Introduction (May 2023)

-

Research Portfolio Optical Imaging

in Life Sciences

Fraunhofer IPT

Production technology at Fraunhofer IPT

Process technology
Prof. Thomas Bergs

- Fine machining and optics
- High performance machining
- Energetic blasting methods
- Technology Transfer Turbomachinery

Production machines
Prof. Christian Brecher

- Precision engineering
- Fiber composite and laser system technology

Production metrology and quality management
Prof. Robert Schmitt

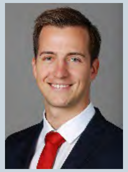
- Production quality
- Production metrology

Technology management
Prof. Günther Schuh

- Strategic technology management
- Operational technology management

Technology Consulting → System-Development → Application

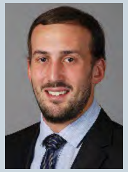
Head of department
Niels König



Optical metrology and imaging methods
Enno Hachgenei

Digital Infrastructures
Pierre Kehl

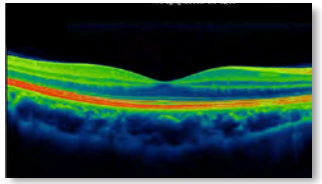
Adaptive Production Control
Simon Hort



Automatization in life sciences
Bastian Nießing

Production metrology
Research areas

Optical metrology and imaging methods

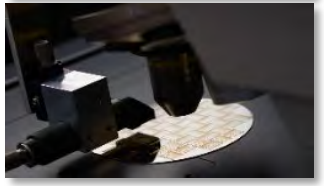


- Optical coherence tomography
- Fiber optics
- Optic testing
- In-line laser process monitoring and control
- Lithography and structure characterization

Digital infrastructures

- 5G in production
- Connected sensor systems
- Edge-Cloud Systems
- Virtualization and real-time communication

Automation in Life Science



- Laboratory automation
- Development of automated cell culture processes
- iPS- and MSC-production
- High-Speed-Microscopy
- Biological image processing

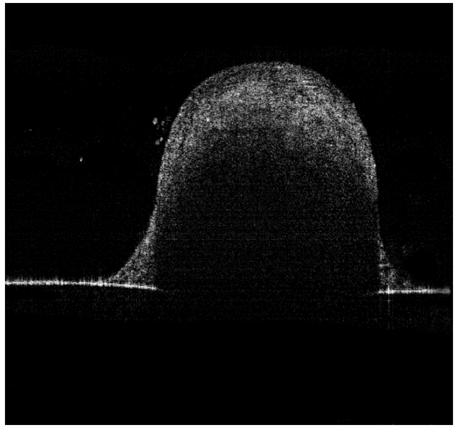
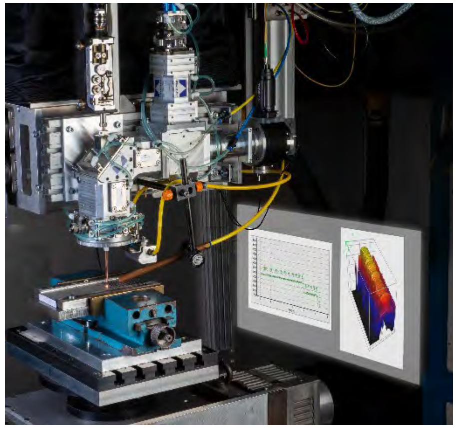
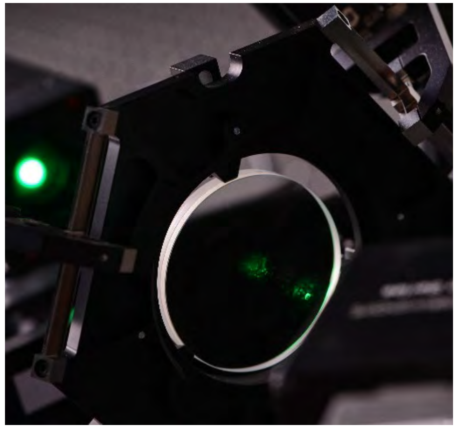
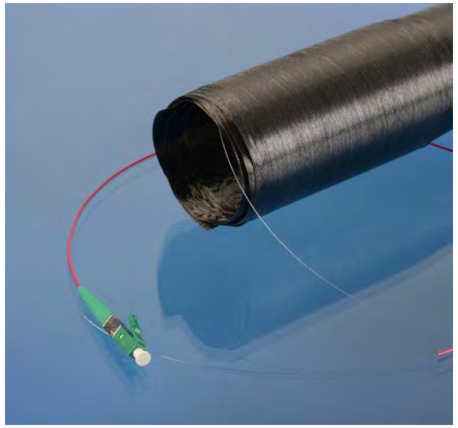
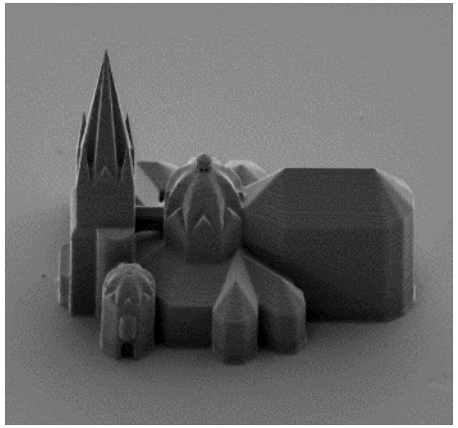
Adaptive production control

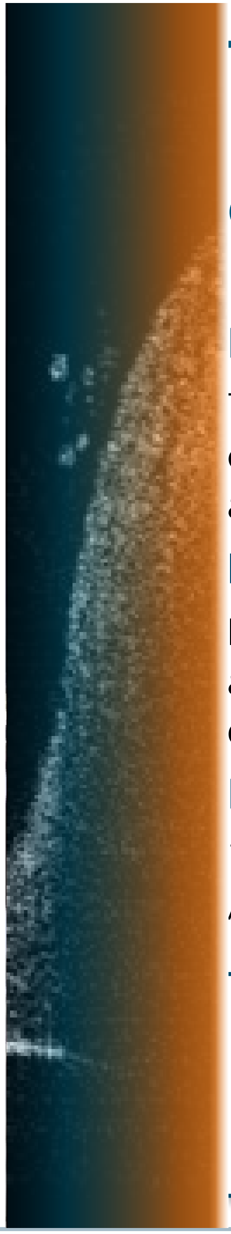
- Flexible production control platform
- Decision support systems
- Implementation of the Digital Twin
- Service oriented machine connections
- Ontologies for production control

Optical metrology and imaging methods

Fields of work in research

Biomedical Diagnosis	Inline laser process control	Optics testing and adjustment	Fiber Sensors	Lithography
– Optical coherence tomography (OCT) – PS-OCT – UHR-OCT – Full-Field OCT	– Low-coherence interferometry – Chromatic-confocal sensors – Plasma analysis	– Wavefront-based optics testing – Tomographic optics testing – Adaptive optics adjustment	– Miniaturized Sensors – Structural assessment – Fiber Optics	– Two-Photons-Polymerization – SLM-Interference-lithography – Characterization of Micro- and Nanostructures



Topic focus - Biomed. OCT

Development of application-specific OCT systems and evaluation of biomedical image data

Description

The developed OCT systems are used for non-invasive, high-resolution characterization of biological materials and samples as well as their functional analysis (e.g. viability measurements of cellular material)

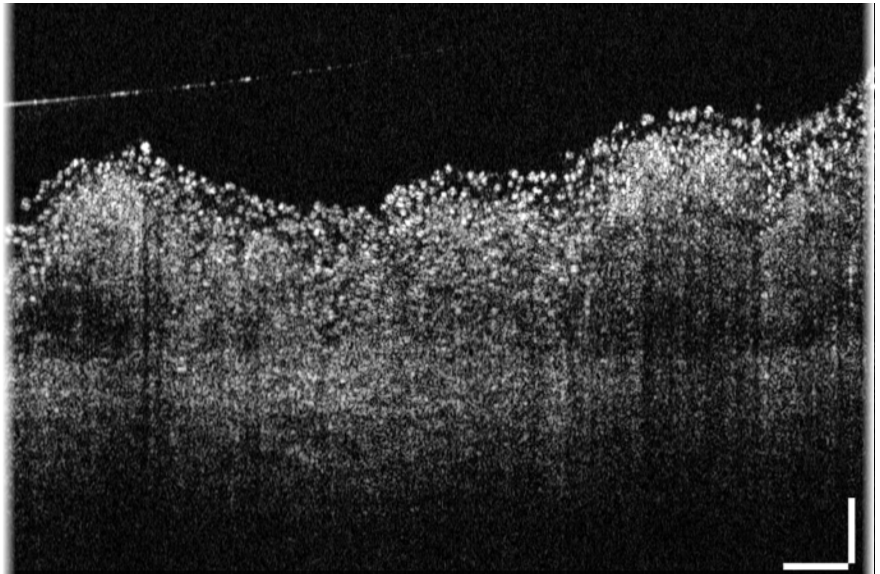
Research focus

In addition to the development of OCT systems, the focus of research is on fast and accurate data and image evaluation using suitable (intelligent) algorithms, e.g. for image registration and object classification.

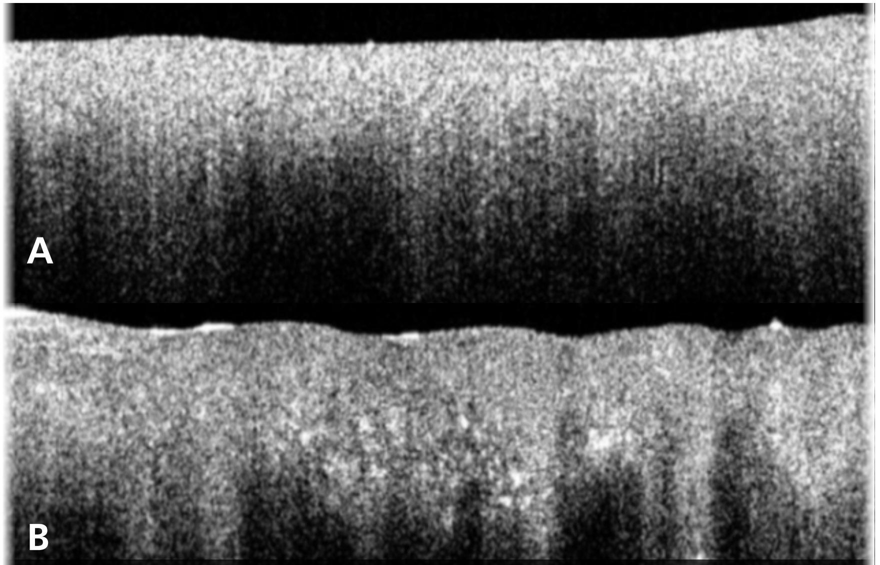
Fields of application

Tissue Engineering: Dual Range Organoid Characterization Quality Analysis of Artificial Tissue Using OCT+KI

> **"Our expertise: we develop OCT systems for biomedical applications with high resolution, high depth measurement range and high measurement frequency."**

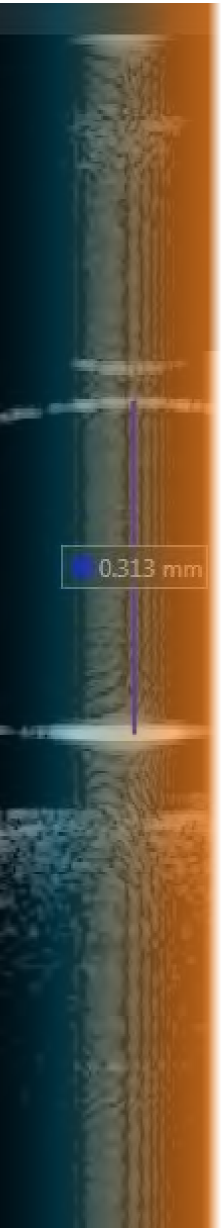


OCT cross section of artificial tissue



OCT cross-section of a healthy liver (A) and a diseased one(B).

Fraunhofer IPT WZL RWTH AACHEN UNIVERSITY



Topic focus - Optics testing

Functional and geometric characterization of medium and small optics

Description

Test, integration and development of suitable methods for the functional and geometric characterization of optics of various shapes, materials and dimensions.

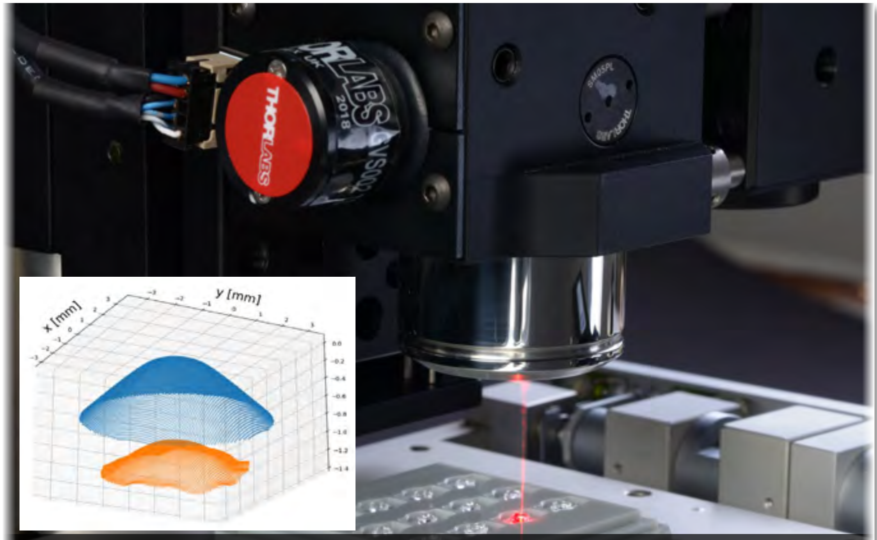
Research focus

In addition to our broad portfolio of commercial and self-developed customized measurement solutions, we also develop algorithms necessary for the automated analysis of relevant parameters in the measured optics

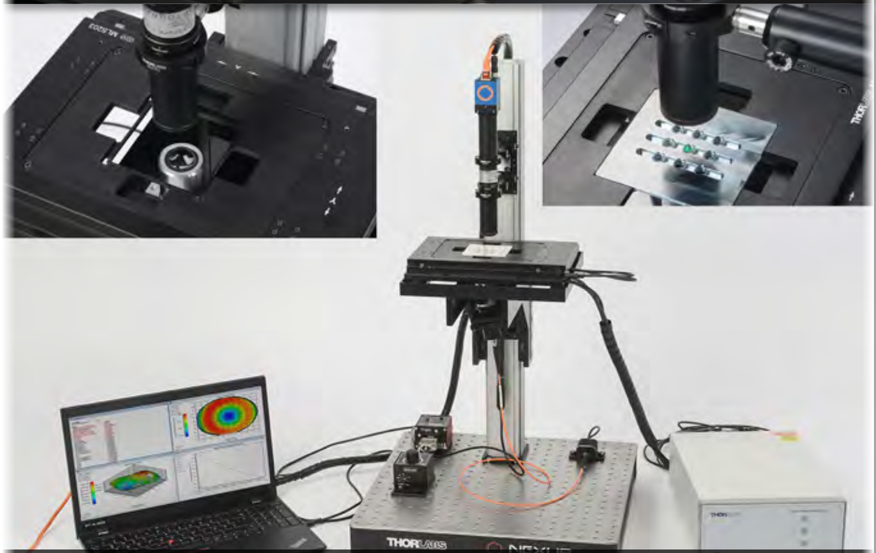
Fields of application

Optics made of different materials (glass, polymer, metal), different sizes (macro, mini or micro optics) and different geometries (plano, spherical, aspherical or freeform)

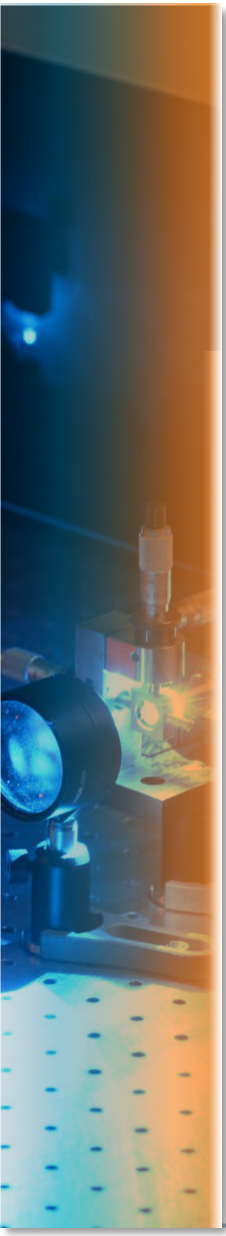
" Our expertise: We can characterize different sizes and shapes of optics with commercial and self-developed metrological systems and methods "



OCT-based geometric characterization of miniaturized lenses



Wavefront sensor-based test rig for functional characterization of lenses



Topic focus - Industrial OCT

Inline characterization and process monitoring using short-coherent interferometry

Description

OCT enables non-contact and non-destructive measurement without affecting the machining process. New insights into the process flow are thus made possible.

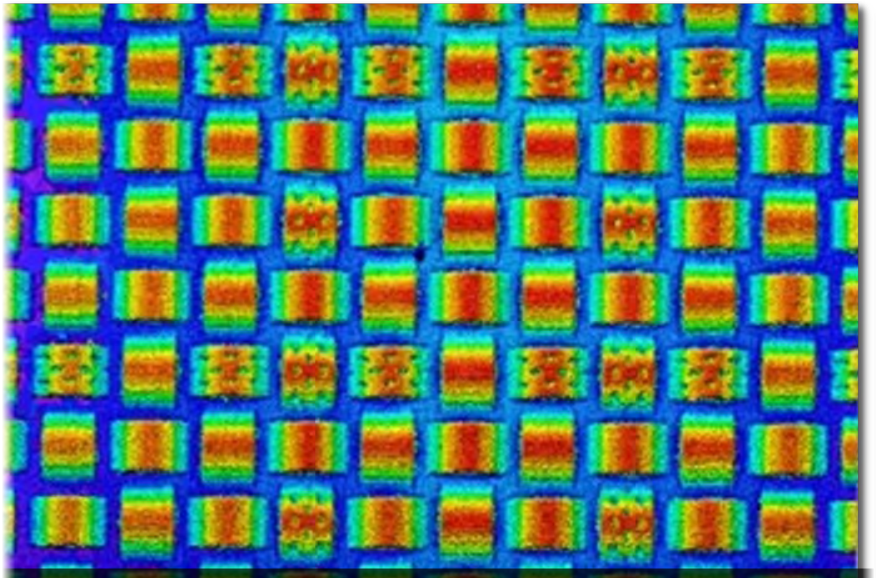
Research focus

Integration of coaxial measuring systems based on optical coherence tomography into industrial machines and development of free-form special measuring systems.

Fields of application

Applications range from process monitoring and 100% in-machine quality control to integration of feedback loops for process regulation.

" Our expertise: design, manufacturing and integration into customer-specific process machines. "



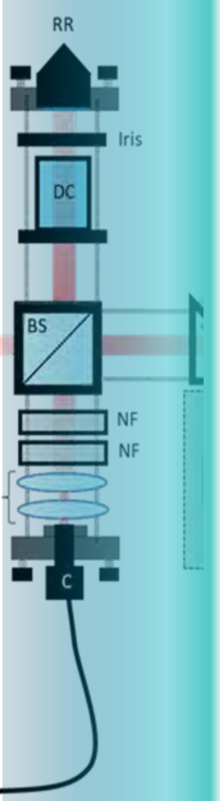
Topographic measurement of a workpiece using OCT

Integration example

Fraunhofer IPT
WZL | RWTH AACHEN UNIVERSITY

Project - IfSidLA

"Development of a method for interferometric film thickness measurement of thin printed resist films."



Project goal

Development of a high-resolution measuring technique for the direct, non-destructive measurement of thin varnish layers on paper, cardboard, foils, etc. (application printing industry)

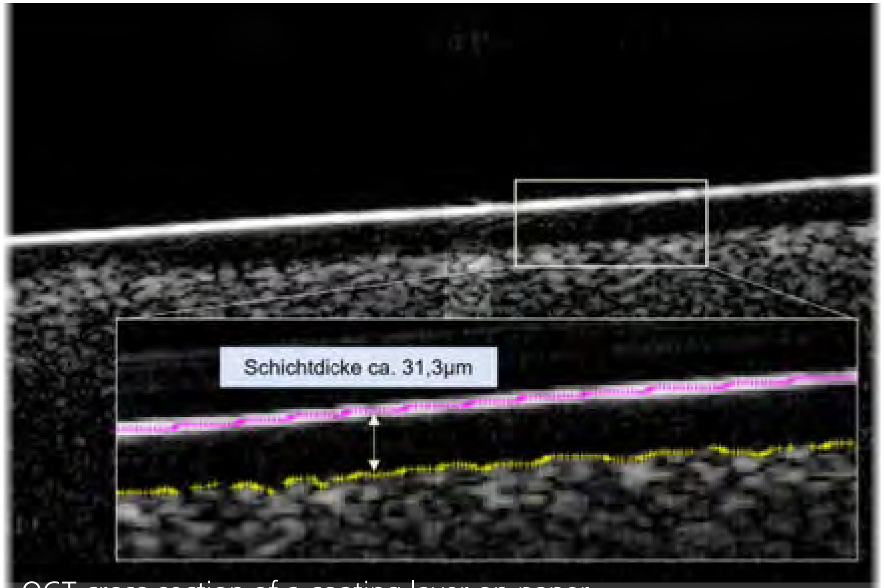
Challenges

Measurement on technically demanding surfaces (roughness of the paper) and implementation of high-resolution measurement technology for fast SD measurement

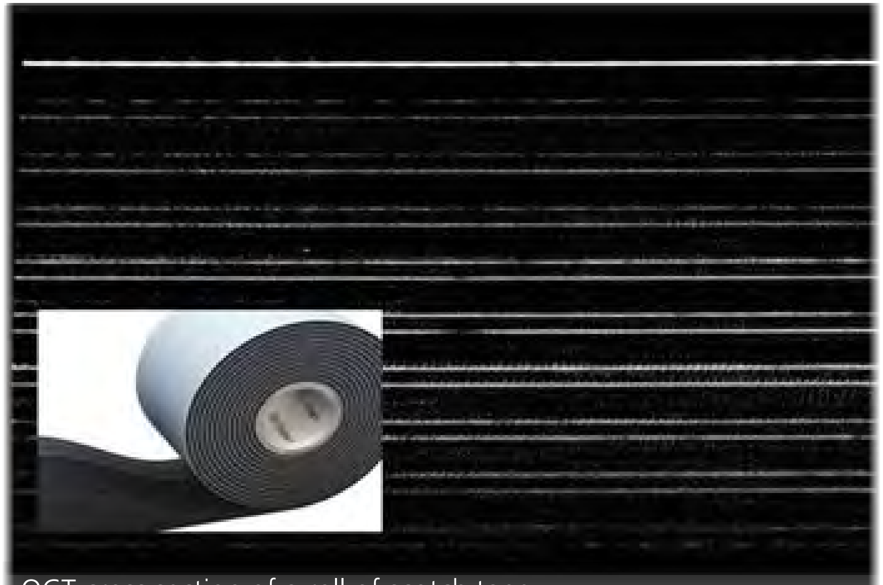
Results

With the help of the development of a high-resolution OCT (UHR-OCT) and the implementation of a layer thickness algorithm, layer thicknesses ~ 1µm could be measured.

"Short summary: In the IfSidLa project, a UHR-OCT was developed which allows the measurement of thin (semi-) transparent layers (up to max. 1µm). "



OCT cross-section of a coating layer on paper

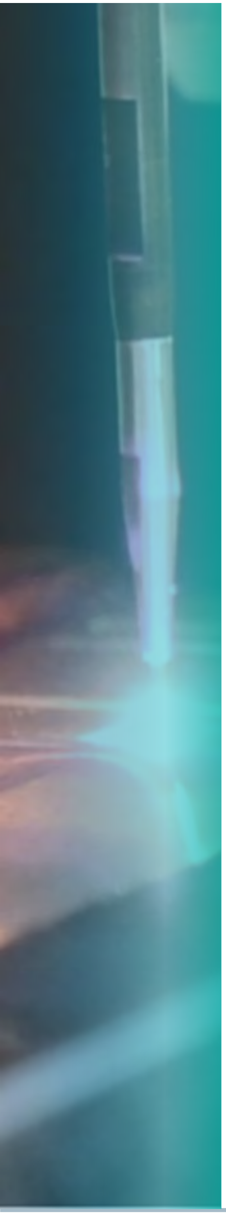


OCT cross section of a roll of scotch tape

  - Information classification -

Project - TopCladd

"Adaptive Laser Cladding for Precise Metal Coating Based on Inline Topography Characterization."



Project goal

Multidirectional and permanent monitoring of weld topography during the wire-based deposition process (*Laser Metal Deposition - wire*: LMD-w) using OCT (Optical Coherence Tomography).

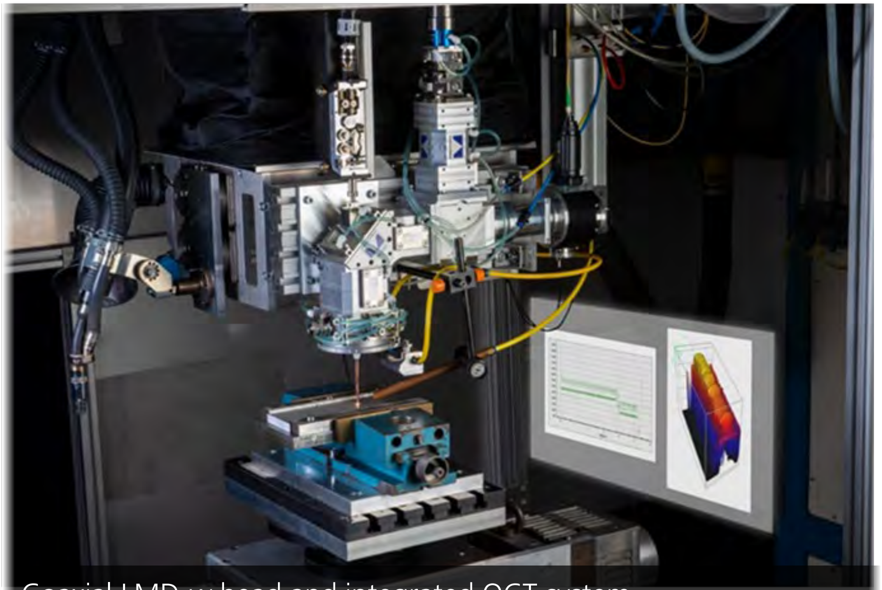
Challenges

Coaxial wire of the LMD-w process head makes coaxial integration of optical measurement technology into the process difficult (→ shadowing)

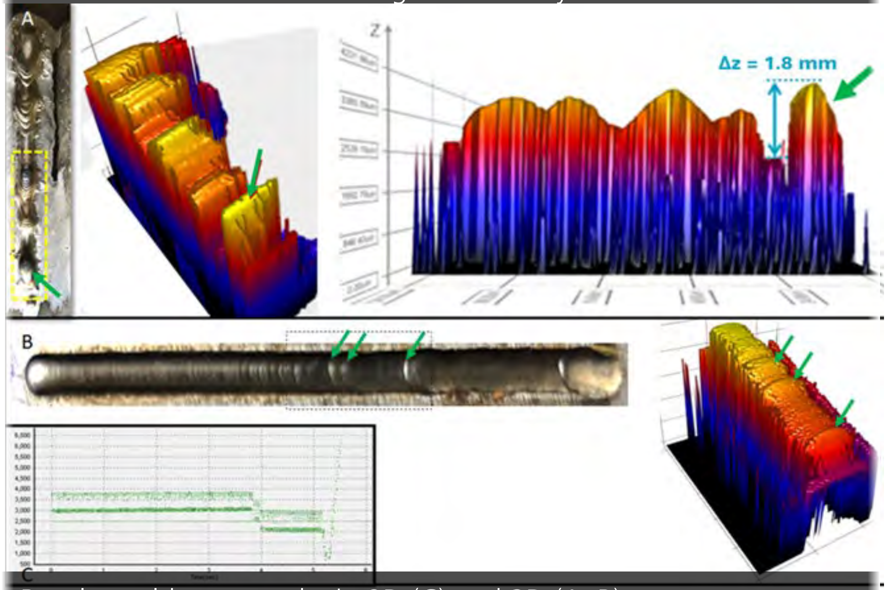
Results

With the help of special optics in the system design, it was possible to coaxially integrate the OCT, which ensures data acquisition during the welding process by circular scanning of the process surface.

" Short summary: In the TopCladd project, multidirectional inline weld monitoring was implemented with the help of integrating OCT into an LMD-w process "



Coaxial LMD-w head and integrated OCT system



Results weld topography in 2D (C) and 3D (A, B)

 10.05.2023

- Information classification -

Fraunhofer IPT
WZL RWTH AACHEN UNIVERSITY

Project - KomFiDis

Ultra-compact fingerprint sensor based on bidirectional OLED microdisplay by applying microlens array.

Project goal

Conventional optical fingerprint scanners have the highest level of forgery protection but a large installation space. In the project, an optical compact fingerprint scanner is to be developed, whereby a bidirectional microdisplay is equipped with suitable microoptics.

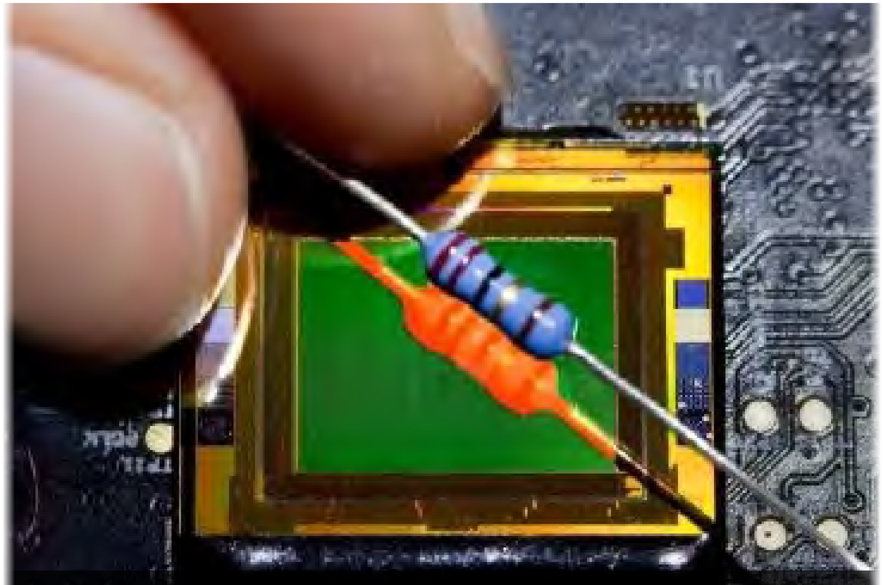
Challenges

The nanostructures for optical light guidance must be written for each pixel and assembled to fit precisely.

Results

An optical microstructure was designed and assembled that increases imaging sharpness. New process chains were designed for this purpose, which made manufacturing and alignment possible.

"In the KomFiDis project, a compact optical fingerprint scanner was designed, with a new light-guiding nanostructure developed. "



Bidirectional display with simultaneous recording and display

Display with finger rest and control electronics

Project - INTENSE

Intelligent light management for energy-efficient lighting through individual nanostructures

Project goal

To make the lighting of the future more efficient, the approach of an intelligent light management system offers to emit light in a more targeted manner. To this end, cost- and resource-saving microstructures for light control are to be produced.

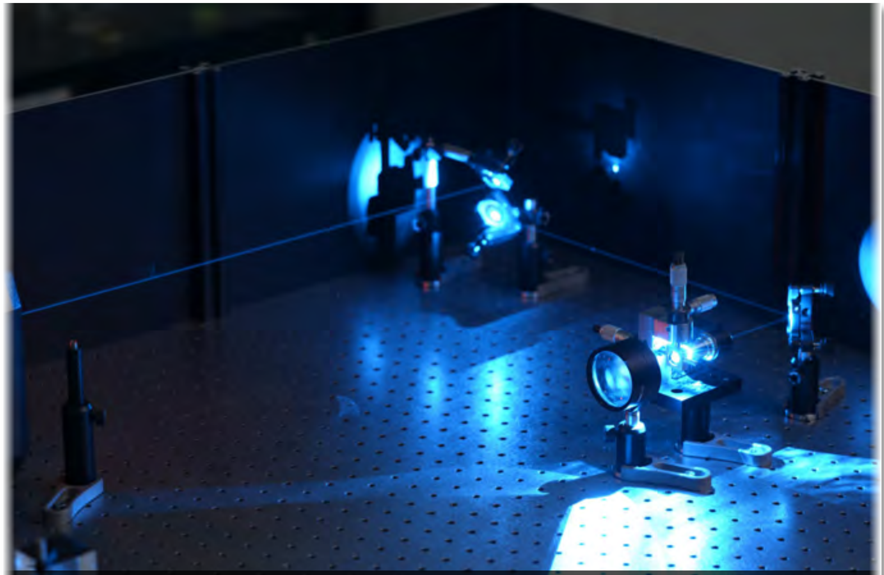
Challenges

To achieve the required fast patterning, the lithographic process is to be parallelized. This is to be done with the aid of a Spatial Light Modulator, which maps a complex interference pattern instead of a single point.

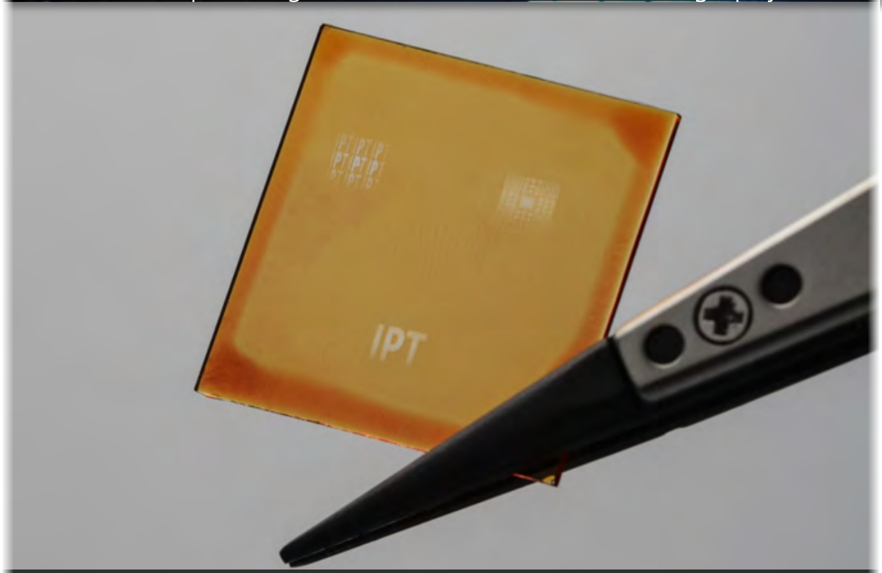
Results

A setup for Spatial Light Modulator-based maskless laser lithography was set up and structures were generated that achieve 11 micrometer resolution for miniaturized optics.

"The INTENSE project developed a lithographic process that enables the rapid fabrication of microstructures for tomorrow's efficient lighting. "



Structure of Spatial Light Modulator-based Laser Lithography.



Fabricated microstructures by parallel exposure

Project - FiberBatt

Long title of the project

Project goal

The aim is to accurately determine the cell condition in order to extend the service life through condition-dependent control of the charging cycles.

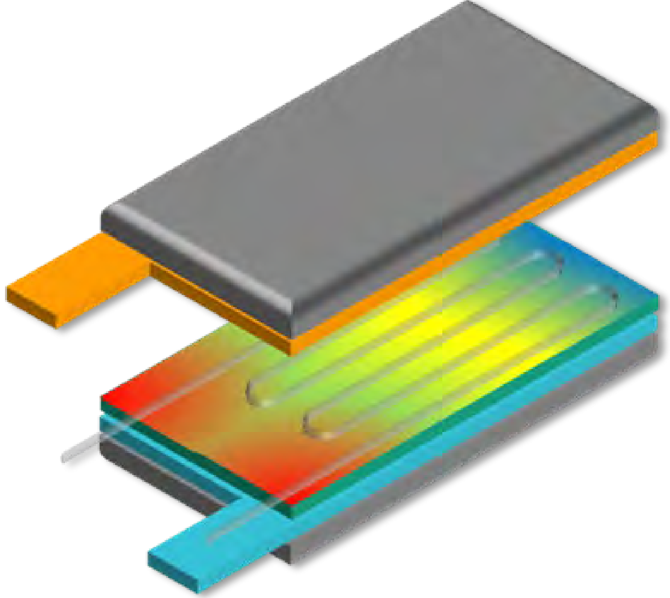
Challenges

A particular difficulty is the reproducible integration of the fragile sensor fibers, as well as the decoupling and validation of thermal and mechanical loads within the cell.

Results

A combined fiber-based sensor for Li-ion pouch cells to detect temperature distributions using optical frequency domain reflectometry and absolute electrode potentials across the fiber coating.

" Short Summary: The FaserBatt project successfully integrated a multimodal sensor for in-situ recording of relevant aging effects in Li-ion cells. "



Battery cell with fiber-based in-situ sensing .

Pouch cell with integrated sensor fiber.

Project - SmartVessel

Fiber-based sensors for intelligent condition monitoring of hydrogen pressure tanks

Project goal

The goal is to integrate fiber-based sensors during hydrogen tank manufacturing for intelligent condition monitoring, lifetime prediction and assessment

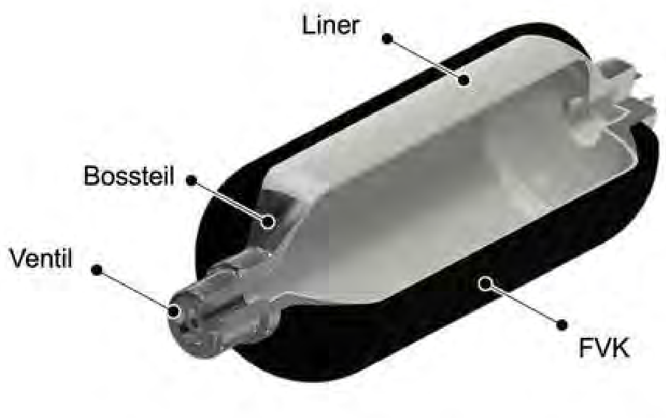
Challenges

Particularly challenging is the process stability to ensure a consistently good integration and to protect the sensors sufficiently.

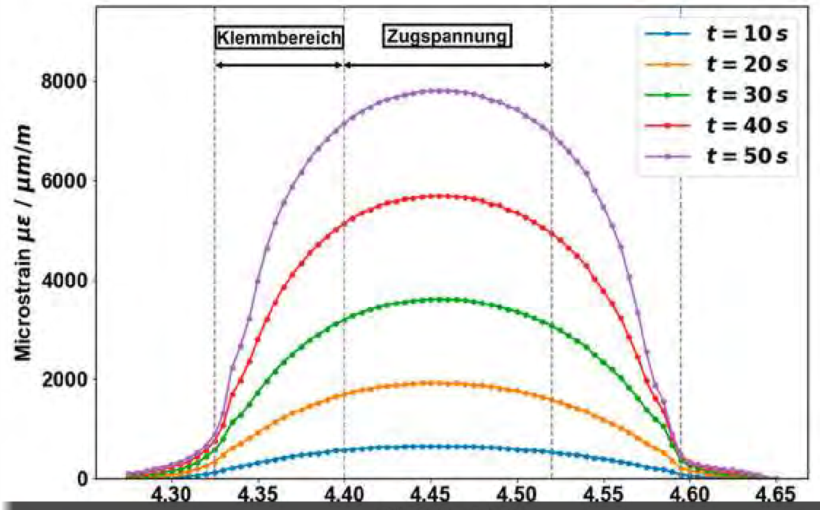
Results

After the selection of suitable fibers, strains could be measured in material tests as well as in tensile burst tests and validated with additional measurement technology.

"In the SmartVessel project, fiber optic sensors were successfully integrated into hydrogen tanks to measure live strain in load tests. "

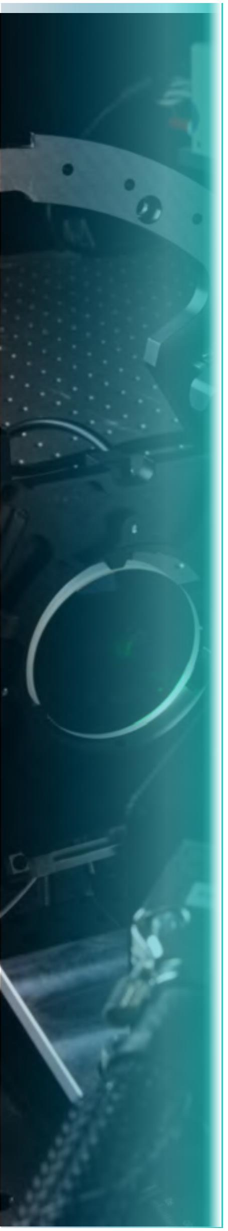


Cross section of a Type IV hydrogen pressure tank.



Strain development in a tensile test determined by means of OFDR.

Fraunhofer IPT WZL RWTH AACHEN UNIVERSITY



Project - WaveAlign

"Wavefront-based alignment of optical systems."

Project goal

Development of an automated alignment station based on wavefront measurement for the active alignment of complex optical systems

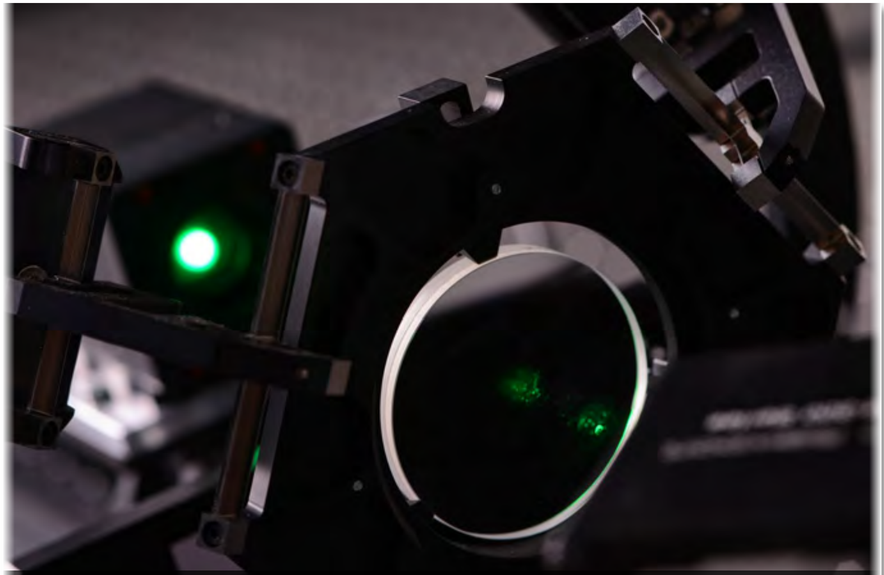
Challenges

Development of an alignment algorithm and integration of hardware and software components to demonstrate the Active Alignment concept in a real production environment.

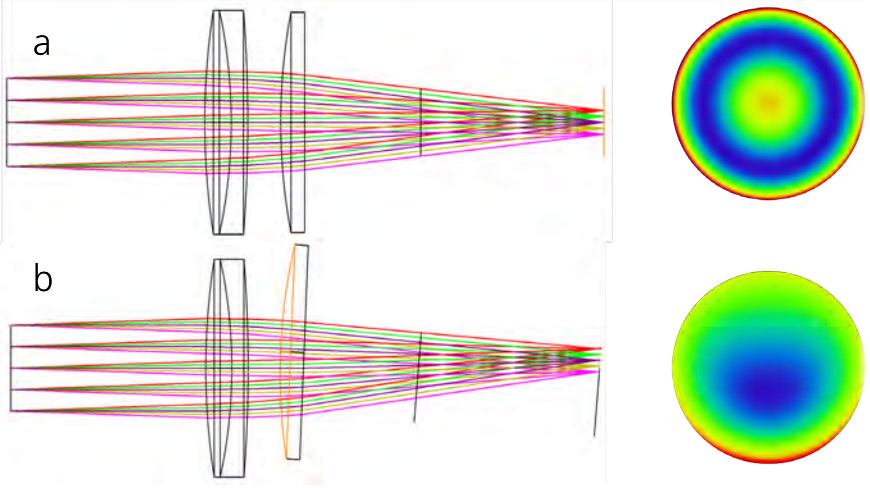
Results

Successful algorithm development and component integration enabled wavefront-based alignment of a multilens system with single-digit micron accuracy

" Short summary: The WaveAlign project successfully developed an alignment algorithm based on optical simulations of the multilens system "



Demonstrator of a wavefront-based adjustment station



a) Adjusted system and corresponding wavefront map
b) Slightly misaligned system and corresponding wavefront map

  - **Information classification** -

Project - ESSIAL

Electrical Steel Structuring, Insulating and Assembling by means of the Laser Technologies

Project goal

In-line process monitoring of a novel process for the production of laser-structured soft magnetic materials using position-compensated optical coherence tomography.

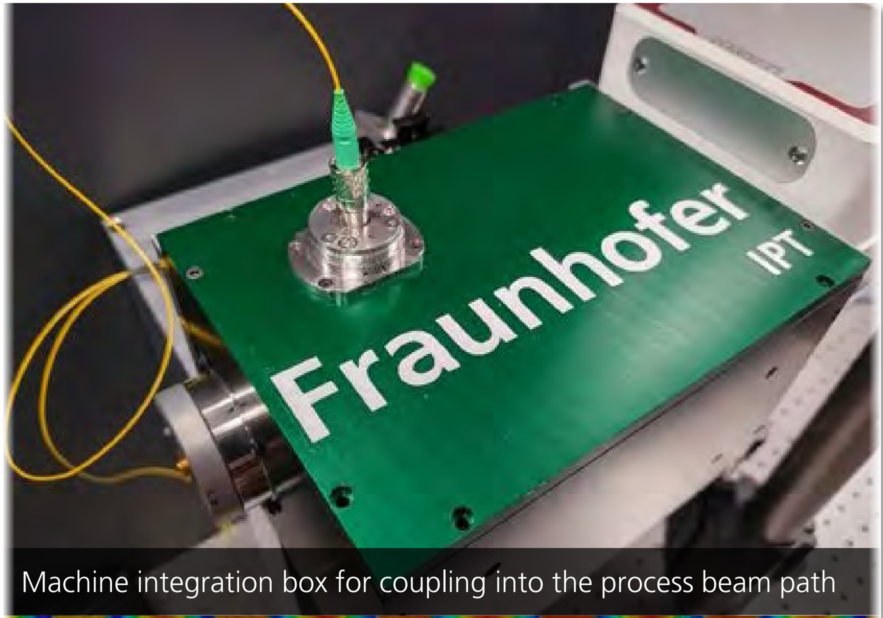
Challenges

For process monitoring, there must be 100% coverage of the processing or measuring beam at all times, without the use of color-corrected f-theta objectives.

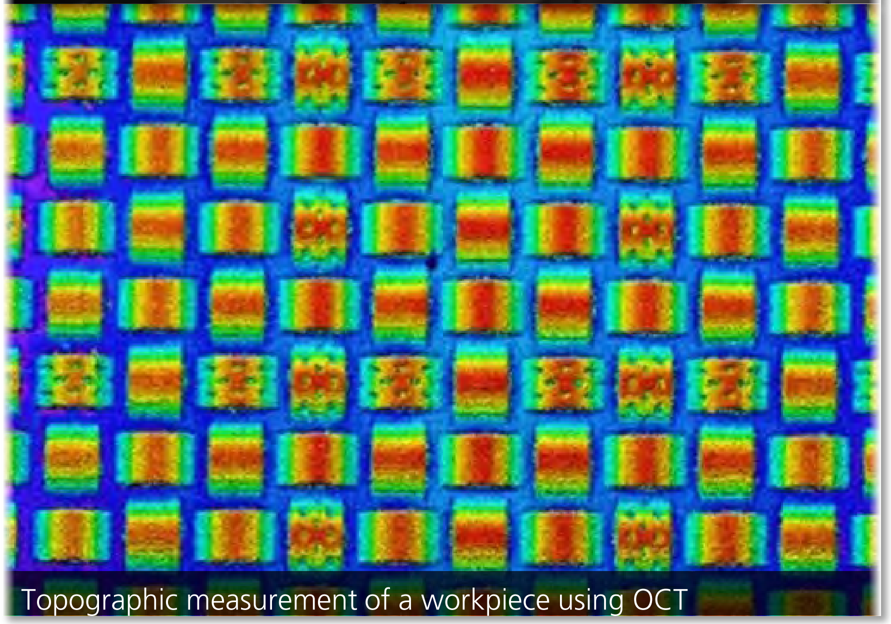
Results

By means of an additional scanning system, the measuring system can be controlled independently of the process, thus providing a new kind of insight into laser processes.

" Short Summary: The ESSIAL project significantly expanded the dynamics and flexibility of in-line OCT."



Machine integration box for coupling into the process beam path


Topographic measurement of a workpiece using OCT

- Information classification -

Fraunhofer IPT

WZL RWTH AACHEN UNIVERSITY

How to Collaborate

Spectrum Cooperation Models

Short-term

- Adapting IPT technology for specific applications (R&D contract)
- Utilizing IPT‘s IP (licensing) + know-how (R&D contract)
- Joint projects with public funding

Mid-term

- Joint research topics
- Exchange of researchers
- Joint papers and conferences
- Mutual support through co-marketing

Long-term

- Establishing institutional cooperation (framework agreement)
  - Option: incl. cooperation with renowned academic institution
  - Focus on relevant strategic topic
- Joint Spin-offs

Contact

-

Enno Hachgenei M.Sc.
Tel. +49 241 8904 - 441
enno.hachgenei@ipt.fraunhofer.de

Fraunhofer IPT
Steinbach Street 17
52074 Aachen
www.ipt.fraunhofer.de