Measurement of the temperature- and frequency-dependent dielectric function
- Development and optimization of microwave units for thermal processes
- The development of processes using microwaves

MICROWAVE-GENERATED PLASMA-ASSISTED CHEMICAL VAPOR DEPOSITION

Plasma-assisted chemical vapour deposition (PECVD) can be used to introduce a thin, functional layer onto the surface of various materials. This coating significantly improves the properties or usability of the component. Microwaves generate plasmas that enable very high coating rates.

Our offer
- Development of coating processes with microwave-generated plasmas according to customer specifications
- Evaluation of specific product properties with appropriate test procedures
- Upscaling the construction of demonstrators

SIMULATION

Modern FEM software packages enable numerically consistent simulation of electromagnetic fields and the associated heating or plasma generation. The simulation supports and accelerates the development of production units and processes in the area of microwaves and plasmas.

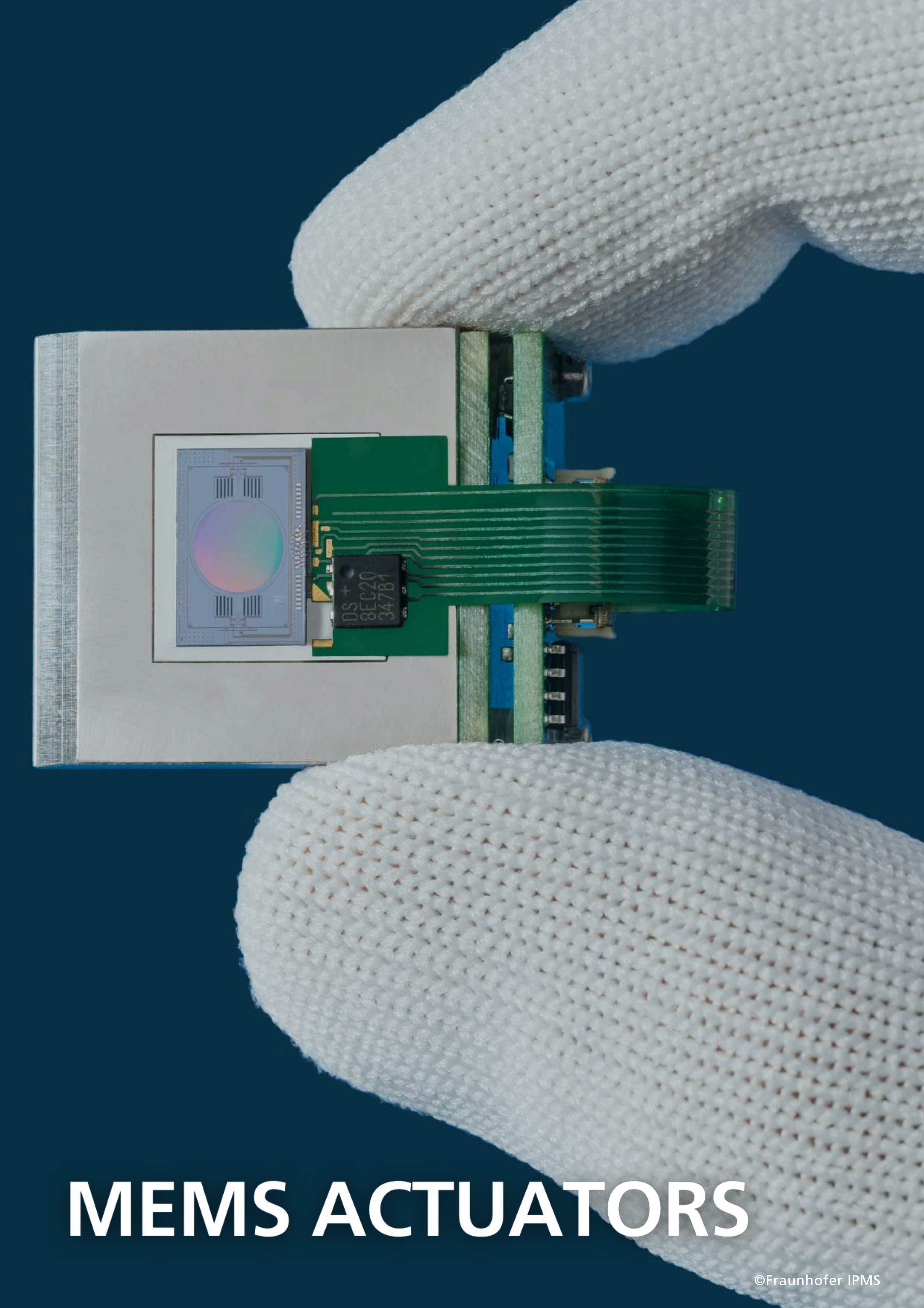
Our offer
- Electromagnetic field simulations of microwave applicators
- Optimization of applicators through simulation

SENSOR AND MEASUREMENT TECHNOLOGY

Microwaves are well-suited for process monitoring and control. One can carry out non-destructive measurements to determine the degree of polymer cross-linking. The concentration of agglomerates and nanoparticles can also be measured in line with the extruder.

We also have a fiber optic measuring device for continuous, spatially resolved temperature and strain measurement along the fiber.

1. Plasma line with magnet; concentrated plasma.
2. Damascus knife, protected with a corrosion-resistant layer applied by Fraunhofer ICT using the PECVD process.
3. Equipment for heating PET-Preforms with microwaves.
4. Simulation of the electrical microwave field in a circulator.
5. Device for measuring the permittivity of materials.
6. Measurement device for lateral measurement of the temperature and stress along a glass fiber.



MEMS ACTUATORS

MEMS Technologies and Post-CMOS Processing

Our technologies - Innovations for your products

- Atomic Layer Deposition (ALD)
- 3D Integration
- Microbolometer
- Vacuum Chip-Scale-Package
- Pressure Sensors
- SPAD in focus

Our technology areas - Our technologies for your development

- Image Sensors: Development of individual sub-steps up to the complete customer-specific process.
- Biofunctional Sensors: Tools for medical diagnostics.
- Specialized technologies: The Fraunhofer IMS also offers special technologies e.g. high-temperature technology.

With its in-house clean rooms, the Fraunhofer IMS offers a wide variety of manufacturing processes for the realization of new technologies. Planarized CMOS surfaces serve as the basis for post-CMOS sensor integration. Furthermore, sensor elements such as optical, mechanical, physical, chemical, and bio-sensors can be realized by combining them with "Micro-Electro-Mechanical Systems" (MEMS) or "Nano-Electro-Mechanical Systems" (NEMS).

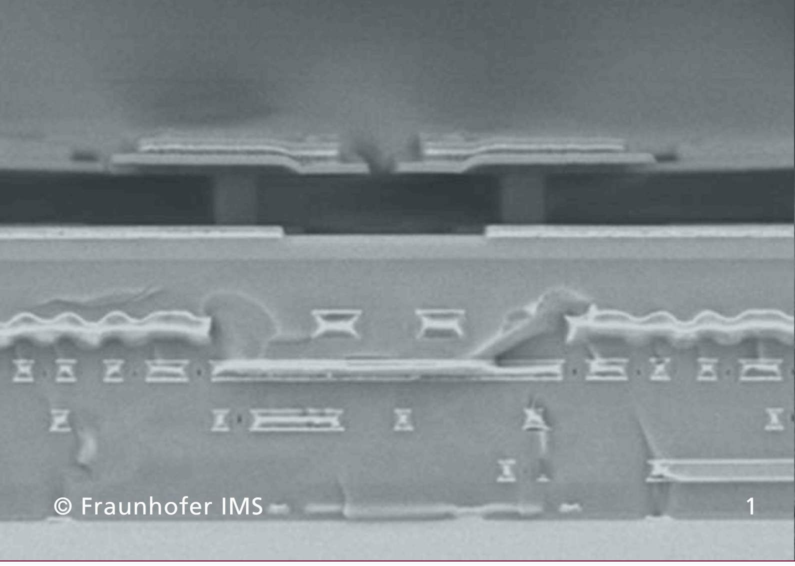
One example of customized MEMS technologies is post-CMOS processes for sensor integration. The Microsystems Technology Lab&Fab (MST Lab&Fab) realizes the fabrication of new devices through layer deposition and patterning.. Sensors that can be realized with this principle are gas sensors, optical sensors, pressure sensors, and also biosensors. If the sensor is then connected to a readout circuit by wafer-to-wafer bonding or C2W bonding, innovative and extremely compact microsystems are created for use in medicine, industry, mobility, space travel, and security technology.

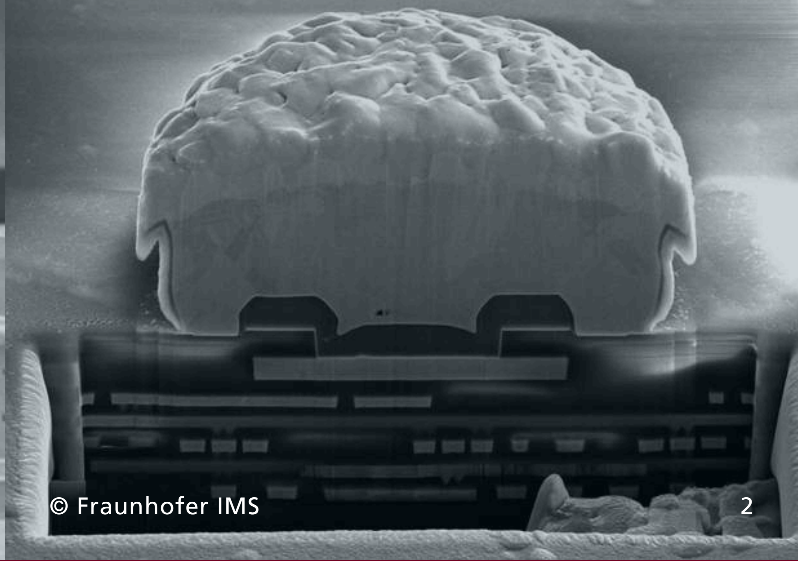
The Fraunhofer IMS offers the optimal technological infrastructure for the development and integration of innovative MEMS technologies. To continue the trend of compact and powerful devices in microtechnology ("More than Moore"), Fraunhofer IMS offers the possibility of 3D integration. Exploiting the third dimension allows for building structures on top of each other, resulting in shorter interconnect paths and higher integration density. In addition, manufacturing each plane in the optimal manufacturing process enhances the possibilities in technology selection, improves yield, and reduces manufacturing costs. For this purpose, two powerful processes are available at the Fraunhofer IMS with the chip-to-wafer and wafer-to-wafer processes. The manufacturing of efficient and compact detectors consisting of optical backside illumination sensors and readout electronics currently utilizes these processes. The MST laboratory precisely connects sensor and circuit wafers in the wafer-to-wafer process, and electrically contacts them using an ALD-optimized material stack. ALD technology can be used to produce not only electrical contacts but also protective layers, optical coatings, MEMS, or NEMS devices for gas or biosensors with nanowires and ultra-thin free-standing membranes. Furthermore, Fraunhofer IMS realizes microbolometers as sensor elements of an uncooled infrared sensor on the CMOS wafer and is thus the only manufacturer of microbolometers in Germany.

Foundry services in the MST Lab&Fab

In addition to complete MEMS solutions, Fraunhofer IMS also offers foundry services in the Microsystems Lab&Fab. The clean room has lithography down to 0.35µm with the possibility to align back to front with 200 nm accuracy. In addition to standard coatings, coating thicknesses of up to 40 µm are possible, as well as colored coatings. Dedicated equipment can be used to bond fully integrated wafers (direct-wafer bonding) or individual circuits on wafers (chip-to-wafer bonding). For plasma processes, sputtering (PVD), plasma-enhanced deposition (PE-CVD), and reactive etching (RIE), and deep etching (DRIE) are available. Further specialties here are the deposition of pure boron as ultra-thin passivation or contacting, silicon carbide, germanium, and differently doped amorphous silicon. By means of electroplating, layers and structures up to 40 µm can be created from gold, copper, tin, and nickel. Atomic Layer Deposition (ALD) is a biocompatible passivation that is very conformal and can be used in many MEMS applications because it is so conformal. A variety of oxides and nitrides as well as metallic layers such as titanium nitride and ruthenium, are possible here.

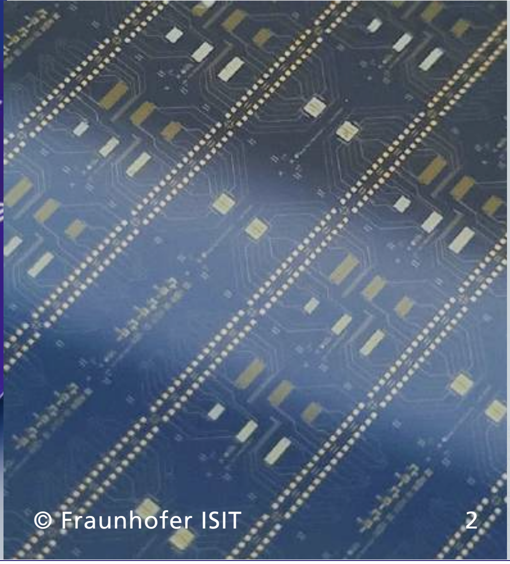
1. MST Clean Room.

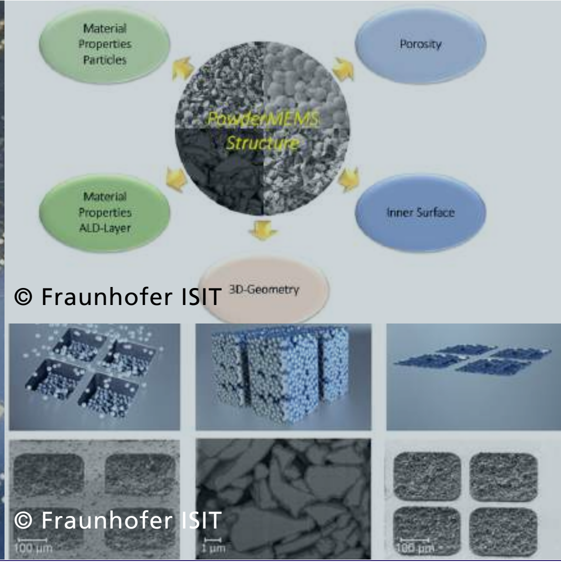




The above processes are all suitable for post-CMOS integration due to low process temperatures. Extensive characterization and analytics support the development and enable precise product controls. For this purpose, the MST Lab&Fab has a 3D microscope, an atomic force microscope (AFM), an electron microscope (SEM) with EDX, a scanning electron microscope for critical structures (CD-SEM), ellipsometers, and profilometers.

1. Cross-section of a microbolometer on CMOS wafer realized by MEMS technologies.
2. 3D integration with SLID bonding realized by MEMS technologies.





PowderMEMS – Patented microfabrication process for the generation of 3-d functional microstructures on wafer level

PowderMEMS structures enable, for example,

- Thermal management
- Integrated micromagnets
- Local porosity
- High density

PowderMEMS is ISIT's patented microfabrication process for the generation of three-dimensional functional microstructures at the wafer level. The Agglomerated Microsystems Group uses PowderMEMS for applications in the fields of MEMS sensors and actuators, microfluidics, energy harvesting, and microelectronics.

The technology opens up numerous degrees of freedom for the realization of novel microcomponents with innovative functionalities. Structures with dimensions ranging from a few tens to hundreds of micrometers can be created at the substrate level from a wide range of materials.

USE CASES

Sensor technology
PowderMEMS enables the integration of large surfaces as well as functional porous microstructures in MEMS sensors. By using the third dimension this is possible with low wafer footprint.

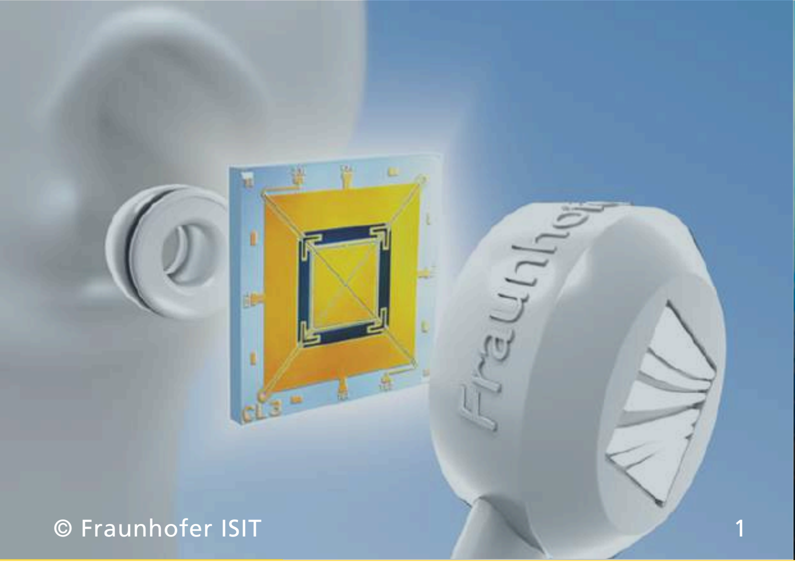
Energy harvesting
Unlike conventional MEMS energy harvesting systems, Fraunhofer's patented PowderMEMS technology allows them to be replaced by denser materials such as tungsten or NdFeB.

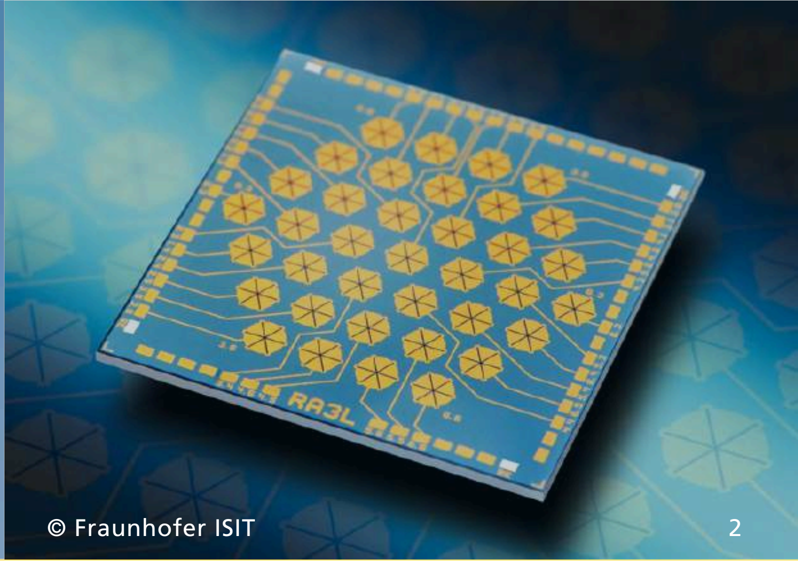
Integrated inductors
The Powder MEMS technology developed at Fraunhofer ISIT offers a wide range of possibilities in the fabrication of inductors and transformers with magnetic core on a substrate (e.g. silicon, FR4) for high frequency applications.

Functional MEMS structures
The multiple degrees of freedom of the PowderMEMS process enable the creation of functional microstructures for a wide range of applications.

PowderMEMS technology
Fraunhofer ISIT's PowderMEMS process enables the integration of almost any material in planar substrates such as silicon, glass, ceramics and PCBs.

1. Fraunhofer IMS develops the smallest nanosensors on the basis of ALD for cell contacting in its project ZellMOS.
2. Picosun R-200: Single wafer processes (200 mm).





Acoustic systems and micro actuators

For many years, Fraunhofer ISIT has been working together with partners from research and industry in the field of acoustic microsystems.

MEMS loudspeaker
One focus is the development of highly miniaturized, integrated MEMS loudspeakers. In contrast to conventional products, these novel chip speakers are based on high-performance MEMS drives. State-of-the-art silicon technology enables the manufacturing of MEMS loudspeakers with micrometer-precise precision and cost-efficient mass production. In addition to outstanding acoustic performance as well as advanced functionalities, the MEMS speakers feature significantly smaller sizes and superior energy efficiency, making them particularly attractive for mobile applications such as augmented reality, hearables, wireless headphones, and hearing aids. ISIT's customers benefit from the patented actuator and speaker concepts.

Ultrasound transducer
Miniaturized ultrasound transducers represent a research focus. ISIT designs the transducers as piezoelectric thickness or membrane transducers, depending on the frequency range. Highly developed process technology platforms with the piezoelectric high-performance materials AlN, AlScN, and PZT form the basis, allowing for the possibility of achieving very high sound pressure levels as well as sensitivities. These capabilities enable the realization of efficient ultrasonic transducers with center frequencies ranging from a few kHz to several hundred MHz. The components developed include ultrasonic arrays for non-contact human-machine interfaces, medical technology applications, and non-destructive testing technology.

1. Illustration of a MEMS-based in-ear system.
2. MEMS Ultrasound Array for Air-Guided Ultrasound.

Scanning Eye - Sensory organ for the car for autonomous driving

In autonomous vehicles, the human is only a passenger. The car keeps the lane independently and recognises obstacles and dangers. To enable the vehicle to recognise its environment, optical sensors replace the driver's eye. Fraunhofer IPMS is developing microscanning mirrors (MEMS scanners) that can perceive their surroundings reliably and without interference while being small and integrable. The vision of safe autonomous driving is thus within reach.

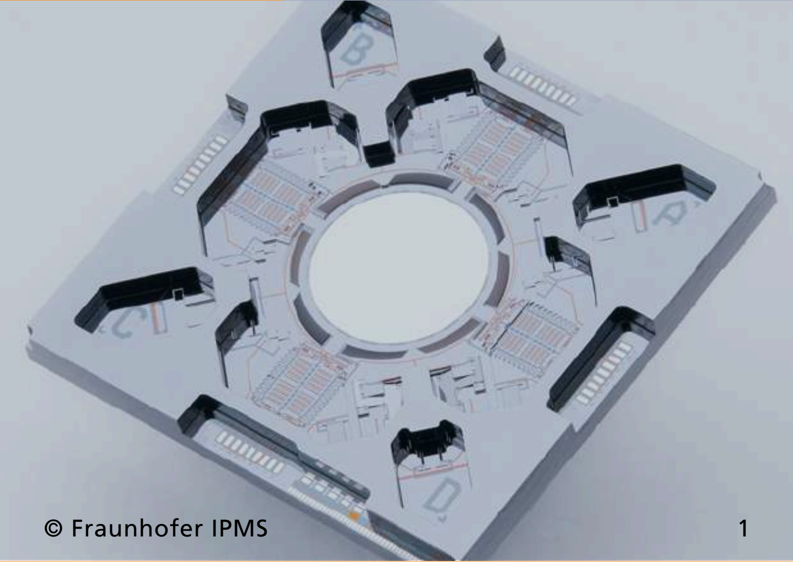
Fraunhofer IPMS' is pursuing the approach of a "scanning eye" to enable digital vision in three dimensions. A micromirror module scans the environment by distributing the light of a laser in two dimensions. The third dimension of the light reflected from the object is determined by the detector signal. There are different methods, such as time-of-flight measurement, coded pulses or demodulation of FMCW signals.

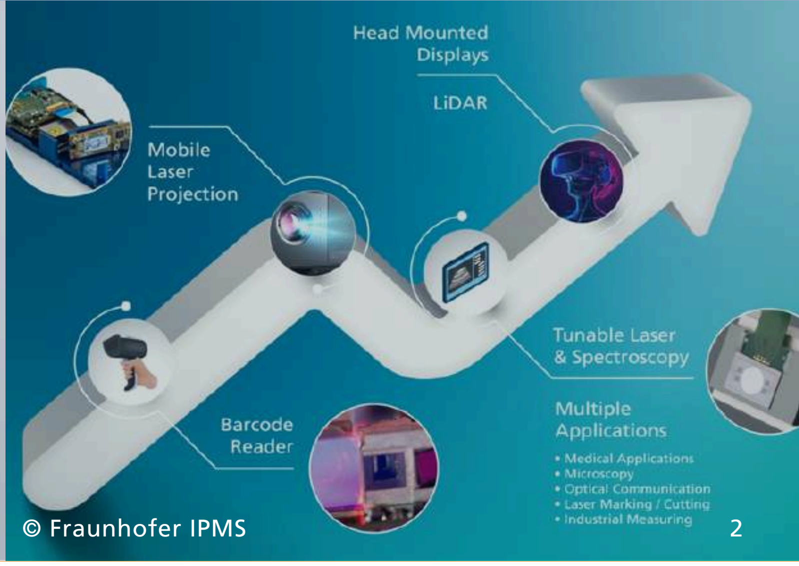
Current LiDAR systems for autonomous driving are based on large rotating mirrors around an axis, which are difficult to integrate into vehicles due to their size and weight. Other disadvantages are the high manufacturing costs and the susceptibility of the rotating parts to vibration and shock. This results in measurement inaccuracies, which in the worst case can lead to system failure and accidents. Alternatives are so-called solid state lidars, which have no moving parts and can be integrated due to their small size, but these have difficulty detecting objects at a greater distance. For safe autonomous driving, detection ranges of a few centimetres to several hundred metres are necessary.

"The special thing about the MEMS mirrors we have developed is that they reliably detect their surroundings at all ranges. In addition, they are so light and integrable that they are not affected by vibrations in the car despite their mobility and thus detect their surroundings without measurement blurring," explains Dr Grahmann, a researcher at Fraunhofer IPMS. "This means that scanner mirror designs from the IPMS fulfil both mechanical mobility and the stability of a solid state LiDAR. In this way, autonomous driving can be implemented safely." Because the MEMS scanner developed by IPMS is made of single-crystal silicon, it is also extremely robust, shock-stable and fatigue-free. Cost-effective semiconductor manufacturing processes allow for scaling effects in production. The CMOS compatibility of the semiconductor chip also enable a high level of integration capability in existing systems.

Advantages of the "scanning eye"
- Non-contact environment analysis
- Ultra-high resolution
- Extremely compact
- Perfect for mobile applications
- Robust, reliable and maintenance-free

1. LiDAR technology to scan the environment for autonomous driving.





MEMS Scanners and Scan Engines

From customer-specific development to pilot production
Scanning mirrors, either resonantly or quasi-statically operated, are the technology of choice when it comes to selectively deflecting light with very compact systems. At Fraunhofer IPMS you will find technological competence for component and system development and application know-how from more than 10 years of development work in equal measure.

In recent years, Fraunhofer IPMS has developed more than 50 different resonant MEMS scanners, which are used as one- or two-dimensional deflecting elements or also for optical path length modulation.

Our offer at a glance
- Tilting and translational mirrors
- 1D and 2D deflection (resonant, quasi-static)
- Large optical scanning range: 136°
- Frequencies: 0.1 Hz - 100kHz
- Mirror diameter: 0.5 - 5 mm (9.0 mm)
- Planarity: better than λ/10
- Highly reflective coatings possible
- Integrated piezo-resistive position sensors

You can expect excellent long-term behavior, high temperature, vibration and shock resistance from our mirrors.

We're happy to develop customer-specific scanning solutions for your application and provide qualified MEMS scanner dies and scan engines in larger numbers via pilot fabrication.

Our extensive packaging and assembly know-how and qualified pilot production make us a strong partner for your project.

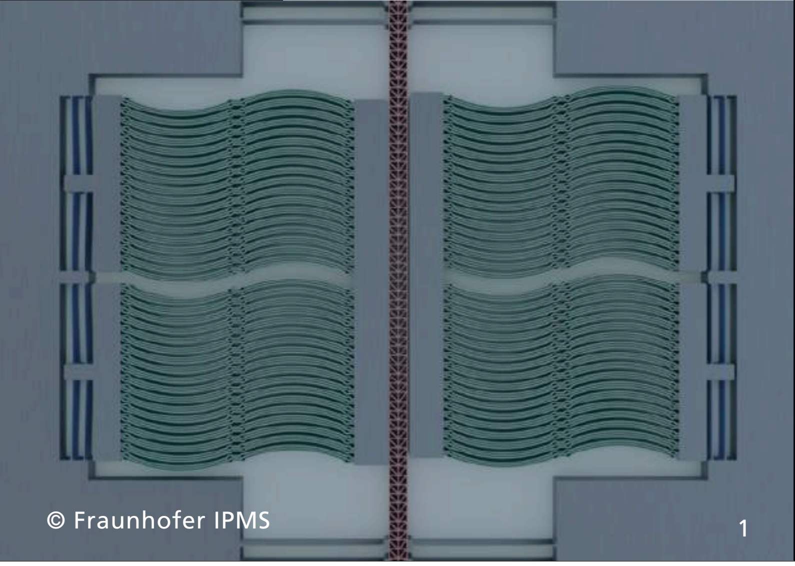
Applications for MEMS scanning mirrors and scan engines
Applications range from bar code reading systems and 3D metrology to laser projection, spectroscopy and focus position modulation.

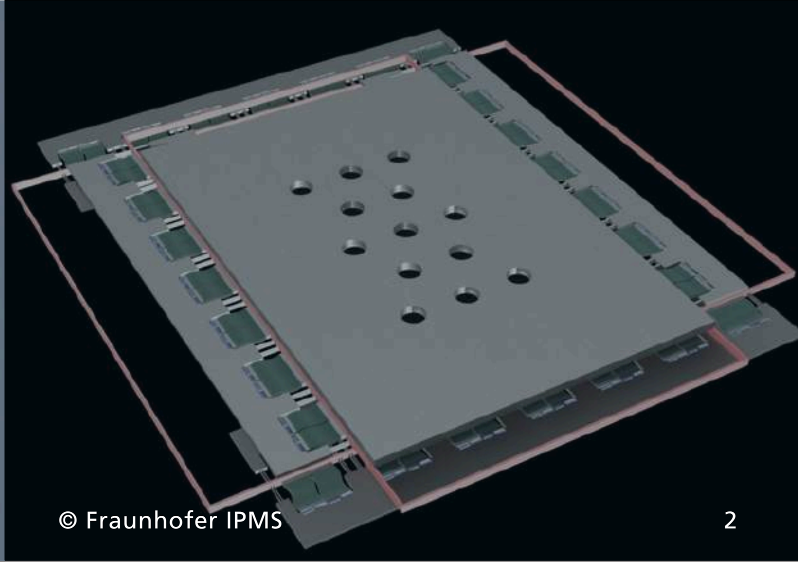
A practical example is a scanner mirror with diffraction grating for spectroscopic applications. This has been offered commercially since 2007 by HiperScan GmbH, a spin-off of Fraunhofer IPMS, in a novel near-infrared microspectrometer.

In addition, Fraunhofer IPMS is working on application-specific scanner mirrors, e.g. for Fourier transform spectrometers, confocal microscopy, highly miniaturized displays, ultra-compact laser projection systems, for image acquisition in endoscopes and for distance measurement (triangulation).

In addition to resonant scanners, quasi-static deflectable microscanners are also being developed for applications such as laser beam positioning or vector scanning.

1. Optical Actuators.
2. MEMS-Mirror applications at Fraunhofer IPMS.





MEMS based Micropositioning Platforms

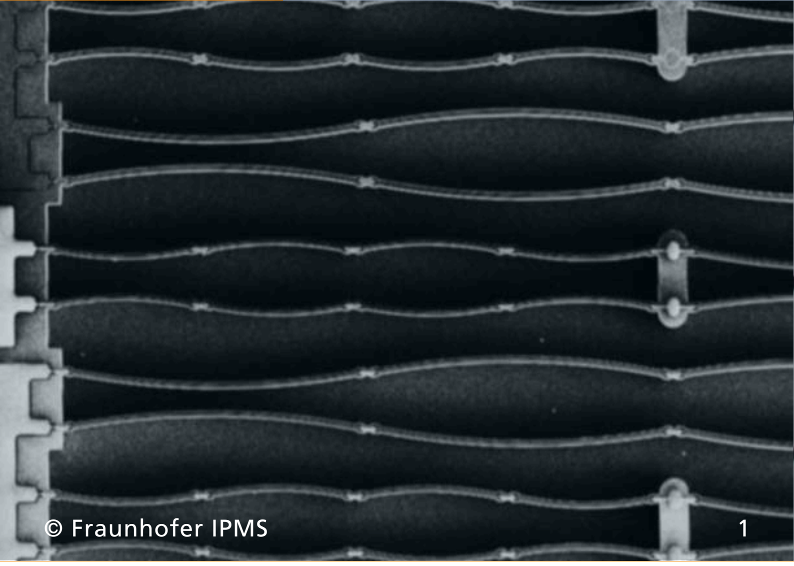
Micropositioning platforms are systems in which a defined, usually centrally located surface can perform lateral, rotational, tilting or lifting movements as well as combinations of these. The drive succeeds via microactuators connected to the platform. The microactuators can be managed in particular by bending transducers.

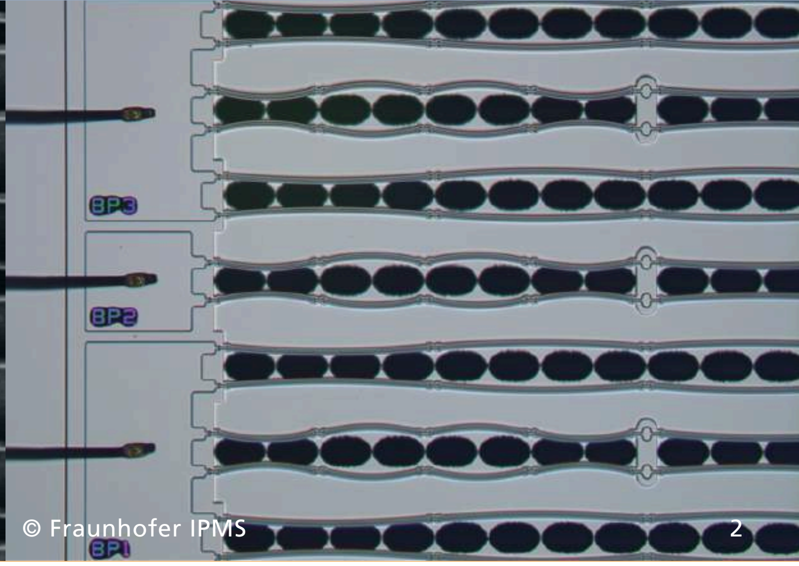
Electrostatic bending transducers are being developed at Fraunhofer IPMS. They are used in the micropositioning platforms as a direct drive. An alternative indirect drive takes the form of an "inchworm" principle. This describes the stepwise displacement of a feed element alternating with a clamping. The feed element itself can be connected to a platform. The feed actuator is formed by the bending transducers. On the other hand, the clamping function can be electrostatic or provided by further bending transducers. With such a MEMS inchworm motor, precise and in sum large travels are possible.

Microactuators and micropositioning platforms belong to the discipline of micro- and nanosystems. Research focuses on dynamics, damping, reliability, tribology, electrostatics, actuation, and packaging and interconnection.

Applications of micropositioning platforms in a broader sense can be found, for example, in analytics for sample placement and micromanipulation or in optical analytics for particularly flat and mobile microscopy systems.

1. The picture shows the basic concept of a NED-Inchworm motor. Blocks of actuators on the left and right side of a so-called feed element can push the latter up or down in the plane. The clamping here is electrostatic.
2. The picture shows two superimposed planes of two NED inchworm motors for combining an X and Y movement. The optics (lens matrix) is located on the upper plane, is connected to the feed elements and is consequently movable in X and Y direction.





MEMS technology for headphones

Headphones with MEMS speakers for the Internet of Voice
Voice-based Internet services are increasingly accepted by many users as a central component of future data processing. For example, in the car, in the smartphone and in the living room. Similarly, renowned hardware and content providers are focusing their business on such products, which are also used in Internet-enabled mobile devices worn directly in the ear. Today, numerous voice-based services are available. Examples include simultaneous translators, payment services and marketing solutions. The vision of an Internet-of-Voice permanently worn in the ear is thus taking shape. Hearables, which are predestined for this, are increasingly claiming the inheritance of smartphones and emancipating themselves from the less smart Bluetooth headsets.

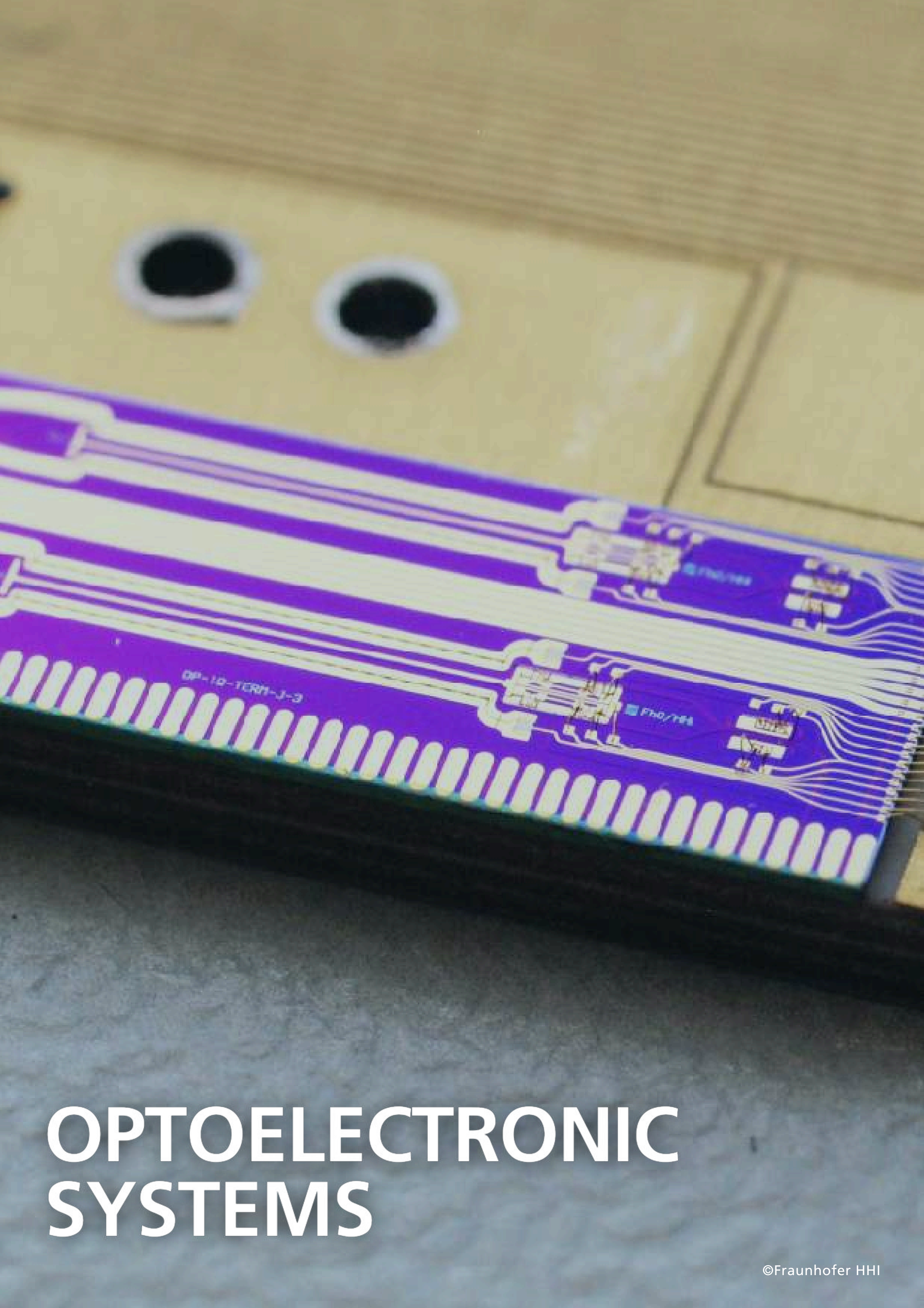
In the future, hearables will not only contain audio technologies, but also powerful processors for data processing and will be directly connected to the Internet via wireless interfaces. Similar to the GPU for smartphone displays, the processors (in addition to the wireless interfaces) will dominate the energy requirements of future hearables and thus their runtime. Since the space and thus the capacity of the battery in the ear is very limited, all other components will have to get by with a very small energy budget to enable sufficient runtime.

Fraunhofer IPMS has developed a new, power-efficient transducer principle for a central core component of the hearables - the in-ear speaker - and presented it in the journal Nature Microsystems and Nanoengineering. By publishing the scientific findings, experts agree on the novelty and significance. This makes the innovative approach accessible to a wide audience of experts.

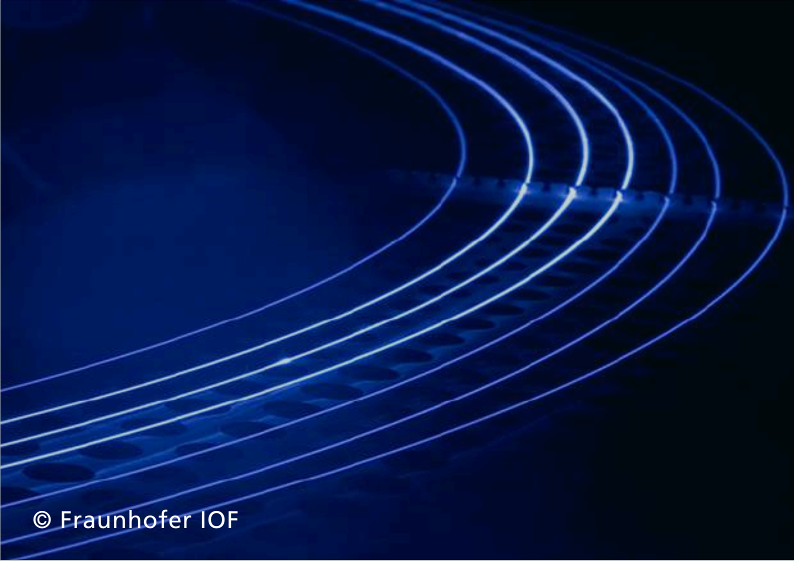
Since submitting the paper to the journal earlier this year, work has continued intensively. The subsequent improved generation of MEMS loudspeakers is already in the lab. In addition to further improved linearity and higher sound pressure, it was also possible to further reduce the drive voltage and thus the power consumption.

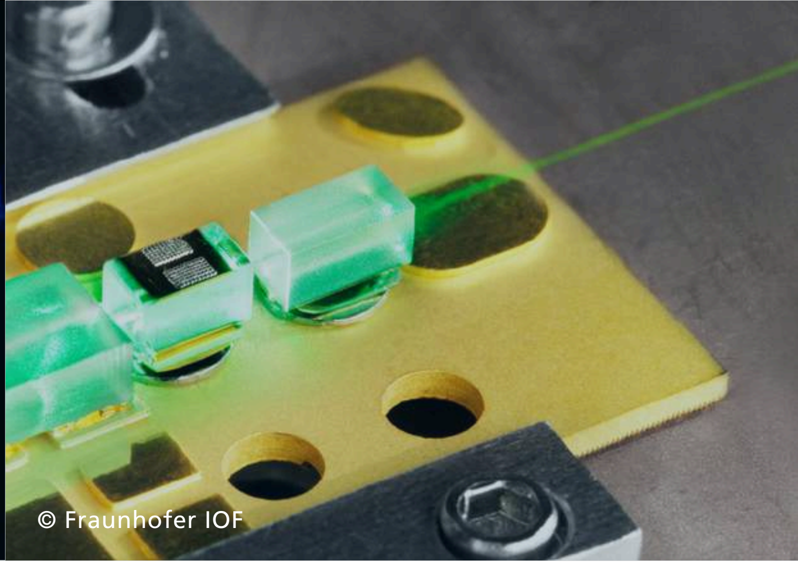
In addition to the further increase in the characteristic values, the integration, in particular with the control electronics, is now increasingly becoming the focus of the work at IPMS.

1. Detail of opened chip of MEMS micro loudspeaker device with parallel arranged actuator pairs.
2. MEMS chip with three micro loudspeaker components on carrier board for control.



OPTOELECTRONIC SYSTEMS





Laser and Fiber Technology at Fraunhofer

Fraunhofer IOF has expertise in laser physics, fiber and optical design, glass chemistry, thermo-optics, packaging and interconnection technology for the development of fiber lasers, and the creation of effective fiber couplers and beam delivery systems. These areas enable the production of high-power fiber lasers with diffraction-limited beam quality.

Fraunhofer IOF covers the entire technology chain in its fiber technology center, from the design and manufacture of laser-active preforms and fibers, preparation and characterization, to system integration of the laser-active special fibers and fiber-optic components. This is essential for the design and application of cw and pulsed fiber laser systems of the highest beam quality ($M^2 < 1.2$) with output powers up to the multi-kilowatt range. By operating technologies on an industrial scale, it is possible to quickly transfer new solutions into applications.

Fraunhofer IOF is one of the strongest research institutes, with global visibility and numerous unique technological features.

Fiber Lasers
Fiber lasers are high-power, coherent radiation sources for scientific and industrial applications. A key application for the development of fiber lasers is laser material processing in production environments.

The various fields of application increasingly require high-power, efficient, and robust lasers with high beam quality. This has led to the development of a new generation of laser systems with improved parameters. These fiber laser systems achieve output values of several kilowatts with virtually diffraction-limited beam quality.

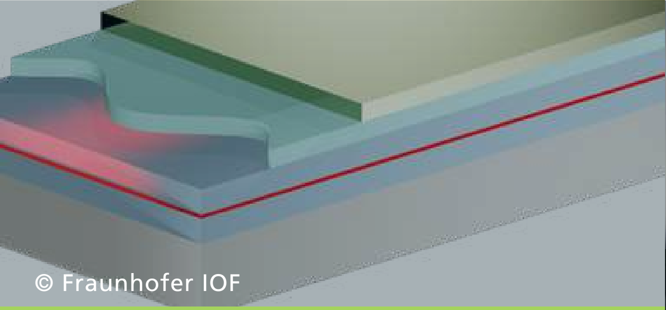
The cooperation of the Fraunhofer IOF with the Institute for Applied Physics at the Friedrich Schiller University in Jena focuses on the development of high-performance laser systems ranging from monofrequency beam sources to ultrashort pulse systems.

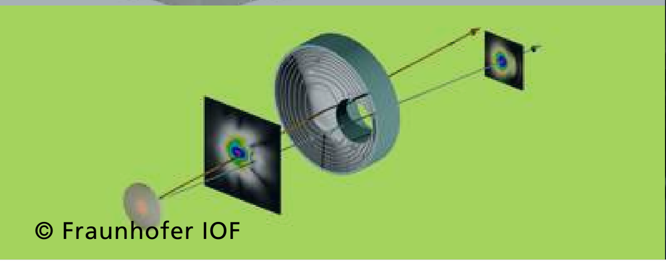
Q-Switched Microchip Lasers
Motivation: Diode-pumped and passive Q-switched microchip lasers based on various laser crystals and saturable semiconductor mirrors are used as absorbers (SESAM) to generate short and ultrashort laser pulses.

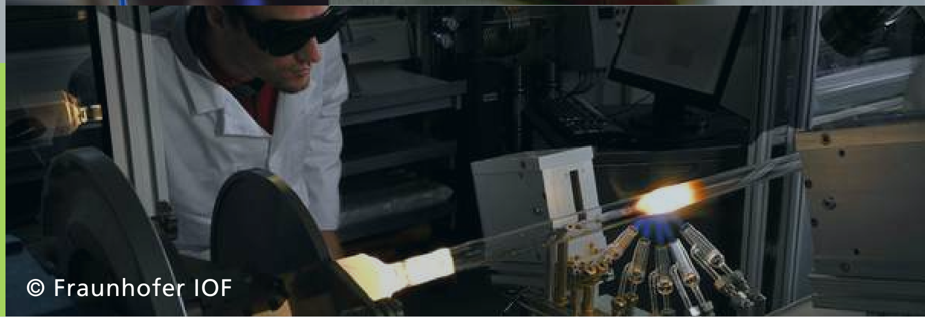
The major disadvantage of Q-switched lasers is a strong time jitter arising from the resonator dynamic, ambient instabilities and the statistical character of the spontaneous emission in the amplification medium.

The monolithically bonded, passive Q-switched microchip lasers at Fraunhofer IOF are based on $Nd3+:YVO4$ and SESAM. They generate pulse durations of less than 200 ps with pulse energies greater than 150 nJ with pulse repetition rates in the range of 100 kHz to a few MHz. These good output parameters are depreciated by the relatively strong time jitter, typically 1% of the pulse repetition period.

Solution: A simple and cost-effective method based on self-feedback is developed to reduce jitter. By using an optical fiber as a delay line, a small amount of the photons are removed from the previous laser pulse and supplied to the laser briefly prior to initialization of the following pulse.







As a result, the statistical initialization of the optical pulses in the laser resonator is replaced by a determinist process and thereby the time jitter reduced.
Implementation of this principle reduces time jitter in a microchip laser by a factor of over two orders of magnitude.

Application: On account of their simplicity, microchip lasers are suitable for a broad range of applications such as frequency multiplication, micromaterials processing and LIDAR.

Semiconductor Lasers
The Fraunhofer IOF has many years of experience in optimizing output radiation of semiconductor lasers and their adaptation to the widest range of applications. Here, a key area of focus lies in improving beam quality. In this field, the Fraunhofer IOF works closely together with external partners. One example is the realization of innovative semiconductor lasers with internal beam shaping optics.

Beam Control and Shaping Systems for Lasers
The use of laser and laser diode sources in metrology, visualization and materials processing requires beam shaping optics on the one hand for production (collimation, circularization and astigmatism correction), on the other for adaption to specific tasks (focusing, line and pattern generators etc.).

The Fraunhofer IOF develops optical designs and adapted set-up and assembly technologies. In addition, special optical elements are manufactured for beam shaping systems (e.g. of laser resonators).

Assembly and Joining Technology for Fiber Lasers and Fiber Optics
The assembly of laser systems requires special construction and joining technologies which enable operation and stability in an industrial environment.

To this end, the Fraunhofer IOF develops both adapted optomechanical components (e.g. for mode and beam shaping of laser resonators) and process technologies for high-performance lasers. These include preparation technologies for high-performance fibers as well as joining technologies such as soldering, bonding and adhesion methods for optics and optomechanics.

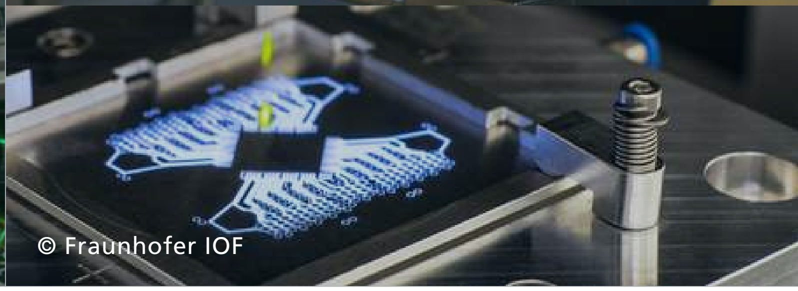
Fiber Optics
The use of laser and laser diode sources in metrology, visualization and materials processing requires beam shaping optics on the one hand for production (collimation, circularization and astigmatism correction), on the other for adaption to specific tasks (focusing, line and pattern generators etc.).

The Fraunhofer IOF develops optical designs, produces special-purpose optical elements for beam shaping systems and creates adapted construction and assembly technologies.

Fiber Technology
Direct access to the entire technology chain from design to preparation and characterization all the way to system integration of the laser-active special fibers and fiber optic components is required for the construction and use of cw and pulsed fiber laser systems of the highest beam quality with output powers up to the kilowatt range.

The construction and operation of the technology for producing the laser-active preforms and fibers for industrial purposes offers the opportunity to transfer existing solutions at laboratory scale to an industrial environment and ensure the long-term and reliable availability of components.

The concentration of fiber design, laser physics and glass chemistry will further develop existing system solutions and generate new fibers and laser systems. These will then be optimized for special-purpose applications.



Fiber-Based Amplification of Laser Sources
Rare-earth doped fibers offer a simple and performance-scalable way of amplifying low-power laser sources to high power while maintaining the optical parameters and beam quality. In addition to ultrashort pulse lasers, these also include Q-switched lasers and continuous sources. An average power of several kW and pulse peak powers up to the GW range are possible.

Preform and Fiber Technology for High-Power Lasers
Motivation: Development of a technologically closed process chain for the production of special fibers with the aim of an economic and reliable process of fibers for scientific and industrial applications.

Characteristics:
- Laser-active preforms and fibers with variable geometries (e.g. 20 µm laser-active core, 400 µm pump core)
- Optimization of the composition regarding maximum pump absorption with low photo darkening
- Design and preparation of micro-structured large core fibers with low numerical aperture in the laser-active area

Application: Development of monolithic fiber lasers with output powers in the kW range, an outstanding beam quality, and a compact, maintenance-free and hard-wearing construction.

Ultrashort pulse fiber lasers
Motivation: With their temporal dynamics, ultrashort laser pulses are of outstanding importance for various interdisciplinary applications. Short pulse durations help to achieve high intensities, and non-linear optical processes can be particularly effectively operated to exploit new wavelength ranges. With the high quality of the generated structures, micro-materials processing also benefits from the use of ultrashort pulses.

Fiber laser systems on the basis of ytterbium are excellently suited to generating and amplifying ultrashort laser pulses. The amplification bandwidth supports pulse durations of a few hundred femtoseconds. In addition, the use of special fibers with very large core diameters enables the amplification of the pulses to energies up to the millijoule range. The beam quality remains excellent. This is of key importance for many applications.

Benefits:
- Huge amplification bandwidth for amplifying pulses with durations of a few hundred femtoseconds
- Resistance to thermo-optical influences, by means of which particular high pulse repetition rates can be achieved
- Excellent beam quality with the guiding properties of the fibers
- Robust in the face of adverse environmental influences
- Low-adjustment and low-maintenance

Applications:
- Micro-materials processing for boring holes and cutting sheets
- Driving parametric processes for refining few-cycle pulses
- Generation of coherent X-ray radiation for basic research in physics, biology and medicine

High Power Fiber Lasers
Rare-earth doped fibers offer a simple and performance-scalable way of amplifying low-power laser sources to high power while maintaining the optical parameters and beam quality. They are used with ultrashort pulse lasers, Q-switched lasers and continuous laser sources.

An average power of several kW and pulse-peak powers up to the GW range are possible.

Lasers and Laser Measurement Technology

Lasers
In this field of research, Fraunhofer ILT develops innovative laser beam sources and high-quality optical components and systems. Fraunhofer's team of experienced laser experts develops beam sources with tailored spatial, temporal and spectral properties and output powers. Their spectrum ranges from diode lasers, fiber and solid-state lasers to high-power CW lasers and ultrafast lasers, and from single-frequency systems to broadband tunable lasers.

Among others, the institute has focused on developing laser systems that achieve high powers with ultrafast pulses. In the Fraunhofer Cluster of Excellence Advanced Photon Sources CAPS, 13 Fraunhofer Institutes have been pooling their expertise to develop high-power ultrafast laser systems and to explore where they can be applied.

Fraunhofer ILT is also developing software for modelling and simulation that enables them to design a specific laser beam for certain tasks, e.g. by shaping the intensity profile. The experts use special algorithms to design optical freeform surfaces for redistributing the laser power through light refraction and reflection.

These lasers and optical systems can be applied in a wide range: from laser material processing and metrology to applications in biotechnology and medical technology all the way to use in space applications and basic research.

In the field of quantum technology, the institute is developing parametric photon sources and frequency converters, integrated optical components and packaging processes for new applications in close cooperation with top international researchers.

Fraunhofer ILT has many years of experience and comprehensive know-how in the field of beam source development and photonics. For customers from industry and research, we develop demand-oriented solutions for implementing new ideas as well as for optimizing existing laser beam sources, in particular with regard to robustness, efficiency and cost-effectiveness.

Laser Measurement Technology
Lasers are ideally suited for the precise measurement of physical, chemical or biological quantities in various fields of application. Fraunhofer ILT develops laser measurement processes, e. g., for tasks in manufacturing and inline-capable process control, and implements them in prototypes and small series together with customers and partners. In this field, the institute is also focusing on material and bioanalytics, identification and analysis technology in the field of recycling, and raw materials as well as measurement and testing technology.

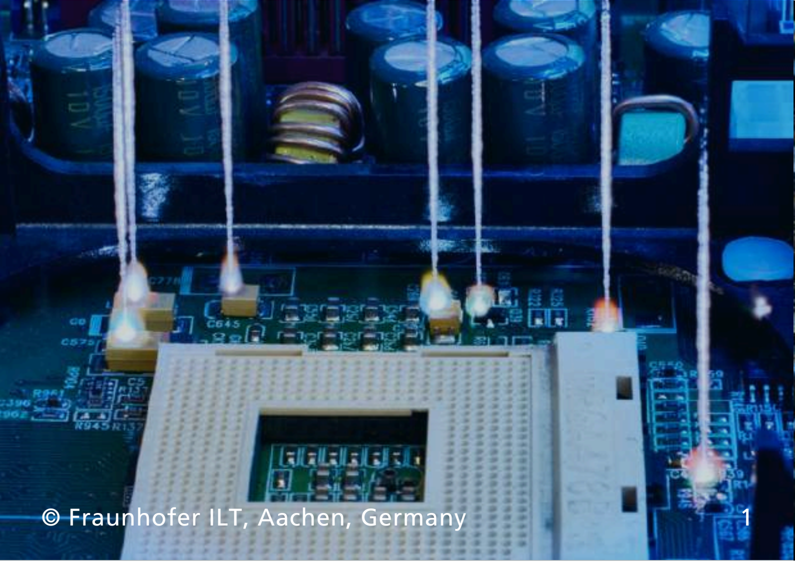
In materials analysis, Fraunhofer ILT has profound know-how in spectroscopic measurement processes at its disposal. Applications in this field include automatic quality assurance, the monitoring of process parameters and the online analysis of, for example, old electronic components, metal scrap or exhaust gases, dust and wastewater. Among other processes, laser emission spectroscopy (laser-induced breakdown spectroscopy LIBS) is used, allowing particularly fast and accurate material identification. In addition to process development, the institute manufactures prototype systems and mobile systems for industrial use.

OUR SERVICES

R&D key topics of the technology focus "Lasers"
- Diode Lasers
- Fiber Lasers
- Non-linear Optics
- Packaging
- Simulation - Optics and Lasers
- Solid State Lasers
- Tunable Lasers
- Ultrafast Lasers

R&D key topics of the technology focus "Laser Measurement Technology"
- Bioanalytics
- Inline Measurement Technology
- Laser Microscopy
- Material Analysis
- Production Measurement Technology
- Real-time Measurement and Control Technology

1. Optical components in a non-linear interferometer.



Together with international partners, Fraunhofer ILT is also breaking new ground in researching modern recycling processes. Solutions are being developed jointly – with laser technology – to make processes more effective and efficient.

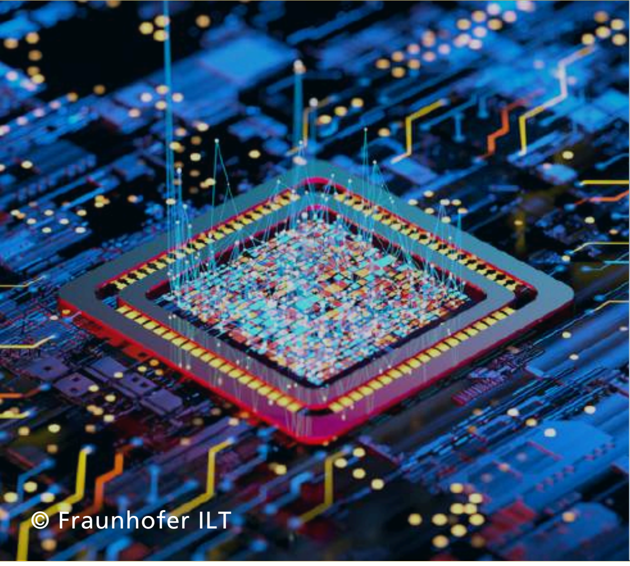
The institute and its partners are focusing on recycling parts and components no longer in use instead of on mining raw materials. Here, inverse production is taking center stage. In contrast to being shredded conventionally and treated with pyrometallurgy processes, old electronics or metal scrap, for example, are first measured and valuable components specifically dismantled or valuable alloys separated before mixing in order to achieve high grade purities.

For analysis in chemistry, biotechnology and pharmacology, Fraunhofer ILT uses and develops laser scattered light analysis, laser-induced fluorescence and microscopy with broadband lasers. It is focusing, for example, on designing inline measurement systems and continuing to develop waveguide technology and probes for chemical process analysis. Thanks to laser-based measurement technology, molecules can be excited selectively and particle sizes or size distributions as well as their chemical composition determined in real time.

As the networked technologies of the Fourth Industrial Revolution advance, the amount of data that must be processed quickly and inline is growing. Real-time signal processing is becoming increasingly important, and not only in production metrology. To this end, Fraunhofer ILT is developing, among other things, absolute measuring interferometric sensors that allow the non-contact detection of geometric features, as well as powerful electronic units for customized applications.

Fraunhofer ILT has extensive know-how in the field of laser measurement technology and develops efficient and adapted laser processes for customers from industry and research.

1. In the field of recycling old electronics, LIBS can be used to quickly and selectively detect individual components or entire groups of components.
2. Analysis of metal scrap by laser-induced breakdown spectroscopy LIBS.



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Laser for Microelectronics

The microelectronics industry is increasingly focusing on trend topics such as miniaturization, 3D integration and artificial intelligence (AI). New developments and technologies such as quantum computing will also provide strong impetus for further advances in the medium to long term. With the increased use of mobile devices and the Internet of Things (IoT), energy efficiency is also an important aspect of microelectronics.

Current challenges in microelectronics
Progressive miniaturization on a nanoscale level represents a technological challenge. Ever smaller structures and 2D materials require innovative approaches to overcome current physical limits. Among other things, chips for 5G applications are to be developed that improve connectivity in various application areas – for example, for autonomous vehicles.

Solutions from Fraunhofer ILT
The experts at Fraunhofer ILT develop and evaluate beam sources for EUV lithography and the corresponding measurement technology in order to advance the miniaturization of electronics. In addition to generating structures on the nanometer scale, the institute also focuses on assembly and connection technology for high-performance electronic components. Together with industrial partners, Fraunhofer ILT is developing new connection technologies for battery contacting and power components.

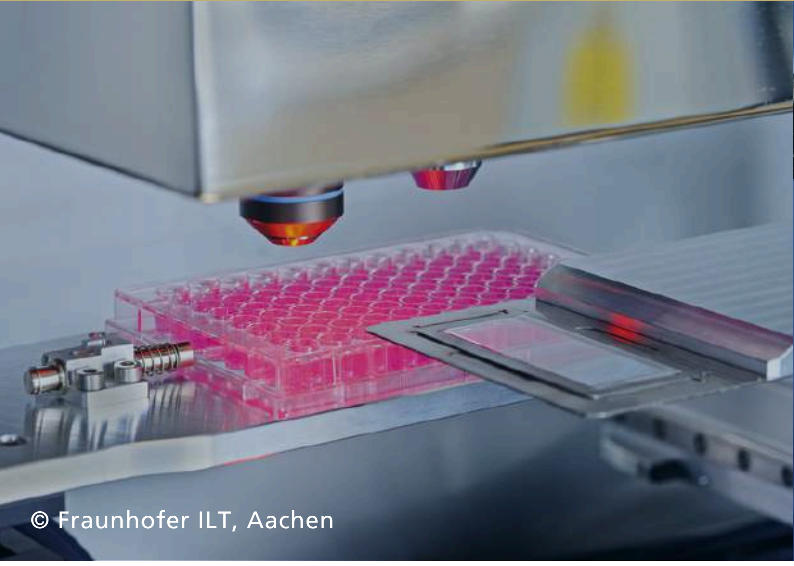
Fraunhofer ILT also has expertise in the structuring and functionalization of surfaces and in 3D volume structuring. For example, microscopic structures can be introduced into glass or sapphire substrates by selective laser etching, structures that can be used to create microfluidic systems for biochemical analyses.

Additively manufactured sensors
The collection of component condition data such as thermal and mechanical load, together with AI, forms the basis for predictive maintenance and big data. Suitable sensors that are integrated into the components are advantageous for collecting this data. Laser-based coating approaches enable the additive construction of sensors on different surfaces, e.g. through the wet-chemical deposition of electrically insulating and conductive materials using printing processes and subsequent thermal post-treatment with laser radiation.

Laser-based packaging
Since they apply energy locally, laser-based packaging processes help progressively increase the integration density of highly sensitive, functional elements in miniaturized microsystems. Processes such as laser soldering, glass solder bonding, laser beam bonding for transparent and metallic materials or micro-welding are precise joining technologies that meet the constantly growing requirements in the packaging sector.

Laser beam soldering, for example, is a method that offers high flexibility in the production of high-density circuits; it improves the thermal performance of electronic components. By precisely controlling the laser beam, high-strength connections can be produced, ensuring reliable and durable chip assembly.

Semiconductor technology
In semiconductor technology, lasers perform a variety of crucial tasks: From the structuring and processing of semiconductor materials such as silicon and gallium arsenide to the ablation and deposition of thin film layers and the doping and activation of materials, lasers play a central role. They are also used for processing wafers and for thermal processes such as the targeted melting of materials. These versatile applications make it possible to manufacture semiconductor components with high precision and quality, thus significantly advancing the development of modern electronic devices and technologies.



Laser for Medical and Biotechnology

Medical technology and health
Artificial intelligence (AI) in diagnosis and treatment, internet-based health devices (IoMT) and personalized medicine: Medical technology is undergoing rapid change. Mobile health apps, digital monitoring of health parameters and remote consultation are on the rise. Robotics in surgery, augmented reality (AR) and virtual reality (VR) and genome editing techniques are topics that are driving doctors and technologists forward on an interdisciplinary basis.

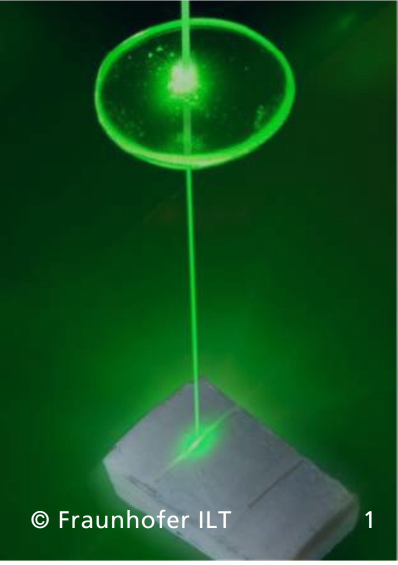
Current challenges in medical technology/health
Demographic change poses particular challenges for the healthcare industry. In ageing societies, the need for medical care is growing. However, there is a shortage of specialists and a lack of financial resources in systems financed by contributions. This dilemma can be solved by technological progress, and laser technology is an important driver here. It enables more accurate diagnoses, more efficient laboratory processes, more effective drugs and therapies, gentler surgical procedures, individualized implants and highly effective personalized medicine. What's more, laser-based inline analytics holds great potential for a key cornerstone of healthcare: environmental protection.

Solutions from Fraunhofer ILT
Fraunhofer ILT develops intelligent, safe and precise laser processes and laser systems for optimal and, at the same time, affordable patient care and the preservation of a healthy environment. They pave the way for automated, minimally invasive surgery, personalized medicine and more time- and cost-efficient clinical and pharmaceutical research based on automated laboratory processes.

Laser and AI-based inline measurement processes and optical analysis methods are used for accurate diagnostics, optimize processes in research and production and make important contributions to health care, for example, through more efficient water treatment. With the development of state-of-the-art optical measurement and analysis methods, Fraunhofer ILT protects processes and interventions in which nanometers and micrometers are often crucial. Software, simulation and the targeted use of AI ensure that processes are developed effectively and the application remains reliable and safe.

Biofabrication
Laser processes are particularly suitable for manufacturing and processing products for the biomedical sector: from precise joining under sterile conditions to the insertion of pores, cavities and channels in micro-fluidic systems and lab-on-a-chip solutions using ultrashort pulse lasers or selective laser etching through to the targeted functionalization of surfaces. The laser technology processes required for reliable, safe and highly efficient bio-fabrication are developed at Fraunhofer ILT, whether for tissue engineering, individualized 3D-printed implants, prostheses or inner ear hearing aids.

Bioanalytics and diagnostics
Fraunhofer ILT laser processes support the automated isolation of pluripotent stem cells for personalized medicine, immune cells for efficient clinical diagnostics and high-producer cells for the production of biologics. Laser-based inline measurement processes ensure the optimal size distribution of nanometer-sized active ingredient particles in drug production. And with various spectroscopic analysis methods and AI, it is becoming increasingly possible to identify and characterize biomaterials based on their molecular building blocks. In addition, measurement methods such as optical coherence tomography (OCT), interferometry and laser- and AI-assisted microscopy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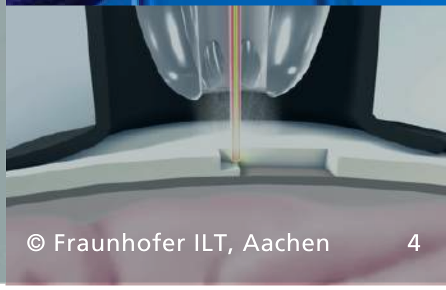
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processes ensure maximum precision in clinical diagnostics, pathology and robot-assisted surgery.

Laser therapy
Laser procedures are playing a transformative role in medical technology. Minimally invasive procedures using endoscopes, laser-based eye surgery, the removal of tattoos and the treatment of skin diseases are just as much a part of the repertoire as innovative approaches to removing bone tissue using short laser pulses instead of saws and milling machines. In dentistry and the treatment of cancer, lasers also contribute to gentler treatments that are less stressful for the patient.

Advantages such as minimal damage to surrounding tissue pay off in faster healing processes and minimized postoperative complications. The laser procedures developed at Fraunhofer ILT thus make important contributions to economical, efficient healthcare.

Laser Osteotome for Awake Brain Surgery
Task: For neurosurgery, researchers have developed novel therapeutic methods that not only significantly improve the quality of life, but also the survival rate of critically ill patients. These methods require, however, that the patient be operated on while awake since complex functions such as speech must be tested during awake brain surgery, yet removing bone from the skull with drills and burrs causes the patient extreme stress. For this reason, a laser osteotome is being developed at Fraunhofer ILT in close collaboration with experts in neurosurgery. This laser osteotome can be used to open the skull bone without vibration or noise, thus significantly reducing the psychological stress as well as the risk of injury for the patient.

Method: For a safe, vibration-free and low-noise ablation process, the drill and cutter are replaced by a MIR (Mid-Infrared) laser beam source, which emits nanosecond pulses with pulse energies in the millijoule range. To ensure that the cutting process is efficient and does not cause any thermal tissue damage, the laser pulses with kilohertz frequencies must be distributed along the cutting line in such a way that a continuous deep kerf is created. This cutting function is made possible by an applicator with an integrated 2D mini-scanner for beam guidance, focusing optics with adjustable focus position and a spray nozzle for wetting the bone surface. Synchronized with the cutting process, an OCT (optical coherence tomography) measuring beam determines the local cutting depth and residual thickness of the bone to control and stop the cutting process shortly before the bone is cut through. In this way, the cutting depth control protects the structures of the brain located under the skull bone.

Results: Process parameters for an efficient laser cutting process were determined in systematic ablation experiments on bovine bone samples. The ablation rates achieved were above dV/dt = 4 mm3/s. The maximum cutting depth was 7 mm with a cutting width of 2 mm. In addition, Fraunhofer ILT has developed a digital model of the laser osteotome, which can be used to simulate the entire operation sequence and develop a hardware control system.

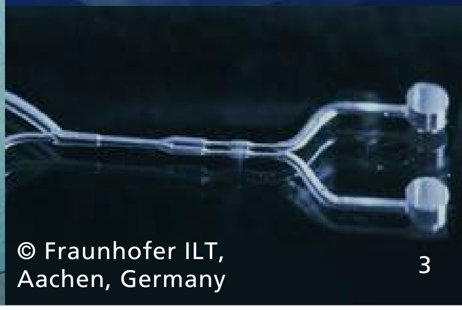
Applications:
Fields of application for the laser osteotome are awake operations for the treatment of complex movement disorders. Awake operations are also becoming increasingly important in the surgical treatment of low-grade gliomas (brain tumors).

The project is being funded by the Fraunhofer-Gesellschaft as part of the ATTRACT research program under the project name STELLA.

Microsurgery
Our range of services: Together with leading experts from the clinic and medical technology, Fraunhofer ILT is developing novel laser-based therapeutic processes for the precise cutting of bones with short-pulse laser radiation. In addition, it is evaluating new laser procedures for the coagulation of blood vessels and for dermatological therapies.

Microsurgical Systems
- “Cold” tissue ablation with USP lasers
- Laser surgery
- Laser coagulation
- Dermatological laser processes
- Mini-scanner technology

1. Laser cut on Hard Tissue.
2. Laser cut on a bovine bone with an aspect ratio of 16:1.
3. Sorting chip for analyzing and isolating cells in a blood sample.
4. Applicator for implementing the laser cutting process on the skull bone.
5. Hand-piece of a Laser Microsurgical System.



Design of the Microfluidic System

- Design of microfluidic structures suitable for manufacturing

Material Selection and Modification

- Selection of the most suitable materials (polymers, silicon, glass, ceramic, metal or hybrid systems)
- Surface modifications such as hydrophobic, hydrophilic surfaces and surface micro-structuring

Prototype Development

- Production of microfluidic prototype systems in the shortest amount of time
- Rapid manufacturing inserts for high precision microinjection molding

Joining and Assembly

- Sealing of microfluidic systems with low mechanical or thermal damage

Serial Production of Microfluidic Systems

- Manufacturing of microfluidic systems in corresponding chemical and bio-medical laboratories
- Development and construction of turnkey production machines

Functional Tests and Quality Assurance

- Air and liquid tightness tests
- Tensile tests

Additive Manufacturing of Medical Implants by LPBF

- Manufacture of individual implants out of titanium and TiAl6V4
- Realization of new implant design, e. g. with complex surface or porous structure

Process Development for Bioresorbable Material

- Stents out of polylactide
- Bone implants out of calcium-phosphate ceramic

Studies for Admission Procedure

- Biocompatibility
- Mechanical properties
- Process chain examination
- Risk analysis

1. Mini scanner of a Laser Microsurgical System.
2. Microfluidics for the analysis of liquid samples.
3. Microfluidic cell sorter in fused silica.
4. 3D network structure (strut thickness < 100 µm).

So that surgeons can better use specific microsurgical methods, Fraunhofer ILT is developing applicators with which they can safely use therapeutic laser processes in OR. These include compact hand-pieces with integrated mini-scanner technology for dosing therapeutic laser radiation at the treatment site as well as optical sensors for the in-situ monitoring of laser cutting and coagulation processes. Fraunhofer ILT develops the applicators and sensors on customer order as OEM components and integrates them into laser-based therapeutic systems.

The services "Microsurgical Systems" offers range from feasibility studies and prototype development to the implementation of small series devices.

Microfluidics

Our range of services: In medicine and biotechnology, laser technology makes a multitude of analytical, diagnostic and therapeutic applications possible. Since laser-based optical measuring and processing processes do not touch the objects they measure, they are ideal tools, in particular when used under sterile and highly selective conditions. They are suitable both for the production of appropriate instruments for medical technology as well as for diagnosis itself.

Fraunhofer ILT develops microfluidic structures and systems for customized applications. With laser-based processes, materials can be characterized, selectively modified on the surfaces or precisely machined on the inside. Not only can plastic, ceramics or silicon be processed, but also glass, metals or hybrid material combinations. For example, the institute uses and continues to develop Selective Laser-Induced Etching (SLE) to produce precise micro-channels, holes and cuts in, for example, transparent components made out of chemically resistant materials such as fused silica, borosilicate glass, sapphire and ruby. Among other things, microfluidic systems with such channels are used in lab-on-a-chip solutions, which enable fast multiplex diagnostics. The micrometer-fine structures can be produced directly from 3D CAD data. In addition, the systems can be sealed by laser radiation with little mechanical or thermal influence.

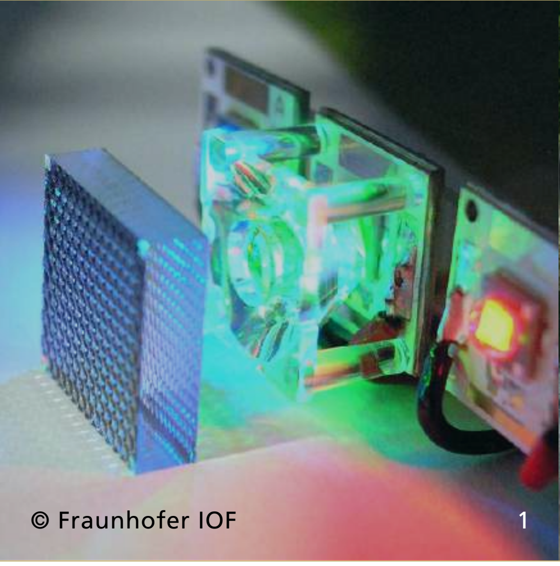
The services offered encompass component development, the rapid production of prototypes for design validation, the development and implementation of assembly and connection techniques, technical function tests and developments for quality control as well as individual consulting.

Implants

Our range of services: In hospitals, patient-specific implants are often required, in particular, as a result of accidents, tumor resections or congenital defects. Developed at Fraunhofer ILT, Laser Powder Bed Fusion (LPBF) can be used to produce individual bioresorbable implants accurately with very large geometric freedom. In addition, the use of the laser significantly reduces time and costs. On the basis of patient-specific data, for example, individual dentures, artificial hip joints or customized bone substitutes can be manufactured using this laser-based 3D printing. Re-sizing or removing implants are not needed thanks to the use of bioresorbable materials.

Complex internal structures can be used to produce implants with bone-adapted stiffness. By integrating defined pores, research has been able to improve the ingrowth behavior of the bone. For example, Fraunhofer ILT is working with medical professionals to develop additively manufactured vertebral body implants that are individually designed and locally adapted for their geometry, rigidity and structure. This significantly reduces the implant failure of cages – inserts for intervertebral spaces.

The range of services includes constructive design, individualized design and process development for the additive manufacturing of (individual) implants using LPBF within the framework of feasibility studies as well as individual consultation.



Photonics for Automotive

Photonics has undergone a revolution in the automotive industry in recent years, transitioning from mere lighting functions to providing cutting-edge technology for imaging, sensing, smart displaying, media, and for communication networks. Consequently, photonics has taken on new dimensions far beyond lighting in cars as well as in automotive manufacturing and quality control. It is not surprising that the automotive industry is showing an increased interest in innovative, photonics-based technologies. Myriad growth opportunities spur the lighting market to expand by about 5 percent p.a. . An even greater boost is expected for the automotive photonics market.

Fraunhofer IOF transfers research into applicable solutions, offering the complete photonics process chain from system design and simulation, via realization of custom-specific solutions to system integration. Thus, we provide our customers with the next generation of innovation in the entire field of photonic applications in cars, automotive technology, mobility and production.

Our customers can benefit from our many years of experience in the field of automotive photonics. The demonstration of our solutions will provide ideas for future projects, which we can tailor to meet your individual needs.

Exterior lighting/Indicators
When it comes to avoiding accidents, communicating with other road users while driving is critical. However, this has posed an ongoing challenge for science. Projecting information on the street beside the vehicle is one solution to the problem. This requires bright, cost-effective, and miniaturized projectors for a small number of image contents.

Fraunhofer IOF has developed a miniaturized micro-optical array-projection technology enabling projection onto tilted and curved screens with brightness up to 3000 lux. Continuous innovation has led to displays which are visible in full daylight. These systems serve as warning indicators for cyclists or as animated graphics to open and close the trunk by waving the foot under the rear bumper. Projecting logos via signature lighting is a sophisticated feature for brand identification. This technology can be integrated into existing lighting systems e.g., in backlights.

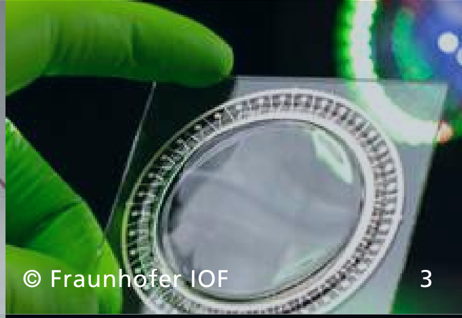
Automobile manufacturers have already integrated this feature into their vehicles, such as the Welcome Light Carpet in current BMW models.

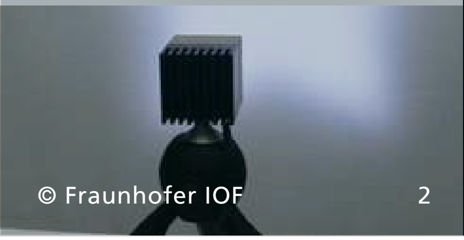
Headlamp/Adaptive lighting system
Adaptive driving beam (ADB) systems provide a comfortable driving experience by enhancing both illumination distance and road safety. With individually addressable beam segments, these systems prevent glare for oncoming and preceding traffic while ensuring clear visibility. Recent advancements of Fraunhofer IOF in micro-optical beam shaping technology have made it possible to build a solid-state ADB system. By using an LED array and precisely controlling channel cross-talk, ADB systems achieve high performance and safety on the road.

Fraunhofer IOF's innovative solid-state lighting system enables the realization of an adaptive high beam and an efficient low beam. Both lighting units can be seamlessly integrated into a vehicle's design language with a high degree of freedom while occupying minimal space.

The maskless irregular micro-optics offer an effective solution for low beam shaping, eliminating the need for absorbing elements. This allows for up to 75% system transmission with a remarkably slim profile.

1. Experimental setup of an RGB-micro array projector.
2. BMW 7 series with array projector developed by Fraunhofer IOF.
3. Micro optic headlight for narrow front lights on car.
4. Segmented, automotive LED driving beam realized as micro-optical, irregular fly´ s eye condenser.





1. LED light source and generated spot on one screen.
2. Star-shape diffusor element.
3. Freeform illumination optics printed with polymer and equipped with additional functions using complex inkjet processes.
4. Printed optical elements.
5. Hydrophobic surface with self-cleaning effect.
6. Antireflective coating for automotive ligthing systems.

Tailored LED backlights

Newly developed light field displays enable a revolutionary approach to rear light design. Large-format 3D effects can be created on an ultra-thin surface, providing vehicles with a unique nighttime appearance.

We developed a technology to realize a 3D rear lamp. The slim size of the display optics (ca. 3 mm) allows compact construction without the need of facetted mirrors to give a 3D impression. The lightfield display is based on multi-aperture micro-optics to display icons or symbols with a ‘floating-in-space’ quasi 3D effect. The displays generate a field of view of 20°…40°. Tiny microlenses of diameter 300 µm together with individually shaped and decentered array of slide mask structures generate eye-catching patterns and motifs.

Combination of lightfield displays with tailored diffusors offer even more creative freedoms to generate unique rear lighting concepts. Additional application of such lightfield displays could be for display of icons, branding or more.

Individualized lighting

Personalizing one’s car is increasingly in demand. The exterior and the technical components as well as individualized interior including illumination have become a means of personal expression.

Several Fraunhofer Institutes are currently cooperating in the lighthouse project »Go Beyond 4.0« developing cutting-edge technologies for individualized products and components in mass production. The participating Fraunhofer Institutes have succeeded in manufacturing electrical conductor patterns, sensors, and lighting components, individually created by using digital printing and laser technologies. The result is the individualization of components in mass production environments with new opportunities for design, material savings, and weight reduction.

This opens up new avenues to design and realize automotive parts in general, and lighting concepts and arrangements in particular. Within the ongoing project, we have demonstrated a prototype of a smart door with novel illuminated inter- action elements for car-to-driver communication and individual LED illumination optics with integrated functionality.

We were also able to apply conductor tracks directly to body parts using digital printing and laser processes. This makes a complex body part lighter and eliminates the need to manually lay a wiring harness.

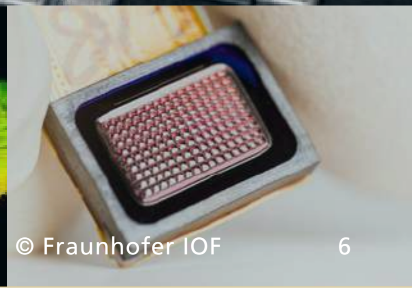
Surface functionalization

In the optical industry, surface coatings play a crucial role in creating tailored surfaces for various applications. At Fraunhofer IOF, we specialize in developing surface functionalization and multi-functional optical coating systems.

Our expertise extends to working with plastics, glass, and metal, and we have successfully transferred these technologies to production and high-volume manufacturing. With our in-depth knowledge and advanced technologies, we excel in designing and simulating optical layer systems, developing coating processes, and characterizing surfaces and coatings.

Our capabilities cover a wide range of surface coatings, including: ultra-broadband antireflective coatings, scratch-resistant coatings on plastics, additional functionalities like anti-fog and self-cleaning, durable metal-dielectric coatings or transparent conductive coatings.

In addition, we offer exhaustive testing procedures such as environmental tests, mechanical testing and evaluation of optical properties. We also specialize in coating failure analysis and lifetime studies. Furthermore, we are equipped to measure light scattering and appearance, providing accurate and reliable data for your specific requirements.



Production control
Many industrial production plants demand 100 percent inspection of the manufactured goods for quality assurance. To guarantee this at high production rates, inline measurement solutions are vital for an efficient production.

We develop customer-specific, fully automatic, robot-based, non-contact, optical 3D measuring inline inspection systems. These systems can measure areas from only a few square millimeters up to several square meters with rates in the millisecond range. We use specially developed optical systems and parallelized 3D algorithms based on multi-processor systems. The full-surface measurement can detect and interpret local deformations and defects simultaneously. The 3D measurement accuracy is in the range of 10-4 of the measurement field diagonal.

We have already integrated systems into the quality control of casted motor blocks, large industrial catalysts, aircraft engines and more. The resulting data is compatible with common CAD systems. Your ideas or projects can be realized based on our experience in 3D metrology of more than 25 years.

Ultrafast 3D capturing
Optical 3D measurement technology is a versatile tool that is employed in many areas of industry and research. Especially highly dynamic processes like the inflation of an airbag require high-speed technology to examine and evaluate these moving objects in full 3D.

Researchers at Fraunhofer IOF have developed projection, acquisition, and evaluation technologies with multi-kilohertz frame rates by using high-speed camera systems in conjunction with gobo-projection and parallelized data processing. This enables us to capture and evaluate up to 1,500 3D-frames per second with each frame composed of 1 million 3D-pixels, or even 50,000 3D-frames per second with each frame composed of 250,000 3D-pixels.

We have already transferred this innovative technology to our customers. One of these systems can capture the crash test of a complete car; another system was optimized to capture a crash test from inside the car – withstanding the strong negative acceleration during the crash.

Driver attention monitoring
A driver attention monitoring system continually assesses driver behavior to determine if a driver has become inattentive. If the driver is not completely focused or a dangerous situation is detected, the sophisticated system will alert the driver.

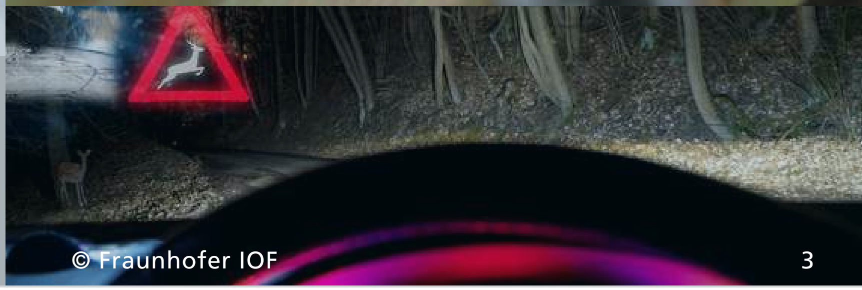
Fraunhofer IOF develops ultra-thin cameras, which can be easily and almost invisibly integrated in the interior of a car. Driver monitoring and inattentive driving detection can be performed as well as passenger (or child) monitoring.

The multi-aperture imaging optics concept ensures thinner objectives better suited to integration in ultra-slim modules. The camera module – with an objective – has a total thickness of 2 to 10 mm and offers wide angle capturing with resolutions ranging from CIV to 8 megapixels.

Our optics solutions rely on parallelized processes for the generation of micro-optical components which differ from conventional lens fabrication. Wafers instead of single pieces are handled for process parallelization, enabling high reliability and low-cost high volume production.

LIDAR
Light detection and ranging (LiDAR) laser systems in vehicles supporting advanced driver assistance systems (ADAS) and are going to play a key role in autonomous and assisted driving. Micro-optical solutions enable compact, lightweight, and cost-efficient systems.

1. Gesture-controlled 3D sensor platform for autonomous component measurement.
2. Inline measuring system for quality assurance in production operations with optical 3D and 2D sensor technology.
3. High-speed 3D measurement system.
4. Demonstration of an airbag deployment: 3D data at four different time points.
5. Freeform microlens arrays after cutting.
6. Miniaturized array camera.



Fraunhofer IOF has a strong competence in the design and manufacturing of wafer-level optical meta-structures for high-efficiency laser beam shaping for ultra wide-angle scenery illumination. Wafer-level integrated micro-optical solutions can also help improve the sensitivity of time-of-flight (ToF) camera sensors, which are an integral part of the LiDAR-package. Those, however, often suffer from a low filling factor of the light sensitive areas due to extensive space for complex read-out electronics.

IOF-fabricated microlens arrays, which are adapted to the primary imaging optics, molded directly on top of the CMOS wafer substrates improved the sensitivity of SPAD sensors by nearly an order of magnitude.

Head-up displays
Head Up Displays project vehicle's status information via the windscreen into the driver's eye box. Providing service data (i.e. speed and navigation) in an overlay while keeping the view on the track ahead, these complex optical systems contribute increased safety and elevated driver experience. However, it is challenging to combine wide field of view, comfortable eye-box size, and compact unit space in these complex optical systems, while making high demands on resolution and high-fidelity projection.

Micro- and nano-optical structures help to overcome such limits. Waveguide-based pupil expander principles request for highly efficient RGB coupling gratings. We master those by electron-beam lithography in large area using the concept of metastructures. These are well-suited for cost-efficient nano-imprint-replication.

Tailored-light diffuser elements, which are utilized as intermediate image screen for the picture-generating unit, exhibit deterministic scattering functionality. Combining achromatic scattering, focusing, and deflection in a single optical enable efficient redirection into the projection path and compact system architectures at the same time.

Driver assistance systems
Night vision cameras can save lives and are therefore already included in higher-priced cars. Typically, they consist of multiple optical elements, which in turn require large adjustment efforts.

Fraunhofer IOF has the expertise to realize miniaturized and robust monolithical optical elements in the centimeter-range using freeform technologies in order to replace complex combinations of classic lenses and mirrors. We have many years of experience in the demanding manufacture of compact free-forms with e.g., four optical surfaces on one substrate (FOV 60° x 40°, expanded bandwidth) and in the areas of system design and data flow, freeform optical manufacturing, and system integration covering the entire process chain.

Our ultra-precise methods significantly reduce manufacturing expense and efforts of tooling adjustment.

1. Qualified short pulse fiber laser for LIDAR applications.
2. Section of the LIDAR fiber laser system in which the fibers are arranged very densely.
3. Compact optical systems enable driver assistance systems in the automotive sector.
4. Freeform lens design for night vision optics.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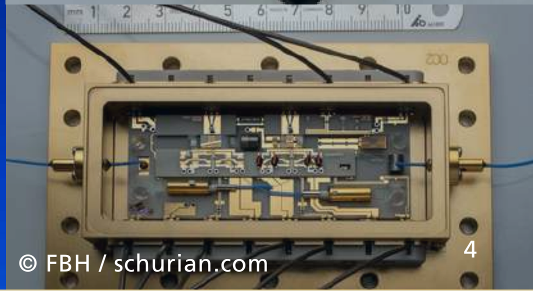
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Optoelectronic devices

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.

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 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.

Laser Modules for Space Applications
This example shows a hybrid micro-integrated narrowband laser module consisting of an extended cavity diode laser and a semiconductor-based optical amplifier (semiconductor optical amplifier). The module provides more than 500 mW of optical power at 1064 nm output with a linewidth of about 20 kHz. It was tested successfully in spring 2018 on board of a sounding rocket, where it served as a local oscillator of a highly stable iodine-based optical frequency reference.

The ceramic has a base area of 80 x 30 mm2.

1. Compact quantum cascade laser modules of the Fraunhofer IAF can be customized to address various applications.
2. Scanning MOEMS grating module.
3. Integrated tunable laser chip employing Fraunhofer HHI's photonic integration technology and assembled on an electronic board designed and fabricated by Fraunhofer IZM.
4. Successfully used in space: a micro-integrated diode laser module.

Smart Optical Systems for Communication & Sensor Technology to shape the 21st century

USE CASES

3D-Camera
Fraunhofer ISIT has developed a 3D camera based on a 2D MEMS scanner.

Laser material processing
Laser material processing is a key technology in the manufacture of modern quality products.

Piezoelectric driven MEMS scanner
Piezoelectric AlScN realizes high driving force, good linearity & long-term stability with low power consumption.

6-axis IMU device (inertial measurement unit, IMU)
MEMS inertial sensors are used for active and passive safety systems such as vehicle dynamics control but also navigation systems, which can also be found in low-cost automotive series.

Fraunhofer ISIT has more than 30 years of experience in the development of optical microsystems. ISIT offers its customers the development of products and technologies in the field of microelectromechanical systems (MEMS). In doing so, Fraunhofer ISIT covers the entire development chain for MEMS systems: from concept to technology.

Your benefits
Fraunhofer ISIT develops both vector scanners and resonant MEMS scanners including drive electronics for various types of laser projection and optical communication, for optical measurement and detection systems (e.g. LIDAR), for high laser power applications in the field of material processing and generative manufacturing as well as for use in optical telecommunication.

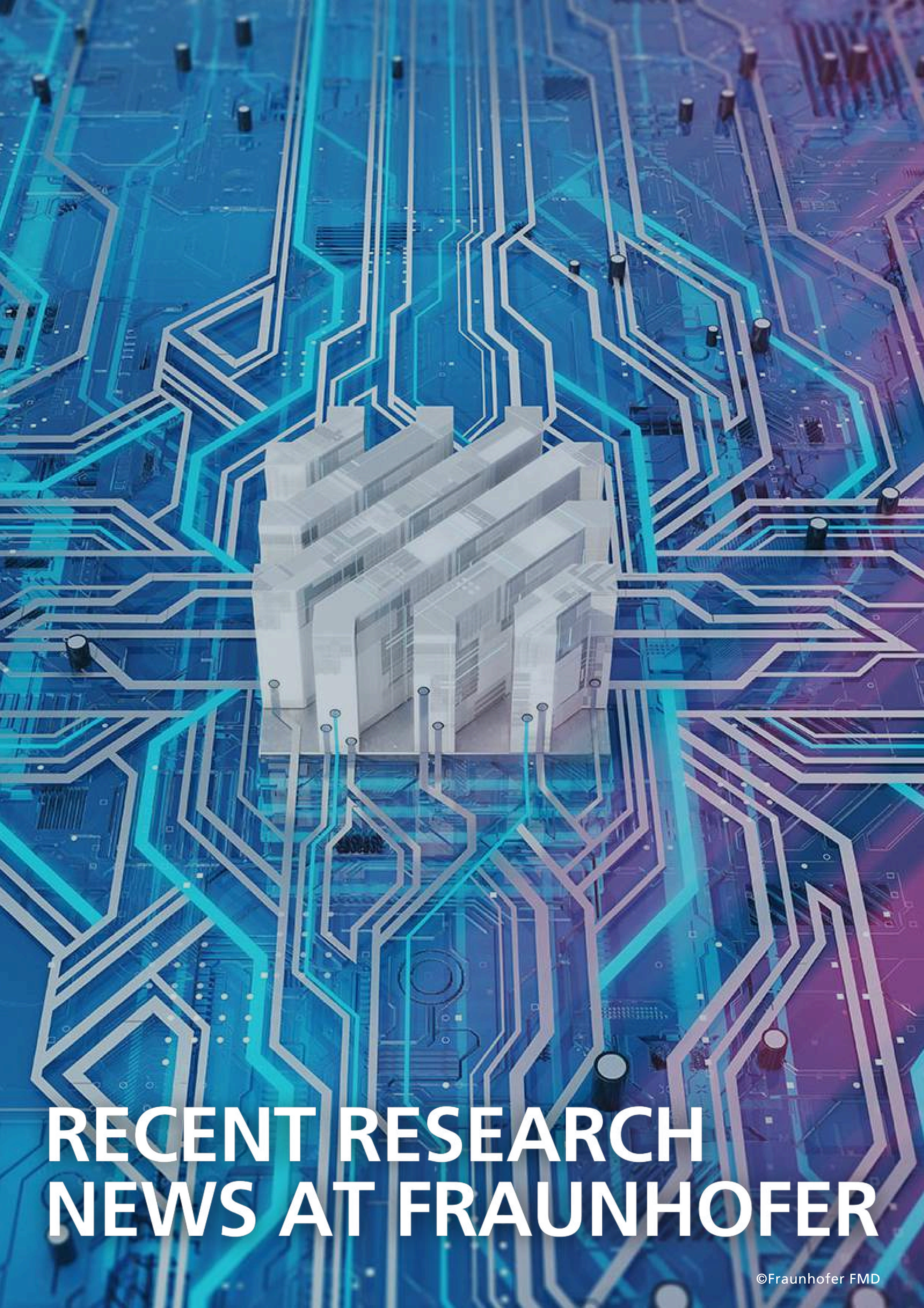
ISIT has a modern 200 mm clean room line for the development and fabrication of silicon and glass microsystems. Due to many years of experience in the development and production of MEMS and MOEMS components, ISIT has a broad portfolio of mature individual processes, as well as various process platforms. By adapting the existing processes to the respective customer requirements, individual solutions can be realized at short notice and transferred to pilot production.

Under the slogan "development and production at one location", ISIT transfers the developed components from prototype to small series production. Together with our industry partners on site a seamless transition to the industrial production of large quantities is finally achieved.

Our portfolio
- Fast laser scanner
- Beam positioning system
- Microlenses & Micro-Optics
- Micromirror Arrays
- Opto-packages for UV to IR
- Infrared sensor technology
- Beam shaping elements
- Apertures
- Display technology

Our offer
- System conception
- Simulation
- Failure analysis
- Wafer-level packaging
- Pilot production
- Packaging and interconnection
- Design
- Manufacturing
- Characterization

Application fields
- Automotive Industry
- Medical Technology & Diagnostics
- Industry
- Telecommunications
- Consumer industry



RECENT RESEARCH NEWS AT FRAUNHOFER

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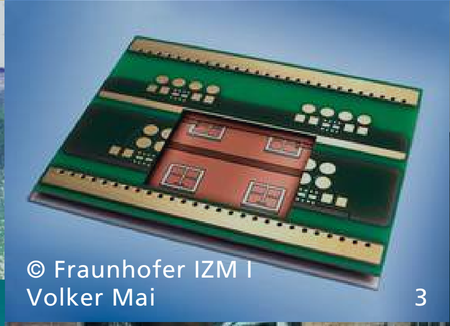


MESHFREE – simulation tool aimed at complex geometries and physics
In common simulation workflows, the preprocessing step of grid generation and grid adaption is time consuming and leads to increasing costs in product development.

For this purpose, Fraunhofer ITWM and Fraunhofer SCAI have created MESHFREE, a solution that follows an innovative point cloud approach which allows engineers to analyze their product design without the deficiencies that come along with meshes.

Electrification in the fast lane: How SiC is driving power electronics forward
The new generations of semiconductors with a wider band gap (WBG), such as silicon carbide (SiC), have the potential to put electric mobility in the fast lane. This is because they yield significantly higher efficiency compared to conventional silicon IGBT circuits and offer numerous other advantages, such as better temperature stability and less power loss.

In his interview with RealIZM, Lars Böttcher, head of the "Embedding and Substrate Technologies" working group at Fraunhofer IZM, spoke about the challenges of packaging SiC power semiconductors for the electric vehicle industry.

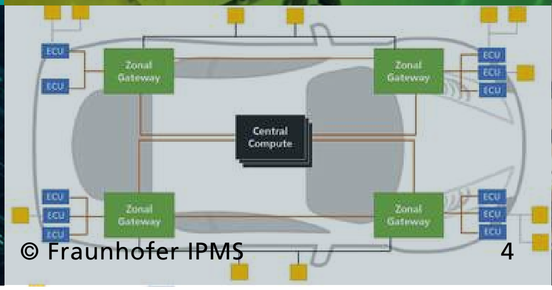
SiC power MOSFETs are a very good option for the highly efficient drive converters with high power density you get with electric vehicles. Put simply: they are efficient, reliable, and compact. Compared to silicon IGBT circuits, silicon carbide (SiC) gives you significantly higher efficiency. SiC is more reliable in terms of temperature stability, allows higher operating temperatures, and has higher dielectric strength.

Optimizing efficiency is not only important for faster switching, but also for improved range and for a longer service life of the batteries in electric vehicles. Another decisive advantage is the lower power loss, which makes it possible to significantly reduce power densities. In the engine compartment of a vehicle, every cubic centimeter is worth its weight in gold. The ability to minimize volume and weight via the traction converters and control inverters gives you a competitive advantage.

Fraunhofer FMD and Intel join forces to accelerate research progress on 3D Heterogeneous Integration for 2030+ in Germany and Europe
Since July 2022 the Research Fab Microelectronics Germany (FMD) and Intel have been collaborating to champion and drive 3D heterogeneous integration R&D in Germany. In a series of technical workshops organized by FMD and Intel Europe Research, experts from FMD, Intel, and German industries have defined the 2030+ research roadmap for 3D heterogeneous integration. Challenges and opportunities have been identified for major application areas such as automotive, industry and high-performance computing establishing the foundation for joint research projects in these critically important areas. This is part of the effort in building a strategic research partnership between FMD and Intel to grow heterogeneous 3D integration capabilities in Germany and in Europe, which is also a key topic of Intel Europe Research engagement in the European R&D ecosystem.

Research Fab for Quantum and Neuromorphic Computing: Launch of the Germany-wide cooperation FMD-QNC
In order to consolidate and expand the existing microelectronic research and development in Germany regarding quantum and neuromorphic computing, the FMD launched on December 1, 2022, a joint project together with four other Fraunhofer institutes, the Jülich Forschungszentrum and AMO GmbH: The Research Fab Microelectronics Germany — Module Quantum and Neuromorphic Computing (FMD-QNC). The German Federal Ministry of Education and Research is funding the equipment and structural setup required for the project.

1. MESHFREE takes the process of virtualization in product development to the next level.
2. Embedded silicon carbide on the way to series production for electric mobility applications, SiCModul project.
3. A look into the power electronics (model) in a circuit board for 90A (HHK project).
4. A historic meeting which marks the beginning of an extraordinary partnership: 1st FMD-Intel workshop on 3D heterogeneous integration for 2030+ in Berlin on October 28, 2022.
5. Research Fab for quantum and neuromorphic computing: Germany-wide cooperation FMD-QNC was launched to develop the future hardware foundation for novel computing technologies.



1. The Research Fab Microelectronics Germany (FMD) is laying the basis for modern education and training programs in the field of micro and nano-electronics with the establishment of the Microelectronics Academy.
2. With the development of modern electronics for resource-saving information and communication technology, the Green ICT @ FMD competence center is contributing to the climate goals of the German government.
3. To reduce resource consumption in the Internet of Things, in applications of AI as well as in data centers, significant progress in micro- and power electronics including their manufacturing processes is therefore required.
4. An automotive megatrend: A central supercomputer controls all car components and can be updated via a Wi-Fi connection.
5. Generic picture of a cable harness: The centralized control system requires fewer cables, which reduces the amount of material and costs involved in production. This makes the vehicle also significantly lighter.
6. Scientist Christopher Taudt works on a setup for optical wafer analysis in the Fraunhofer AZOM's cleanroom section. New methods in the fabrication process will increase the quality of these wafers and improve the reliability of electronic components.

Towards top-level training quality: Fraunhofer starts setting up a Microelectronics Academy

By establishing the Microelectronics Academy, the Research Fab Microelectronics Germany (FMD for its acronym in German) is laying the foundation for modern training programs in the field of micro and nanoelectronics aimed at counteracting the shortage of skilled workers in Germany. In cooperation with educational institutions and industry partners, the academy intends to work out a set of practice-based modules during a one-year design phase and subsequently test them over the next three years. Funding for this project is provided by the Federal Ministry of Education and Research as part of the Federal Government's Framework Programme for Microelectronics.

Launch of the Competence Center Green ICT @ FMD

Aiming to contribute to the reduction of the digital technologies' footprint via research and development, the Fraunhofer and Leibniz institutes cooperating within the framework of the Research Fab Microelectronics Germany (FMD for its acronym in German) are jointly establishing a cross-location competence center for resource-conscious information and communication technology (Green ICT @ FMD). The project, launched on August 1, 2022, is receiving 34 million euros in funding from the German Federal Ministry of Education and Research under the Green ICT initiative. The latter is in turn part of the German government's Climate Action Programme 2030.

A supercomputer on wheels

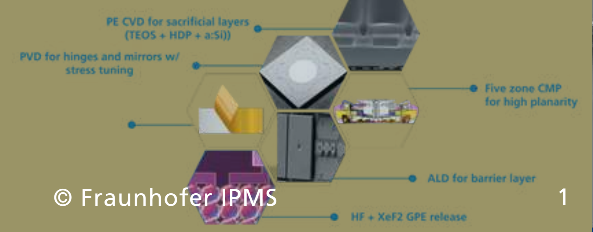
Modern cars are packed full of electronics. Managing all the computers and assistance systems is a complex task, and the cable harnesses increase the weight of the car. In the joint research project CeCaS, Fraunhofer researchers are working on a systems architecture based on the idea of managing all electronic components centrally from one computer platform. This will make it easier to construct highly automated, connected vehicles. The core element of this Fraunhofer technology is an extremely reliable Ethernet backbone that works in real time.

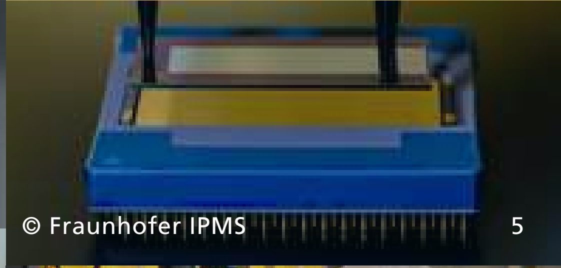
Imagine a car with components that are controlled from a central supercomputing platform instead of by dozens of intricately interconnected computer systems; you could easily install updates via Wi-Fi without going to a mechanic, and integrate new functions as needed. This is the vision that the Fraunhofer Institute for Photonic Microsystems IPMS and partners from the automotive industry are working toward as part of a joint research project, CeCaS (Central Car Server — Supercomputing for Automotive). The goal is to remodel the computer architecture used in cars from the ground up so that it is fit to meet the high demands associated with automated, connected vehicles. The idea is to turn cars into supercomputers on wheels, where the components can communicate with each other in real time. The German federal government is supporting the project as part of its initiative for funding research on electronics and software development methods for the digitalization of automobility (MANNHEIM).

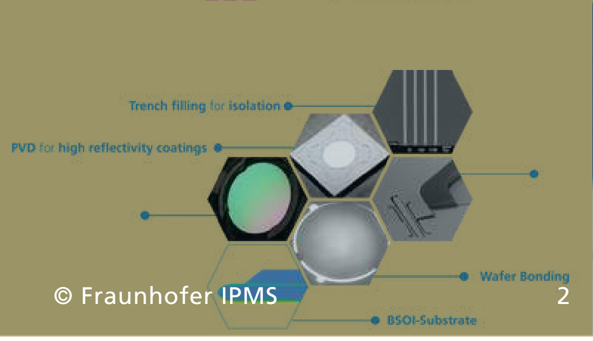
There is an urgent need for a new computer architecture in cars. Trends such as automation and connectedness are increasing data volumes in cars enormously. This is why vehicle manufacturers are looking for solutions that will allow them to standardize vehicle technologies, manage all components via a central instance, optimize communication between systems and provide the required computing power in real time.

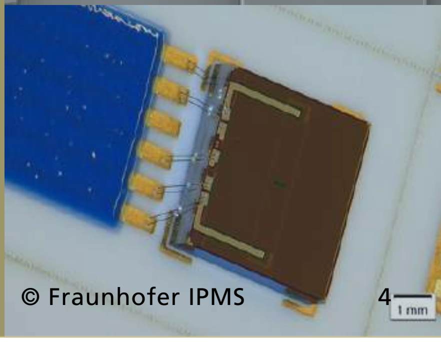
Higher reliability for next-generation electronics

The Europe-wide research initiative coordinated by Infineon Technologies AG aims to improve the reliability and performance of electronic systems and microelectronic components. Fraunhofer Application Center for Optical Metrology and Surface Technologies (AZOM), the Westsächsische Hochschule Zwickau (WHZ) and the Research and Transfer Center (FTZ) are the Zwickau partners in the collaboration.









High-performance electronics provide the basis for future-oriented and safe technologies. Using innovative methods and processes, experts from European science and industry have subscribed to increase the reliability of machines and systems and improve manufacturing processes in microelectronics. "In iRel 4.0, we don't leave out any component. Wafer, chip, package or user system are all being optimized. As a result, production errors in the manufacturing process are reduced and the quality and lifetime of products are increased," emphasizes Prof. Peter Hartmann, head of Fraunhofer AZOM and professor at the Faculty of Physical Engineering/Computer Science WHZ.

The research institutions contribute expertise in laser-based surface technology (WHZ), development of process-accompanying measurement technology (AZOM), and control electronics and software development (FTZ). To this end, the scientific institutions have 1.6 million euros at their disposal. The project partners are jointly developing a complex system to provide new production technology. It will focus in particular on improving the quality, reliability and safety of subsequent products. Independent of any restrictions, the local consortium has already started the intensive cooperation and is digitally connected to the overall consortium.

Platform for trustworthy electronics

The Velektronik project aims to create a platform for trustworthy electronics. It will address overarching issues in the three pillars of the microelectronics value chain: design, production, and analysis. For example, trustworthy design methods, analysis processes, and approaches for particularly trustworthy manufacturing processes for small series are being researched. The envisaged platform will focus on the technological overview, contributions to the necessary standardization, the network of research and industry, and the final know-how in order to provide concrete answers with solution concepts to the increasing demand for higher trustworthiness in electronics. The cooperation partners from the Fraunhofer-Gesellschaft and the Leibniz Association in the Research Fab Microelectronics Germany are working on this together with the edacentrum.

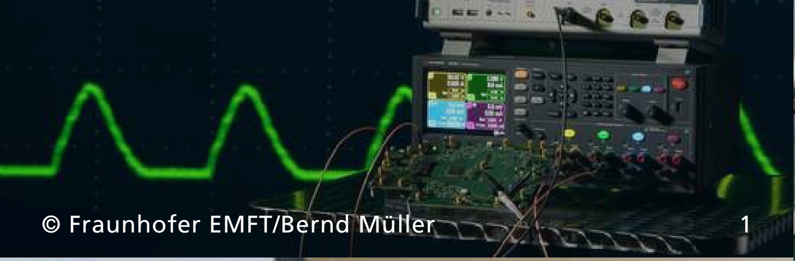
200 mm MEMS Processes

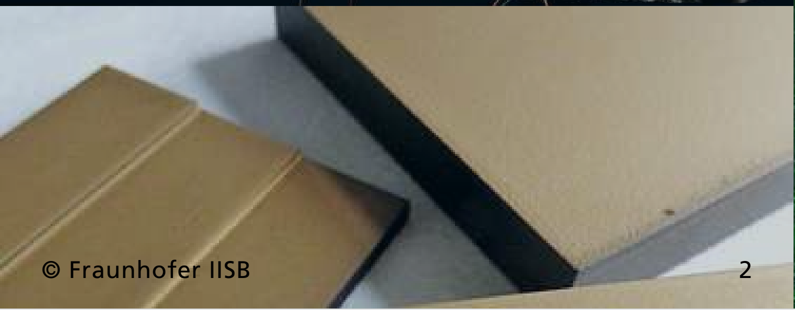
In our state-of-the-art 200 mm clean room, we offer comprehensive wafer processes that are tailored to the individual needs of our customers. We use our flexible and industry-compatible process line for this. Our offering includes both complete processes and specialized individual processes to meet the most diverse requirements in MEMS, micro-display and CMOS production, from front-end to back-end-of-line. Our overall processes include surface micro-machining, bulk micro-machining and monolithic MEMS-on-CMOS integration as well as active silicon/electronic devices (CMOS). In addition, we offer a wide range of individual processes, including in particular silicon deep etching, various depositions (CVD to ALD), wafer bonding, dicing & packaging and inline characterization. With state-of-the-art technology and an experienced team, we guarantee the highest quality and reliability in every step of the production process.

We offer you:

- Surface micro-machining
- Bulk micro-machining
- Monolithic MEMS-on-CMOS Integration
- Active Silicon/Electronic Devices
- Deep silicon etching
- Deposition
- Wafer Bonding, Dicing & Packaging
- Inline Characterization

1. Process and technology capabilities in the field of surface micro-mechanics.
2. Process and technology capabilities in the field of bulk micro-machining.
3. Integration of MEMS on CMOS.
4. Ion-sensitive field-effect transistor of the Fraunhofer IPMS.
5. Pick and place of a spatial light modulator (SLM).





1. Measurement setup for an eight-channel ultrasonic transceiver chip.
2. TaC coated graphite parts.
3. Data acquisition is performed with the help of cameras and a LIDAR sensor.

Ultrasound-based proximity sensors for human-machine interaction
Intelligent interactive systems for human-machine interaction (MMI) are increasingly being used in many applications in the areas of Industry 4.0, Smart Health, Smart Security and Automotive. Here, sensor systems for non-verbal information exchange in the near-distance and contact range are essential for both functionality and security. In order to meet the increasing demands in terms of performance, energy efficiency and functionality, researchers at Fraunhofer EMFT are working together with three other Fraunhofer institutes to develop a modularized MEMS technology and sensor platform.

Functional Coatings (SiO2, Si3N4, SiC, TaC)
We use spray coating of e.g. SiO2, Si3N4 and SiC to functionalize crucibles and other furnace parts in order to reduce harmful defects and impurities and to increase the lifetime of the furnace parts. For Cz silica crucibles we have a qualified vacuum bake out test procedure in order to investigate bubble behavior and cristobalite formation. Another focus is on ultra-high-temperature and chemical resistant protective TaC coatings on graphite and other materials. We develop this novel patented technology for applications in semiconductor industry, especially for SiC PVT crystal growth and epitaxy, but we address also space and aviation applications.

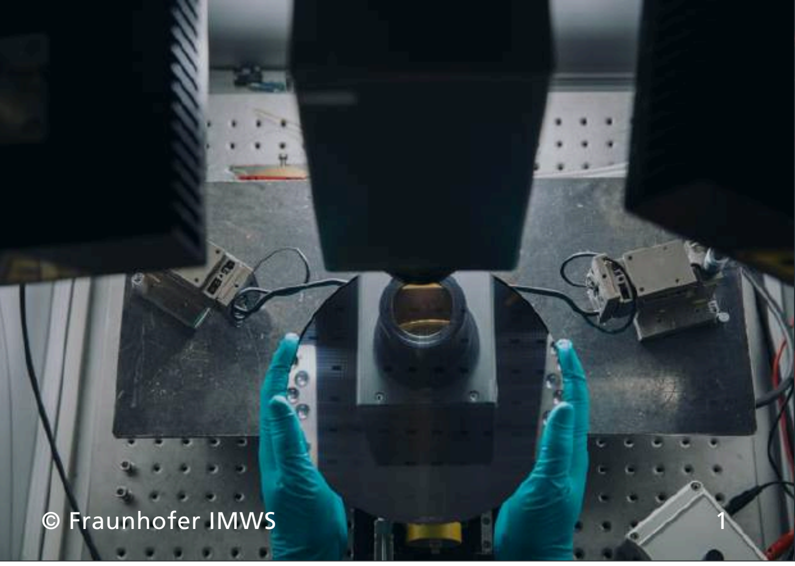
Effective AI training with LIDAR data
Artificial intelligence (AI) can only operate as powerfully as the quality of the trained data allows. In particular, this applies to deep learning, which uses neural networks inspired by the human brain. Tools for labelling camera images are already established on the market, but corresponding tools for labelling laser scanner data are not yet available.

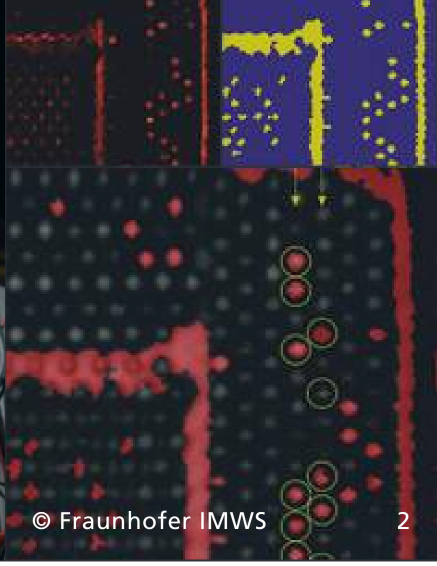
In many self-driving vehicles, LIDAR sensors, laser scanners, are part of the sensor technology that is used for environment detection. To ensure that the vehicles can make any use of the data, the AI in the vehicle must be trained. For LIDAR data, however, there are only a few data sets available so far. With our labelling tool FLLT.AI, one can easily create datasets for LIDAR and simultaneously use recorded video data to automatically pre-label the LIDAR data. Furthermore it is easy to manually post-process the LIDAR data. In addition, tracking labels are used to continue from one LIDAR scan to the next. Thus, on average, only 10 % of the time is needed to generate high-quality learning data.

Today, it is often the case that the AI needs to get specifications in a so-called “supervised learning” environment. Here, the data used for training must be processed by humans beforehand, labelling various objects in the data. In the future “unsupervised learning” may work without humans. In this case, the AI tries to determine differences in the data during the training and thus will be able to determine classes itself. However, checking whether these classes are correct and the determination of the parameters during trainings still has to be executed by a human.

Through various interfaces offered by the FLLT.AI tool, data recorded with LIDAR sensors and cameras can be directly integrated into the FLLT.AI tool. We are also working on integrating other sensors, such as RADAR. For the data labelling, we use our own very powerful AI server farm to run the neural networks. At the same time, we are also working on the AI-Flex project to develop an ASIC specifically for running neural networks.

Research into self-driving vehicles is already very advanced in terms of environment recognition. This means that traffic areas with relatively low complexity, such as highways, can already be mastered well. A major challenge is the decision-making in complex traffic scenarios, such as those found in cities, but also on rural roads with many intersections. The number of possible traffic situations there is very high and therefore requires a huge amount of data to prepare the AI.





Reliable microelectronics through failure analysis with artificial intelligence
The use of machine learning methods offers novel possibilities for automation, and thus for increasing the efficiency of failure diagnostic methods for electronic components and systems. Together with partners, the Fraunhofer Institute for Microstructure of Materials and Systems IMWS in Halle (Saale) wants to pioneer the way. The new methods are intended to facilitate the detection and analysis of complex failure modes. Furthermore, increasingly automated failure analysis and defect categorization will allow more components and data to be analyzed in order to detect and eliminate quality problems that have been undetectable up to now. This allows the production quality and lifespan of the components to be increased even further.

Whether it's about new mobility, intelligent production, or modern energy technology: reliable and robust electronics are a prerequisite in all of these areas for long-term success in the market. “There a general trend in electronic components towards integrating more and more functionality into smaller and smaller packages. This high integration density is a constant challenge to the quality and reliability of the components. If you want to find out – regardless of whether it’s during production, product qualification, or on a product returned by the customer – where which defect is located and what caused it, then more sophisticated technologies are always necessary”, says Frank Altmann, who heads the activities of the Fraunhofer IMWS in the new project. “Powerful and constantly improved methods for failure analysis are therefore of fundamental importance. On the one hand, this will help the industry develop reliable electronic products. On the other hand, in applications such as autonomous driving, communication technology, or medical applications, it must be ensured that the electronics will continue to operate reliably under the particular environmental conditions.”

The Fraunhofer IMWS is already helping the electronics industry find answers to their questions, in particular through its deep understanding of degradation mechanisms and the causes of material failures, and develops a variety of methods for failure analysis and material characterization. In cooperation with our partners in the project “Failure Analysis 4.0 – Key for reliable electronic devices in smart mobility and industry production”, our goal is to make even more efficient failure analysis tools and workflows available. In this project, the project partners want to use methods of artificial intelligence (AI) to enable faster and better detection and classification of defects.

The project with the component manufacturers BOSCH, Infineon, ST-Microelectronics, and ERICSSON, the diagnostic device manufacturers PVA TePla AS, CyberTECHNOLOGIES, KERN Mikrotechnik, Matworks, TESCAN/Orsay, Gimic AB, Excillum, and Direct Conversion as well as research facilities at the University of Stuttgart, Ecole de Mines, University of Saint-Etienne, and the Research Institutes of Sweden (RISE) runs until March 2023. “We want to utilize the enormous potential of AI-based methods for almost fully automated failure analysis and data handling based on the concept of Industry 4.0. This will significantly improve the performance of analyses, the precision, and the success rate when troubleshooting and determining the causes of failures”, says Altmann.

The Fraunhofer IMWS focuses on the research and development of AI methods to analyze the signals generated by non-destructive defect detection methods like scanning acoustic microscopy (SAM) and lock-in thermography (LIT). The goal is to develop concepts for monitored as well as unmonitored machine learning and integrate them into diagnostic devices for data acquisition and evaluation.

Various advantages would be gained if it were possible to link data obtained using different analysis methods such as electrical measurements, material characteristics, defect localization methods, micro-structural analysis methods, and the layout of an integrated circuit and then analyze the data using a correspondingly trained and self-learning algorithm. This would allow defects to be detected automatically and their signatures to be determined, classified, and compared with existing failure catalogs –

1. Non-destructive diagnostic methods such as lock-in thermography are one of the focal points in the project.
2. Results of error detection by Independent Component Analysis (ICA). Top left: Weighting matrix of the component, which is characteristic for defective bumps. Top right: Classification mask, derived from the weighting factors of the defect signature. Below: Classification mask (red) above an acoustic micrograph image for simplified visual assessment. Yellow circles indicate where defective FC contacts were checked by cross section and SEM imaging. SEM examinations were only performed on columns three and four (from the right side of the image), which are marked with yellow arrows at the top.

this would then substantially reduce the time required for failure analyses, standardize the analysis workflow, and reduce the subjective influence of humans on the results of the analyses. “This is especially important for complex failure modes that occur very rarely but can still lead to serious impairment of the function of electronic components”, says Altmann.

In order to realize this holistic approach to failure analysis workflows, though, numerous research questions need to be answered in the project. For example, individual analysis devices from various stages of the process need to be connected to each other using standardized hardware and software interfaces, guidelines and database systems for structuring, processing, and storing component-specific characteristic and analysis data need to be defined, new AI-enhanced analysis methods need to be created, and AI-based algorithms need to be developed.

Altmann summarizes as follows: “In the current failure analysis workflows, numerous methods that provide additional, complementary component analysis data are used, and this data usually needed to be evaluated manually up to now. The automated, cross-process provision and AI-based evaluation of this data, including determination of the causes of failure, has enormous potential for further increasing the efficiency of quality controls used in production, and thus for increasing product reliability and quality in spite of increasingly shorter development cycles.”

New biosensor research group at Fraunhofer IMS aims to enable ultra-fast identification of pathogens

With the help of optical biosensors, bacteria and viruses could be detected in seconds. Patients would no longer have to wait days for their test results, sterile rooms, medical equipment, production processes and food could be monitored in real time. A new working group has been founded at the Fraunhofer IMS in Duisburg that wants to make all this possible.

The plan is to achieve ultra-fast "in situ identification" of pathogens. To this end, the new 5-member working group led by bio-sensorics expert Dr Sebastian Kruss wants to functionalize biosensors in such a way that they indicate bacteria, viruses and other pathogens optically and consequently without contact. This would eliminate the time-consuming preparation of samples.

With the help of such fast and inexpensive diagnostics, a whole series of current challenges could be effectively countered, from the rapidly increasing antibiotic resistances to the spread of new types of viruses. Last but not least, the Corona pandemic could be fought much more effectively with the help of optical biosensors.

So far, there are only a few commercially used biosensors, such as the blood glucose sensor for diabetes patients. Their mostly low sensitivity and the lack of system integration are exemplary for several obstacles that have so far limited the application of such sensors in other areas.

Dr. Sebastian Kruss is breaking new ground: he combines single-molecule sensitivity with single-photon detectors. At the same time, he is increasing the number of sensors that can be evaluated. An "artificial nose" constructed in this way could detect a whole range of different substances simultaneously. The sensors are based on nano-materials that glow in a non-visible range of light. The materials are chemically modified so that they bind antibodies or other biological motifs and thus change their optical properties. Highly sensitive detectors read the optical signals of the nanomaterials and thus identify various biomedically relevant analytes. The search for new vaccines and drugs could also benefit from this.

1. Dr. Sebastian Kruss heads a new research group at the Fraunhofer IMS in Duisburg. By 2025, it aims to develop biosensors that can detect corona viruses in real time, among other things.

RECENT ACTIVITIES, EVENTS CALENDAR, AND MEDIA COVERAGE

Fraunhofer Office India: Highlights of 2024

JANUARY 2024

09.01.2024: 5th Meeting of the German Innovation Forum at Siemens Healthineers
The German Innovation and R&D Forum, conceptualized and driven by Fraunhofer Office India brings thought-leaders, experts to discuss, brainstorm on avenues for building a sustainable future by leveraging joint innovation capabilities of German companies in India. The fifth meeting of the forum was held at Siemens Healthineers on 09.01.2024 and witnessed active participation from Fraunhofer, German Consulate and from leading German organizations like Bosch Global Software Technologies Ltd., Continental Automotive India Ltd., Festo India Pvt. Ltd., Siemens India Ltd., Infineon Technologies, Mercedes-Benz Research & Development India Ltd. and SAP Labs India. A Project Planning Workshop was facilitated, and the forum members were divided into five working groups during this meeting to define the tech challenges under each theme, next steps, potential partners involved (German companies from the pool), project lead, resources needed and a define the timeline of delivery. The meeting was steered jointly by Fraunhofer Office India and Siemens Healthineers.

12.01.2024: Meeting with Corporate Social Responsibility (CSR) team of Bosch Global Software Technologies Pvt. Ltd.
The CSR team of Bosch had visited Fraunhofer Office India to understand the activities of German Innovation and R&D Forum which has been conceptualized by Fraunhofer office India, followed by discussion on activities of Fraunhofer in AQUA-Hub project and opportunities in Bio-economy etc.

FEBRUARY 2024

20.02.2024: 6th Meeting of the German Innovation Forum at MBRDI
The sixth meeting of the forum was held at Mercedes-Benz Research & Development India Ltd. (MBRDI) on 20.02.2024 and witnessed active participation from Fraunhofer, German Consulate and from leading German organizations like Bosch Global Software Technologies Ltd., Continental Automotive India Ltd., Festo India Pvt. Ltd., Siemens India Ltd., Siemens Healthineers, Infineon Technologies and SAP Labs India. A project planning workshop was organized with all the forum member companies, co-led by Fraunhofer and MBRDI. The aim of this workshop was to refine the objectives of projects formulated during the previous meeting and to establish a comprehensive execution plan with specific timelines.

20.02.2024 – 23.02.2024: The Smarter E India/Intersolar India 2024
Fraunhofer Office India held a booth at the Smarter E India / Intersolar India 2024 Exhibition (Expo) as a part the 'German Pavilion', organized by The Indo-German Chamber of Commerce (IGCC) in collaboration with the Indo-German Energy Forum (IGEF).Mr. Sanmati Naik coordinated and represented Fraunhofer at the booth, where Fraunhofer competencies in the areas of Energy sector (Renewables, Energy Storage, E-Mobility and Hydrogen Tech) were showcased in the form of posters, brochures, and video display.

Mr. Sanmati Naik represented Fraunhofer during the session "Technology - Electrolyser Technology Advancements and Ammonia-to-power Technologies" and delivered presentation on Fraunhofer's perspective/activities in 'Advanced R&D in Manufacturing of Electrolysers and Fuel Cells'. Mr. Naik also participated in the event 'Business Roundtable on Green Hydrogen' and briefly mentioned activities of Fraunhofer in Hydrogen domain with Indian government and industry.

1. Group photograph with entire German Innovation Forum.
2. Group photograph with CSR team of Bosch.
3. Group photograph with entire German Innovation Forum.
4. Fraunhofer booth at The Smarter E India/Intersolar India 2024.
5. Mr. Sanmati Naik (C) along with other speakers.

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MARCH 2024

01.03.2024: Visit of Mr. Andreas Aepfelbacher, Deputy Head & Head of Investment Manager, Fraunhofer Venture to India

Mr. Andreas Aepfelbacher had visited Delhi and Bangalore as a part of the Delegation of Incubators and transfer centres from Germany to India, organized by German House for Innovation and Research (DWIH). Fraunhofer Office India had organized meetings for him in Bangalore with some high-level potential clients like Axilor Ventures and h2e Power Systems Pvt. Ltd.

11.03.2024: Workshop on Sensor Systems

A joint workshop was organized by Ministry of Electronics & Information Technology (MeitY), Govt. of India, Centre for Materials for Electronics Technology (C-MET) and Fraunhofer with participation of nearly 50 industries to develop a strategic roadmap for creating an R&D&I ecosystem in "Sensor Systems" in India. The purpose of organizing this workshop was to gain insights into the primary technical challenges encountered by industries and the specific sensor needs in diverse sectors such as IoT, Industry 4.0, Smart Cities, Smart Agriculture, Healthcare, Oil & Gas, Construction, etc. In Sensor Systems, Fraunhofer has very strong portfolio in Sensor design, fabrication, integration, characterization, and testing within systems. Three Fraunhofer Institutes namely (i) Fraunhofer Institute for Electronic Nano Systems (ENAS) (ii) Fraunhofer Institute for Integrated Circuits (IIS) and (iii) Fraunhofer Institute for Electronic Microsystems and Solid-state Technologies (EMFT) participated in this workshop. Serving as a catalyst, the workshop has established a foundation for collaborative sensor development between C-MET and Fraunhofer. The workshop was organized in hybrid format at C-MET, Hyderabad. This collaboration involves targeted research and development in sensor systems, covering applications, processes, and materials. Additionally, it involves the establishment of testing centres and the transfer of technology to the Indian industry.

APRIL 2024

10.04.2024: Visit of Mr. R. Madhan, Director, Indo-German Science and Technology Centre (IGSTC) to Fraunhofer Office India

Fraunhofer Office India had facilitated a meeting between IGSTC and German Innovation Forum (GIF) Member Companies for an exploratory discussion on programmes and initiatives of IGSTC which could be interesting for German Innovation Forum. The participants included senior representatives from Festo India, Siemens Healthineers, Mercedes-Benz R&D India and Bosch Global Software Technologies.

12.04.2024: 07th Meeting of the German Innovation Forum at Festo India Pvt. Ltd.

The seventh meeting of the forum was held at Festo India Pvt. Ltd on 12.04.2024 and witnessed active participation from Fraunhofer, German Consulate and from leading German organizations like Bosch Global Software Technologies Ltd., Continental Automotive India Ltd., Mercedes-Benz Research & Development India Ltd. (MBRDI), Siemens India Ltd., Siemens Healthineers, Infineon Technologies and SAP Labs India. A project planning workshop was organized with all the forum member companies, co-led by Fraunhofer and Festo. The aim of this workshop was to refine the project descriptions formulated during the previous meeting and establish a comprehensive execution plan with specific timelines.

16.04.2024: Visit of BMW Innovation Team to Fraunhofer Office India

Mr. Philipp Janello and Ms Nicole Kast from Group Inventions, Innovation Management, Innovation Strategy and Academic Relations of BMW Group had visited Fraunhofer Office India to understand the activities of Fraunhofer in India and explore potential cooperation.

1. L to R: Mr. Andreas Apfelbacher, Mr. Siddharth Mayur (h2e Power), Mr. Prashanth Kamath (homiHydrogen), Mr. Sanmati Naik, Mr. Aditya Fuke.
2. L to R: Mr. Andreas Apfelbacher, Mr. Venugopal Ganapathy (Axilor Ventures), Mr. Sanmati Naik, Mr. Aditya Fuke.
3. Joint Workshop on Sensor Systems, organized by Fraunhofer, C-MET and MeitY.
4. 4th and 5th from left: Mr. R. Madhan and Ms. Anandi Iyer along with other members of German Innovation Forum.
5. 7th meeting of German Innovation Forum.
6. L to R: Mr. Philipp Janello, Ms. Anandi Iyer, Ms. Nicole Kast, and Mr. Aditya Phuke.

MAY 2024

06.05.2024: Visit of State Office of Invest in Bavaria to Fraunhofer Office India
Ms. Agata Butenko, Manager Investor Services and Mr. John Kotayyil, Executive Director, from State of Bavaria India Office visited Fraunhofer Office India for an introductory meeting and identify opportunities of strengthening cooperation between Bavaria and India in topics of electronics and embedded systems.

16.05.2024: Visit of Fraunhofer Office India to IIT Ropar
Ms. Anandi Iyer and Mr. Aditya Fuke from Fraunhofer Office India had visited Indian Institute of Technology – Ropar (IIT Ropar) to discuss the modalities of cooperation between Fraunhofer and IIT Ropar in topics like Hydrogen Tech – Fuel Cells, Storage tank and Circular Economy, Bio-economy and Wastewater treatment, and planning the visit of Fraunhofer Senior Experts to IIT Ropar later this year. The meetings were held with Prof. Rajeev Ahuja, Director, IIT Ropar and senior professors and department heads, and some start-ups incubated at IIT Ropar.

JUNE 2024

04.06.2024-05.06.2024: Global Female Leaders Summit
Management Circle AG had organized Global Female Leaders Summit on 04 and 05 June 2024 in Frankfurt and invited Ms. Anandi Iyer as a speaker in the panel discussion on “Trust-Based Leadership – Navigating in Turbulent Times”. She was also invited as a speaker in the panel discussion on “Technology and Democratization of Digitalisation” in the thematic session Think Tank Academy.

05.06.2024: 7th Robotomation Symposium
German Mechanical Engineering Industry Association (VDMA) had organized 7th Robotomation Symposium in Pune on 05 June 2024. Fraunhofer is one of the supporting members of OPC Hub in India. The OPC Hub is represented by Siemens in India. Together with Siemens, Fraunhofer Office India had held a booth to present the OPC Hub, with details on the membership and its application in industries like Machine Tool, Automotive, Electric Vehicles, Agricultural Equipment, Construction, Component Suppliers, Startups, Food and Beverage and Packaging. Mr. Aditya Fuke, Senior Manager – Strategic Projects, Smart Cities & IoT represented Fraunhofer and jointly managed the OPC Hub India booth with Siemens at the symposium.

07.06.2024: 08th Meeting of the German Innovation Forum at Infineon Technologies India Pvt. Ltd.
The eighth meeting of the German Innovation Forum was held at Infineon Technologies India Pvt. Ltd. on 12.04.2024 and witnessed active participation from Fraunhofer, German Consulate and from leading German organizations like Bosch Global Software Technologies Ltd., Continental Automotive India Ltd., Mercedes-Benz Research & Development India Ltd. (MBRDI), Siemens India Ltd., Siemens Healthineers, Daimler Truck Innovation Centre India (DTICI), Festo India Pvt. Ltd and SAP Labs India. A project scoping workshop was organized to fine-tune the project descriptions which were developed during 7th GIF meeting held at Festo. MBRDI and Fraunhofer also jointly conducted a survey related to a joint Knowledge Paper on “Improving Innovation Capital in India” under the theme Thought Leadership. The event was wrapped with brainstorming with the audience on their first impressions on innovation in India and their opinions on filing and managing the IPRs from India.

18.06.2024: Visit of Daimler Truck Innovation Centre India (DTICI) to Fraunhofer Office India
Mr. Dayakar Devaraiah, Vice President and Head of Innovation and Connectivity Tech and Mr. Sachin Patidar, General Manager - Product development, Data analysis and Innovation from Daimler Truck Innovation Centre India (DTICI) had visited Fraunhofer Office India to discuss DTICI’s participation in German Innovation Forum and the activities planned for the future.

1. L to R: Ms. Agata Butenko, Ms. Anandi Iyer, Mr. John Kottayyil, and Mr. Aditya Fuke.
2. Ms. Anandi Iyer being felicitated by Prof. Rajeev Ahuja, Director, IIT Ropar.
3. Meeting with Team of AWADH (Technology Innovation Hub on Water at IIT Ropar).
4. OPC Booth at 7th Robotomation Symposium.
5. Visit of DTICI team to Fraunhofer Office India.
6. 8th meeting of German Innovation Forum.

1. Dr. Philipp Ackermann, German Ambassador to India and Bhutan, honouring Ms. Anandi Iyer, Director, Fraunhofer Office India.
2. Workshop at BeST, IISc Bengaluru.
3. Road Safety India – Project Planning Workshop at Bosch.
4. L to R: Mr. Achim Burkart, Consul General, German Consulate Bangalore, Ms. Anandi Iyer, Director, Fraunhofer Office India, Mr. Rajesh Nath, Manging Director, VDMA India.
5. 9th meeting of German Innovation Forum.
6. Meeting with Ms. Judith Weinberger-Singh, Resident Representative, HSS India.

19.06.2024: Ms. Anandi Iyer, Director, Fraunhofer Office India honoured with the German Federal Order of Merit

Ms. Anandi Iyer has been honoured with the Bundesverdienstkreuz (Federal Order of Merit) by the German government. Dr. Philipp Ackermann, German Ambassador to India presented Ms. Iyer with this honour. This prestigious recognition celebrates her outstanding contributions to Indo-German relations for over 25 years, coinciding with 50 years of Indo German Science and Technology Cooperation. The Bundesverdienstkreuz, Germany's highest civilian honour, is a deep appreciation of Ms. Anandi Iyer's tireless dedication to fostering international collaboration, innovation, and the empowerment of women in science and technology. This recognition underscores her significant impact on the global stage and reaffirms the importance of her contributions to the Indo-European partnership.

JULY 2024

04.07.2024 – 05.07.2024: Visit of Mr. Sebastian Stegmüller, Head of Mobility and Innovation Systems, Fraunhofer IAO to India

Mr. Sebastian Stegmüller, Head of Mobility and Innovation Systems, Fraunhofer IAO had visited Bangalore, India from 04-05 July 2024. Fraunhofer Office India had coordinated a workshop with Bengaluru Science & Technology Cluster (BeST) of Indian Institute of Science (IISc) Bangalore and invited industry partners of BeST for a roundtable meeting during the visit of Mr. Sebastian Stegmüller. He presented the research area Mobility and Innovations to the stakeholders who represented industry, start-ups and academia. A project planning workshop to develop a detailed project plan on "Road Safety in India" with a rough budget and timeline was also organized with Bosch Global Software Technologies (BGSW), Continental Automotive India Ltd. and Mercedes-Benz Research & Development India Ltd. He also had an introductory meeting with the leadership of Micelio Mobility Pvt. Ltd. to explore cooperation in innovative mobility solutions.

05.07.2024: VDMA Symposium on "Smart Manufacturing Technologies - Revolutionizing the Future"

The German Engineering Federation (VDMA) India had organized a Symposium on "Smart Manufacturing Technologies - Revolutionizing the Future" on 05 July 2024 in Bangalore. Ms. Anandi Iyer was invited as the Guest of Honour in the inaugural session of the symposium. She delivered a presentation on "Smart Manufacturing @ Fraunhofer", which was very well received by an audience of industry representatives from Machine Tool, Automotive, Electric Vehicles, Electrical equipment and Agricultural Equipment manufacturers.

12.07.2024: 9th meeting of German Innovation Forum

The ninth meeting of the German Innovation Forum was hosted by Fraunhofer Office India and witnessed active participation from German Consulate and from leading German organizations like Bosch Global Software Technologies Ltd., Continental Automotive India Ltd., Mercedes-Benz Research & Development India Ltd. (MBRDI), Siemens Healthineers, Daimler Truck Innovation Centre India. A project scoping workshop was organized to discuss the methodologies for delivery in each project developed under the themes of Mobility, Sustainability and AI, which was followed by reviewing the programme of the Conference on German Innovations in India, scheduled for 12 August 2024 in Delhi.

16.07.2024: Visit of Hanns-Seidel-Stiftung to Fraunhofer Office India

Ms. Judith Weinberger-Singh, Resident Representative, Hanns-Seidel-Stiftung India and her colleague Mr. Sandeep Dubey, Programme Manager visited Fraunhofer Office India to discuss collaboration opportunities on topics like water, circular economy and Responsible AI.


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23.07.2024: Visit of German Consulate General Bangalore to Fraunhofer Office India
Ms. Annett Bässler, the new Deputy Consul General of German Consulate in Bangalore visited Fraunhofer Office India to understand the activities of Fraunhofer in India and discuss the new avenues of cooperation between Fraunhofer and German Consulate in various of topics of Science & technology.

25.07.2024-29.07.2024: Visit Tamil Nadu Industrial Development Corporation (TIDCO) to Fraunhofer IPT, Fraunhofer FFB and Fraunhofer Innovation Platform for Advanced Manufacturing at University of Twente in Enschede
Fraunhofer has established a partnership with Government of Tamil Nadu, serving as the Technology Partner to Tamil Nadu Industrial Development Corporation (TIDCO), to develop an Innovation Cluster in Advanced Manufacturing within the state. Fraunhofer Office India had coordinated a visit of high-ranking delegation of Govt. of Tamil Nadu, led by Mr. Sandeep Nanduri, MD, TIDCO and Ms. Mariam Baldev, Special Secretary Industries Department, Govt. of Tamil Nadu, to experience the capabilities and best practices of Fraunhofer and its expertise in facilitating a region-specific innovation ecosystem. The visits were organized at Fraunhofer IPT in Aachen with focus on Advanced manufacturing ecosystem and to Fraunhofer FFB in Münster with focus on Battery ecosystem in city of Münster. Fraunhofer Office India had also coordinated the visit of Indian delegation to University of Twente in Enschede, Netherlands where Fraunhofer IPT has collaborated to set up Fraunhofer Innovation Platform for Advanced Manufacturing at University of Twente. This visit was organized to showcase select successful projects of Fraunhofer outside Germany.

AUGUST 2024

12.08.2024: Leadership Meet hosted by German Ambassador
The German Ambassador to India, Dr. Philipp Ackermann hosted a power breakfast meeting with Secretaries of Govt. of India, leadership Indian Industry Associations and leadership of German companies involved in German Innovation Forum. The constructive discussion addressed opportunities and challenges, with the Indian side appreciating the initiative of German Innovation Forum and suggesting a detailed collaboration plan for engagement with relevant Indian Ministries.

12.08.2024: Conference on German Innovations in India
Fraunhofer Office India had coordinated a high-level conference Delhi to inform the Indian Government and the innovation ecosystem about the potential to engage with the German Innovation Forum members and amplify the position of German companies in India with their stakeholders. The conference was supported by German Embassy New Delhi and by leading German organizations which are partners to German Innovation Forum (GIF), namely Bosch Global Software Technologies Ltd., Continental Automotive India, Daimler Truck Innovation Centre India, Festo India Pvt. Ltd., Infineon Technologies India, Mercedes-Benz Research & Development India, SAP Labs India and Siemens Healthineers. The Knowledge Paper on "How to transform India as the Global Innovation and Product Technology Hub", authored by Ms. Anandi Iyer, Dr. Fabian Hecklau (Fraunhofer IPK) and Mercedes Benz Research and Development India) was released by Dr. Philipp Ackermann, German Ambassador to India and Dr. Neeraj Sinha, Scientist G, Office of the Principal Scientific Advisor to Govt. of India. The Leadership of the German companies presented their vision of engagement in India, and the key area of focus. The final session was addressed by Ms. Sunita Mohanty, Senior Vice President and Chief Investment Officer, Invest India in conversation with Ms. Anandi Iyer, giving recommendations for a sustained framework of Indo-German collaboration to co-create innovative solutions for India.

16.08.2024: Visit of BMW Group to Fraunhofer Office India
Mr. Oliver Scheickl, Head of DevOps Hub India - Automotive Software and Mr. Naveen Shankar Nagaraja, Senior Researcher AI, Project Lead from BMW Group visited Fraunhofer Office India for an introductory meeting to present the vision of BMW Group to set up DevOps and Business IT Centre in India.

1. Visit of Ms. Annett Bässler, Deputy Consul General, German Consulate Bangalore to Fraunhofer Office India.
2. Visit of TIDCO to Fraunhofer IPT, FFB and University of Twente.
3. Meeting of German Innovation Forum Leadership at German Ambassador's Residence.
4. Conference on German Innovations in India and release of knowledge paper.
5. Visit of BMW Group to Fraunhofer Office India.



1. Dr. Stephan Guttowski, Managing Director, Fraunhofer FMD giving the Keynote Speech.
2. Meeting with Dr. Ajai Chowdhry, Founder- HCL, Chairman – EPIC Foundation.
3. 10th meeting of German Innovation Forum.
4. Meeting with National Institute of Solar Energy (NISE), MNRE.
5. Visit of Ms. Svenja Schulze, Federal Minister for Economic Cooperation and Development (BMZ) to Fraunhofer booth.

SEPTEMBER 2024

11.09.2024-13.09.2024: Productronica India 2024

Fraunhofer Office India had coordinated the participation of Fraunhofer EMFT in Productronica India 2024 from 11 – 13 Sept 2024. It is an international trade fair for electronics development and production in India and organized by Messe Muenchen India. Fraunhofer EMFT had exhibited “Mobile Learning Hub”, a training platform that leverages augmented reality (AR) to deliver immersive soldering and casting trainings, seamlessly merging physical practice with virtual instruction. Fraunhofer’s booth witnessed more than 100 visitors in 3 days expressing interest to learn more about this platform, followed by discussion on modalities of cooperation with Fraunhofer. Fraunhofer Office India will be the point of contact between Fraunhofer EMFT and potential Indian clients for facilitation of all the enquiries received on the exhibit.

12.09.2024: SEMICON India 2024 and visit of Dr. Stephan Guttowski, Managing Director, Fraunhofer Research Fab Microelectronics Germany (FMD) to India

SEMI and Messe Muenchen India have partnered with Electronic Industries Association of India (ELCINA) to organize the inaugural edition of SEMI’s flagship event, SEMICON India in Noida from 11-13 Sept 2024. The SEMICON India exhibition and conference was co-located with Electronica India and Productronica India – Southeast Asia’s largest electronics industry fairs. SEMICON India 2024 was actively supported by the India Semiconductor Mission, an initiative of the Ministry of Electronics and Information Technology (MeitY), Govt. of India.

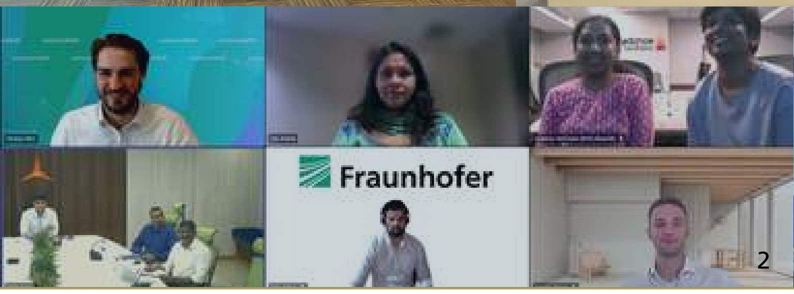
Fraunhofer Office India had coordinated participation of Dr. Stephan Guttowski, MD, Research Fab Microelectronics (FMD) Germany & Fraunhofer Group for Microelectronics as a speaker in two sessions – (i) he was invited as a Keynote Speaker in Session on “Global Market, Local Execution – The Benefits of Cross-Regional Partnerships” and (ii) as a panellist in the panel discussion on “Convergence of MedTech, Semiconductors and AI for Transforming Global Healthcare”. Both the sessions were very well received by the audience who were majorly from Indian Government, industries from both India and abroad, academia and start-ups. Fraunhofer Office India had also coordinated high-level meetings for him. He met with (i) Mr. S. Krishnan, Secretary, Ministry of Electronics & Information technology (MeitY), Govt. of India and with (ii) Dr. Ajai Chowdhry, Founder- HCL, Chairman – EPIC Foundation.

13.09.2024: 10th Meeting of German Innovation Forum

The 10th meeting of the German Innovation Forum was hosted by Daimler Truck Innovation Centre India (DTICI) and witnessed nearly 25+ leaders and experts participating from leading German organizations in India such as Continental India, Festo, MBRDI, SAP Labs, Siemens Healthineers, Fraunhofer, and German Consulate Bangalore. The agenda of this meeting was to review the Project Technology Pitches and briefly outline the project implementation plan. The meeting was jointly coordinated by Fraunhofer Office India and DTICI. Dr. Stephan Guttowski, Managing Director of Research Fab Microelectronics Germany (FMD) & Fraunhofer Group for Microelectronics gave a Special Address on the profile and core competencies of Fraunhofer Research Fab Microelectronics, and its role in boosting cross-sector R&D in Microelectronics for industrial innovation across Germany and Europe.

16.09.2024-18.09.2024: 4th Global RE-INVEST Renewable Energy Investors Meet & Expo

The 4th Global RE-INVEST Renewable Energy Investors Meet & Expo was organised by the Ministry of New and Renewable Energy (MNRE), Government of India. Fraunhofer Office India represented Fraunhofer ISE within the German Pavilion at RE Invest 2024. The ‘German Pavilion’ was organized by the Indo-German Chamber of Commerce (IGCC) in collaboration with the German Agency for International Cooperation (GIZ) on behalf of the German Federal Ministry of Economic Cooperation and Development (BMZ). Ms. Anandi Iyer and Mr. Sanmati Naik coordinated and represented Fraunhofer



at the pavilion booth, where Fraunhofer competencies in the areas of Solar PV and Manufacturing sector were showcased. Ms. Svenja Schulze, Federal Minister for Economic Cooperation and Development (BMZ) visited Fraunhofer booth during this expo. Several high-level meetings, one of them being with National Institute of Solar Energy (NISE), MNRE, Govt. of India was held at Fraunhofer booth to discuss new areas of cooperation.

25.09.2024: Visit of Electronics, Products, Innovation, Consortium (EPIC), Foundation to Fraunhofer Office India

Mr. S. Sridhar, Executive Director, EPIC Foundation and Mr. Ravi Thumboochetty, Managing Trustee, Thumboochetty Foundation visited Fraunhofer Office India to discuss strategic cooperation with Fraunhofer in setting up of Electronics System Design & Manufacturing (ESDM) ecosystem in two locations in Karnataka.

30.09.2024: Fraunhofer IPT – TIDCO Project Kick-off Meeting

Fraunhofer IPT has formed a strategic partnership with Tamil Nadu Industrial Development Corporation (TIDCO) for developing the Innovation and Knowledge Ecosystem of Tamil Nadu. The project was kicked-off in September 2024 online, in presence of senior officials from both sides, Mr. Sandeep Nanduri, Managing Director of TIDCO, Mr. Vishnu, MD & CEO of Guidance Tamil Nadu, Mr. Tim Latz, Head of Department Technology Management from Fraunhofer IPT and Ms. Anandi Iyer, Director, Fraunhofer Office India, members of the Steering Board of this project. The project is led by Mr. Marc Schauss from Business Development Green Production of Fraunhofer IPT and supported by a team of analysts and experts from Fraunhofer, TIDCO and Guidance. This is one of the flagship projects of Fraunhofer in collaboration with the Indian state government, demonstrating Fraunhofer's capabilities as a Technology Partner in developing a region-specific innovation ecosystem involving local stakeholders from government, industry and academia.

OCTOBER 2024

18.10.2024: 26th Meeting of the Prime Minister's Science, Technology & Innovation Advisory Council (PM-STIAC)

The 26th Meeting of PM-STIAC was organized by Office of the Principal Scientific Adviser to the Government of India on 18 Oct 2024 in Delhi. Ms. Anandi Iyer in her capacity as Director Fraunhofer Office, as well as the Co-Chair of the Science, Innovation and Technology Committee of FICCI, was invited as a keynote speaker to deliver a talk on "Insights for Industry requirements", focussing on "Accelerating Industry-Academia Partnership for Research and Innovation in India".

24.10.2024 - 26.10.2024: Golden Jubilee Celebrations of Indo-German S&T Cooperation and Visit of Dr. Johann Feckl, Director and Section Head Precompetitive Research and International Relations, Fraunhofer Gesellschaft to India

Golden Jubilee Celebrations of Indo-German S&T Cooperation was organized by Department of Science & Technology (DST), Govt. of India on 24 Oct 2024 in Delhi. Dr. Johann Feckl was invited as a speaker in the session on "Fostering Joint Applied Research through the Indo-German Science & Technology Centre (IGSTC)" in this landmark event. The event was co-chaired by Dr. Jitendra Singh, Union Minister of Science & Technology, Govt. of India and Ms. Bettina Stark-Watzinger, Federal Minister of Education and Research, German Federal Ministry of Education and Research (BMBF). During his visit, Fraunhofer Office India had also organized some high-level meetings for him with: (i) Prof. Ajay Kumar Sood, Principal Scientific Adviser to Govt. of India (ii) Mr. S. Krishnan, Secretary, Ministry of Electronics & Information Technology (MeitY), Govt. of India (iii) Mr. Prashant Kumar Singh, Secretary, Ministry of New & Renewable Energy (MNRE), Govt. of India.

1. Visit of EPIC Foundation to Fraunhofer Office India.
2. Fraunhofer IPT – TIDCO Project Kick-off Meeting.
3. 26th meeting of PM-STIAC.
4. Meeting with PSA to Govt. of India.
5. Golden Jubilee Celebrations of Indo-German S&T Cooperation.

1. Ms. Iyer during her presentation at the German Business Breakfast roundtable.
2. Ms. Anandi Iyer and CEOs of Indian and German Companies along with Shri. Narendra Modi, Hon'ble Prime Minister of India and Mr. Olaf Scholz, Chancellor of Federal Republic of Germany.
3. Signing of MoU between Fraunhofer ACMA Mobility Foundation.
4. Ms. Anandi Iyer along with other jury members presenting the awards.
5. Mr. Sebastian Stegmüller in the panel discussion.

24.10.2024 – 26.10.2024: Asia Pacific Conference, Visit of Mr. Olaf Scholz, Chancellor of Federal Republic of Germany to India

Dr. Hans Feckl and Ms. Anandi Iyer participated in the German Asia-Pacific Business Conference, the biggest business summit of German- Asia Business, which is held biannually in Germany/Asia. Ms. Anandi Iyer was invited to moderate a panel on Sustainability: "Keen on Green" as part of the official Asia Pacific Conference.

Additionally, Ms. Anandi Iyer was the Keynote Speaker at the German Business Breakfast roundtable organised by Germany Asia Business Association (OAV) and KPMG on the 24th of October and she delivered a talk on "India as an Innovation Powerhouse" to a large number of German business leaders accompanying Chancellor Scholz to India.

25.10.2024: India – Germany CEOs Forum

Ms. Anandi Iyer was nominated by the Government of India to the India - Germany CEOs Forum held on 25 Oct 2024 in Delhi. The Forum chaired by Shri. Narendra Modi, Hon'ble Prime Minister of India and Mr. Olaf Scholz, Chancellor of Federal Republic of Germany serves as a high-level platform to engage business and industry leaders from India and Germany. 10 CEOs from each country have been nominated to this Forum, to work towards deepening economic and trade linkages between the two countries. The topics of focus are Sustainability, Innovation and Technology, Digitalisation and Skilling. In the next few months, concrete projects and activities will be drawn out by the Forum Members.

26.10.2024: Signing of MoU between Fraunhofer ACMA Mobility Foundation

The ACMA Mobility Foundation (AMF), an initiative of the Automotive Component Manufacturers Association of India (ACMA), signed a MoU with Fraunhofer to foster Research and Development (R&D) collaboration for India's auto component industry. Formalized during the 18th Asia-Pacific Conference of German Business (APK 2024) held in New Delhi, this strategic partnership aims to provide a robust platform for industry-driven research and innovation to the Indian auto component industry as it transforms to support the mobility industry in addressing challenges of carbon neutrality, circularity, safety and environment. Through this collaboration, AMF and Fraunhofer will leverage their expertise to drive advancements in technology, sustainability, and product innovation, thereby contributing to the growth and competitiveness of the Indian automotive ecosystem. Dignitaries present during the signing of MoU: (i) Mr. Vikrampati Singhania, Director, AMF & MD, JK Fenner (India) (ii) Mr. Vinnie Mehta, Director General, ACMA (iii) Dr. Johann Feckl, Director and Section Head Precompetitive Research and International Relations, Fraunhofer Gesellschaft (iv) Ms. Anandi Iyer, Director, Fraunhofer Office India.

30.10.2024: Industry – Academia Partnerships for Research and Innovation in India

Office of the Principal Scientific Adviser to the Government of India had organized a panel discussion on "Industry – Academia Partnerships for Research and Innovation in India" on 30 Oct 2024. Ms. Anandi Iyer was invited as one of the speakers in this panel discussion, where she shared her perspectives from academia and industry on how collaborations can bridge gaps, foster technology-driven solutions, and enhance India's research and innovation ecosystem.

NOVEMBER 2024

08.11.2024: Micelio Clean Mobility Summit 2024

Micelio Mobility had organized its second edition of Clean Mobility Summit on 08 Nov 2024 in Bangalore. Mr. Sebastian Stegmüller, Division Director Mobility and Innovation Systems from Fraunhofer IAO Director was invited as a speaker in the panel discussion on "Collaborative Models for Startup Corporate Innovations in Clean Mobility" in this summit. On this occasion, Micelio had also organized a Micelio Mobility Awards for innovators, path-breakers, and visionaries working towards emission-free transportation. Like every year, Ms. Anandi Iyer was invited as one of the jury members along with other industry pioneers to decide the winner in each of the categories.








15.11.2024: Fraunhofer IPT – TIDCO: Design Thinking Workshop
Fraunhofer IPT is the Technology Partner to Tamil Nadu Industrial Development Corporation (TIDCO) to establish an Innovation Cluster in Advanced Manufacturing in Tamil Nadu. The project team had visited Chennai from 11 – 15 Nov 2024 to conduct onsite interviews with key stakeholders from industry, academia and government. A final design thinking workshop was organized on 15 Nov 2024 in Chennai where the project team from Fraunhofer IPT presented their results and prioritized the industry sectors according to growth potential and the sectors' respective contribution to the Tamil Nadu's GDP.

19.11.2024: Visit of Dr. Anna Christmann, Commissioner for Start Ups and Digital Economy, Federal Ministry for Economic Affairs and Climate Action (BMWK) to India
Ms. Anandi Iyer met with Dr. Anna Christmann, Commissioner for Start Ups and Digital Economy, Federal Ministry for Economic Affairs and Climate Action (BMWK) during her visit to Bangalore on 19 Nov 2024 at Bengaluru Tech Summit (BTS) 2024.They discussed several opportunities between India and Germany on strengthening the ties in Innovation and Start up ecosystem.

21.11.2024: Visit of Shri. Jyotiraditya M Scindia, Minister of Communications, Govt. of India to Fraunhofer HHI in Berlin
Fraunhofer Office India had coordinated a visit of high-ranking delegation of Govt. of India, led by Hon'ble Minister of Communications Shri. Jyotiraditya Scindia to Fraunhofer HHI in Berlin. The objective of this visit was to introduce the competencies of Fraunhofer HHI to India and set a ground for a long-term strategic partnership between India and Germany in Wireless Communication and Quantum technologies. The topics identified are: (i) Quantum Communications (ii) 6G Terahertz technologies (iii) Adoption of 5G industry use cases (iv) setting up 5G OpenRAN testing and integration centers in collaboration with Fraunhofer (v) AI / Digital Twins for smart city and agriculture use cases. The MoU between both sides will be signed soon along and specific project agreements will be drawn. Centre for Development for Telematics (C-DOT) will be the nodal agency of Indian Ministry of Communications to cooperate with Fraunhofer HHI on these topics.

25.11.2024 - 28.11.2024: AsiaBerlin Summit 2024
The Berlin State Department has been organising the Asia Berlin Summit since 2007 forming the collective platform that brings together communities withing the startup ecosystems across Asia and Berlin. The event organised in cooperation with the AsiaBerlin Forum e.V. had organized AsiaBerlin Summit 2024 from 25 – 28 Nov 2024. Besides being invited to a VIP Breakfast Meeting with Ms. Franziska Giffey, Berlin Senator for Economy Energy and Enterprise, Ms. Anandi Iyer was invited as one of the speakers in the panel discussion on "how innovation is driving transformation in the global business landscape, particularly in the context of connecting Berlin's startups to the dynamic ecosystems across Asia". The panel discussed emerging technologies, collaborative opportunities and challenges in fostering cross-border partnerships.

27.11.2024: Indo- German Business Roundtable at the Indian Embassy in Berlin
Asien Bruecke e.V organised the Indo-German Business Roundtable in collaboration with the Indian Embassy in Berlin and the German Indian Innovation Corridor Ms Anandi Iyer was invited to a panel discussion on Sustainable Manufacturing along with Mr Clas Neumann Head Senior Vice President & Head SAP Labs Global and Mr Bhuwan Aggarwal, Head - Tata Consultancy Services, Europe. The event was attended by leaders from business, think-tanks and politics to explore Indo German collaboration in manufacturing & co-production.

1. Group photograph with workshop participants.
2. Ms. Anandi Iyer giving her insights for the project development activity in the workshop.
3. Dr. Anna Christmann and Ms. Anandi Iyer.
4. Visit of Shri. Jyotiraditya M Scindia, Minister of Communications, Govt. of India to Fraunhofer HHI in Berlin.
5. Ms. Anandi Iyer at Asia Berlin Summit.
6. Ms. Anandi Iyer (6th from L) along with Mr. Ajay Gupte, Ambassador, Indian Embassy in Berlin (4th from L).
7. Ms. Anandi Iyer in the panel discussion.

DECEMBER 2024

11.12.2024: TiE Global Summit (TGS) BLR 2024

TiE Global Summit (TGS) is hosted by TiE Bangalore in collaboration with the Karnataka Digital Economy Mission and the Government of Karnataka and supported by Ministry of Electronics & Information Technology (MeitY), Govt. of India and Software Technology Parks of India (STPI). This year's summit marked the 9th edition of TGS and coincides with TiE Bangalore's 25th anniversary—a milestone in the journey to empower and uplift entrepreneurs globally.

Ms. Anandi Iyer was invited as the Chairperson of the panel on "Global Perspectives that Inspire Change" in the EdVentures Conclave: Shaping Future-Ready Leaders in this summit. The EdVentures Conclave is a transformative platform fostering innovation and entrepreneurship on campuses. It brings together thought leaders and stakeholders to explore global trends, actionable insights, and strategies for empowering students and institutions. The sessions aim to reshape education, drive campus innovation, and prepare future-ready leaders for tomorrow's challenges.

1. Ms. Anandi Iyer chairing the panel discussion.

EVENTS CALENDAR 2025 (Organized / Participation by Fraunhofer Office India)

Date	Events	Place
23.01.2025 – 29.01.2025	Indian Machine Tool Expo (IMTEX) 2025	Bangalore
27.01.2025 – 31.01.2025	Visit of Prof. Dr. Thilo Bein, Head of Knowledge Management, Fraunhofer LBF to IIT Madras to conduct workshops on Battery, Charging, Motors and Drives	Chennai
03.02.2025 – 06.02.2025	Visit of the Delegation from Badenwuerttemberg led by Dr. Hoffmeister-Kraut, Minister for Economics. Dr. Markus Wolperdinger, Director, Fraunhofer IGB will participate in the Delegation, leading the topic of Greentech.	Mumbai, Pune, Delhi
10.02.2025 – 14.02.2025	Aero India 2025 Fraunhofer Aviation & Space Alliance is setting up a booth in the German Pavilion.	Bangalore
11.02.2025 – 14.02.2025	India Energy Week	Delhi
12.02.2025 – 25.04.2025	Inauguration of the Women-in-STEM exhibition and Symposium conceptualized by Ms. Anandi Iyer, Director Fraunhofer Office India, Dr. Andrea Gassmann, Director, Experiminta Science Centre Frankfurt and Dr. Christiane Bucher, Head, Akademie des Handwerks. Dr. Kristina Sinemus, Minister for Digitalisation, State of Hessen has agreed to be the Patron.	Frankfurt
12.02.2025 – 14.02.2025	The smarter E India / Intersolar India 2025, participation by Fraunhofer	Gandhinagar
20.03.2025	DWIH Annual Conference on Indo-German Forum: Research, Innovation and Transfer Ms. Anandi Iyer has been invited as a speaker for the "Roundtable Innovation: Pathways for Industry cooperation and Technology Transfer" in this conference. Release of SME Innovation Paper jointly prepared by Fraunhofer and DWIH is also planned.	Delhi
06.03.2025 – 08.03.2025	2nd India Semiconductor and Packaging Ecosystem Conference (ISPEC)	Gandhinagar

Date	Events	Place
18.03.2025 – 22.03.2025	India Smart Utility Week (ISUW)	Delhi
19.03.2025 – 21.03.2025	Internet of Things India Expo; 32nd Convergence India Expo	Delhi
19.03.2025 – 21.03.2025	Embedded Tech India Expo	Delhi
19.03.2025 – 21.03.2025	10th Smart Cities India Expo	Delhi
31.03.2025 – 04.04.2025	Hannover Messe 2025	Hannover
23.06.2025 – 27.06.2025	India Energy Storage Week (IESW) International Conference & Exhibition	Delhi
01.09.2025 – 03.09.2025	SEMICON India 2025	Noida
July / August 2025*	7th Fraunhofer Innovation and Technology Platform (FIT) Focus: Electronics & Semiconductors	Delhi*
17.09.2025 – 19.09.2025	electronica India 2025, productronica India 2025	Bangalore
Sept 2025*	ACMA 65th Annual Session	Delhi
30.10.2025 – 01.11.2025	Renewable Energy India REI Expo 2025	Noida

Fraunhofer in India: Recent Media Coverage

German Ambassador to India Philipp Ackermann, Fraunhofer Office in India Director Anandi Iyer (Image Credit: X/@AmbAckermann)

Fraunhofer Office India Director Anandi Iyer honoured with Germany's Federal Cross of Merit

ANI | Updated: Jun 22, 2024 02:38 IST

New Delhi [India], June 22 (ANI): Anandi Iyer, Director of the Fraunhofer Office in India, has been honoured with the Bundesverdienstkreuz (Federal Cross of Merit) by the German government. The recognition celebrates her outstanding contributions to India-Germany ties for more than 25 years, coinciding with 50 years of Indo-German Science and Technology Cooperation.

Fraunhofer Office India Director Anandi Iyer honoured with Germany's Federal Cross of Merit

ANI 22 June, 2024 02:47 am IST

German Ambassador to India Philipp Ackermann, Fraunhofer Office in India Director Anandi Iyer (Image Credit:

India-Germany partnership takes a leap forward with launch of knowledge paper on sustainable innovation

ANI 12 August, 2024 02:47 pm IST

New Delhi Hosts Key Conference on Indo-German Technological Collaboration

The conference "Sustainability: The Technology Imperative for Our Future: German Innovations in India" in New Delhi highlighted the expanding collaboration between India and Germany in technology and sustainability.

Written by Express Defence
August 12, 2024 15:43 IST

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Gita ghosh, Deputy General Manager, Strategic IP and Innovation Management, Mercedes-Benz R&D, India (MBRDI), Anshuman Awasthi, Sr. Vice president & Head of Innovation, Mercedes-Benz R&D, India (MBRDI), Dr Philip Ackermann, German Ambassador to India and Bhutan, Anandi Iyer, Director, Fraunhofer Office, India,

भारत को सस्टेनेबल इनोवेशन हब बनाने में तेजी लाती जर्मन तकनीक

सोनम मिश्रा
16.08.2024

भारत को वैश्विक इनोवेशन हब बनाने में तकनीक और रिसर्च की केंद्रीय भूमिका है. नई दिल्ली में आयोजित एक सम्मेलन में जर्मन कंपनियों ने भारत को लेकर अपनी योजनाओं और निवेश के संभावनाओं पर चर्चा की.

Tidco collaborates with Germany-based Fraunhofer Institute

Yogesh Kabirdoss / TNN / Oct 24, 2024, 21:25 IST

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A delegation from Tamil Nadu led Tidco MD Sandeep Nanduri visited key Fraunhofer facilities in Germany and the Netherland...

CHENNAI: Tamil Nadu Industrial Development Corporation (Tidco) has collaborated with Germany-based Fraunhofer Institute for Production Technology (IPT) for advancing TN's innovation and knowledge ecosystem.

Through this partnership, Tidco seeks to integrate global best practices and drive the implementation of innovation clusters like university research parks, centres of excellence (CoEs) and knowledge city-like initiatives in the state.

Tamil Nadu Partners with Germany's Fraunhofer IPT to Build Innovation Ecosystem

INDIA-GERMANY NEWS | NEWS | 2 months ago | thedialog

Photo: Project Kick-off September 2024 (virtual)

ACMA Mobility Foundation signs MOU with Fraunhofer Institutes

in Newscast – by Richa Tyagi – October 28, 2024

ACMA Mobility Foundation partners with Fraunhofer for advanced R&D in auto component industry

The ACMA Mobility Foundation has signed an MOU with Fraunhofer-Gesellschaft for R&D collaboration in India's auto component industry. This partnership aims to enhance technology, sustainability, and innovation. It involves joint projects on sustainable production and road safety. The MoU will be in effect for three years, with possible extensions.

ACMA Inks MoU With Fraunhofer Institute To Advance R&D In Component Sector

By MT Bureau – October 26, 2024

ACMA Mobility Foundation, Fraunhofer Institutes Join Forces to Propel R&D in India's Auto Sector

ACMA Mobility Foundation partners with Fraunhofer Institutes to drive R&D in Indian auto components

This collaboration focuses on applied research in sustainability, circularity, and road safety, aims to in innovation in India's auto component sector.

By Autocar Pro News Desk | 26 Oct 2024 | 2133 Views | Share -

ACMA and Fraunhofer partner to propel innovation in sustainable auto component manufacturing

by Staff Writer | October 26, 2024 | SHARE

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- We offer different possibilities for training and continuing education of personnel
- We observe technological trends and market developments and can carry out feasibility studies for you
- We accompany you through R&D projects as well as technological and process development
- You can take advantage of the results of our preliminary research in the areas of micro- and nano-electronics as well as microsystem and communication technologies (through license contracts)
- You will benefit from our wide-ranging research network and numerous cooperation arrangements with renowned international research institutes and universities

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