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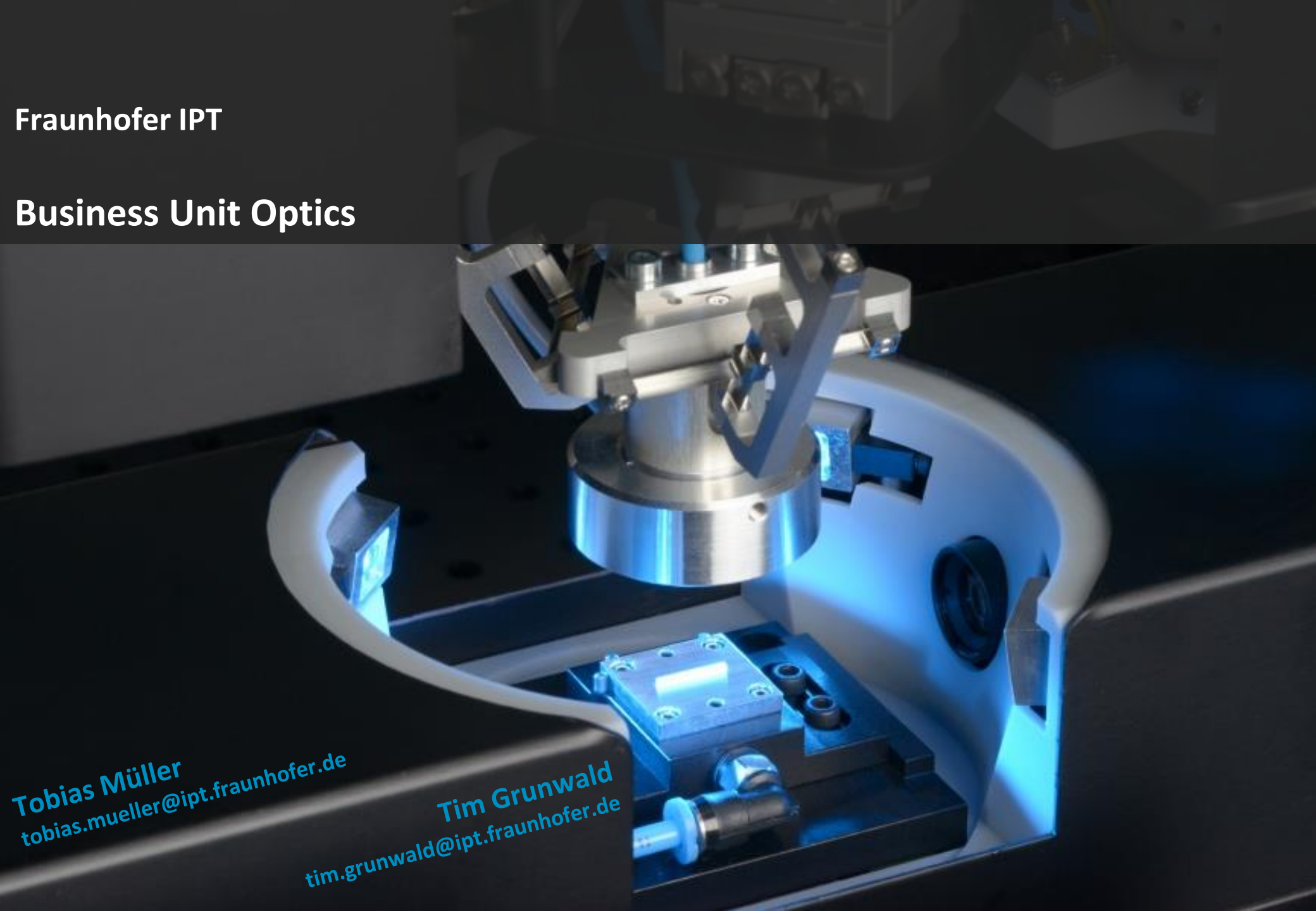
Business Unit Optics



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Fraunhofer IPT

Production Technology in Aachen

RWTH AACHEN UNIVERSITY

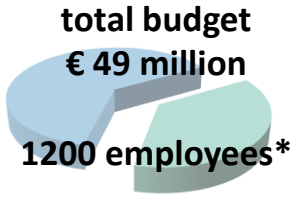
- Founded in 1870
- 44,500 students, 7,185 graduates
- 9 faculties, 260 institutes
- 5,370 researchers, 540 professors
- € 900 million Budget
  (thereof € 325 million external funding)

Faculty of Mechanical Engineering

- 12,575 students, 2230 new immatriculations
- 2,170 graduates, 225 doctorates
- 1,340 researchers, 66 professors
- € 316 million budget,
  thereof € 92 million external funding via Fraunhofer Institutes and others

Focus Production Technology

- **Laboratory for Machine Tools and Production Engineering**
- **Fraunhofer Institute for Production Technology IPT**



*) thereof approx. 50% students

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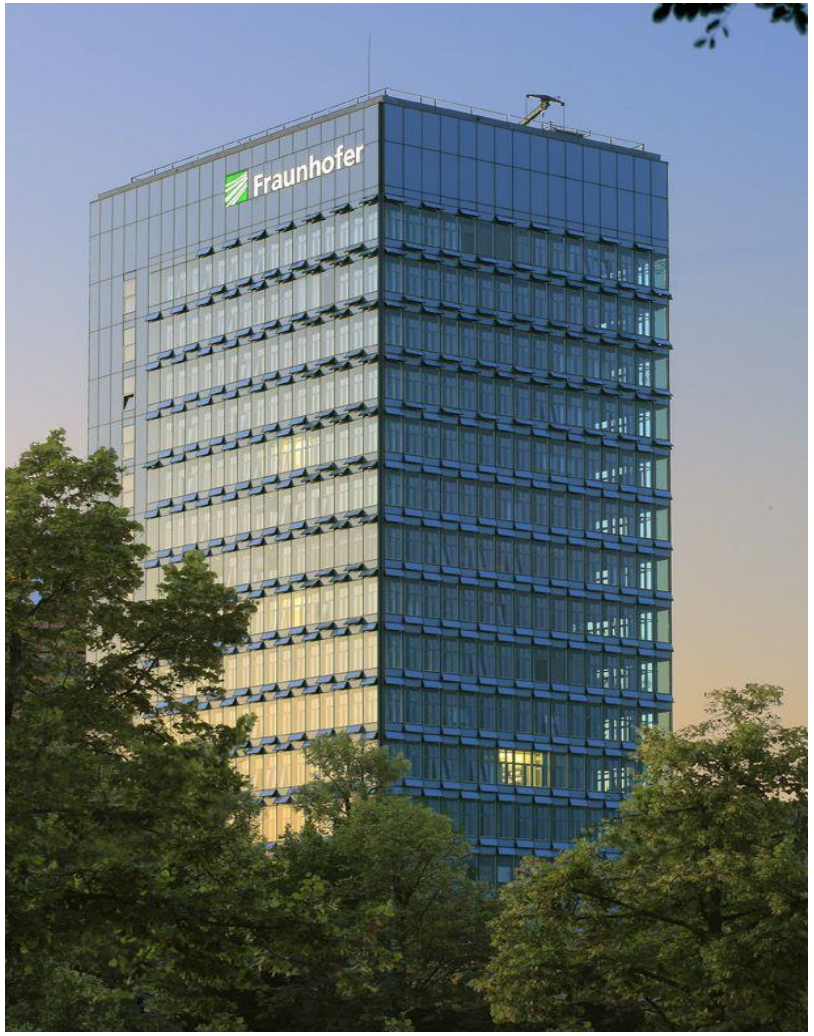
The Fraunhofer-Gesellschaft



Target

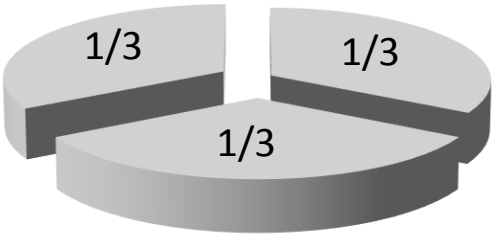
- Contract research for industry and society
- Transfer of results to industrial applications

Organisation

- Founded in 1949
- Legal status as non-profit organisation
- Headquarters in Munich

Budget Funding of the Fraunhofer Institutes

- Basic funding by federal state
- Funding via public projects
- Funding via industrial projects



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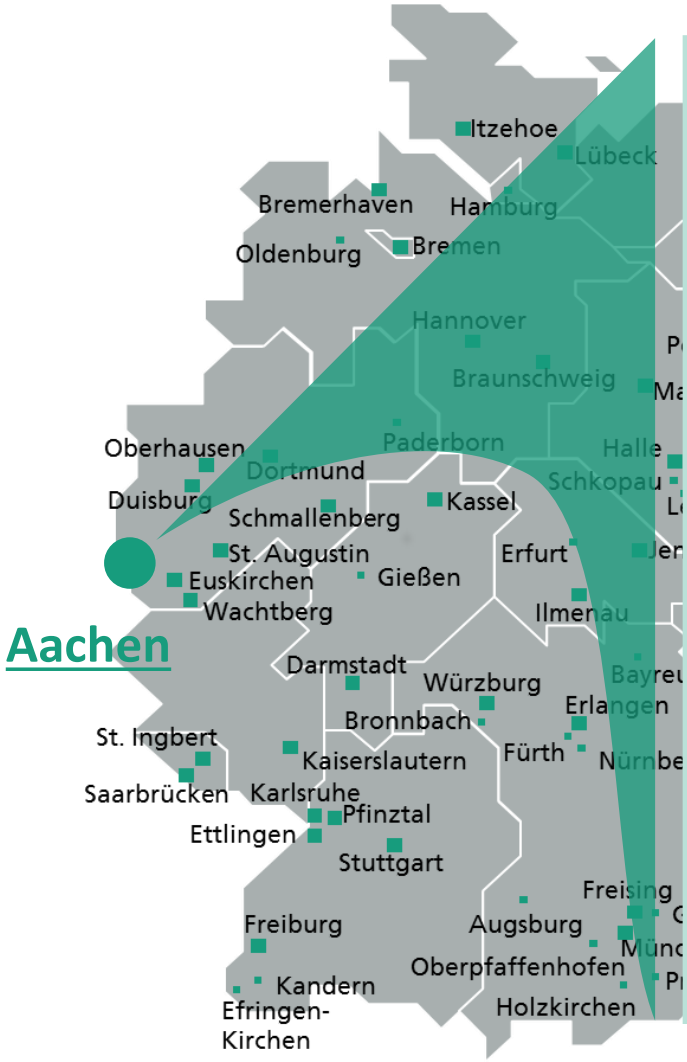
The Fraunhofer Institutes in Aachen



Fraunhofer in Aachen

Fraunhofer IPT	Fraunhofer ILT	Fraunhofer IME
Production Technology	**Laser Technology**	**Molecular Biology and Applied Ecology**

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Fraunhofer IPT

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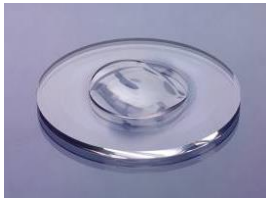
Business Units at the Fraunhofer IPT

Tool and Die Making

Turbo-machinery

Optics



Production of Lightweight Components

Life Sciences Engineering

Process Technology | Production Machines | Production Quality and Metrology | Technology Management

Digitalization and Networks

Technology Development

Management Methodologies

Consulting

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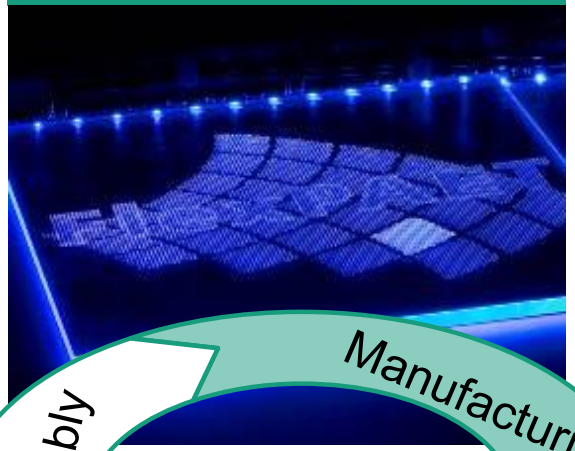
Optics in Aachen

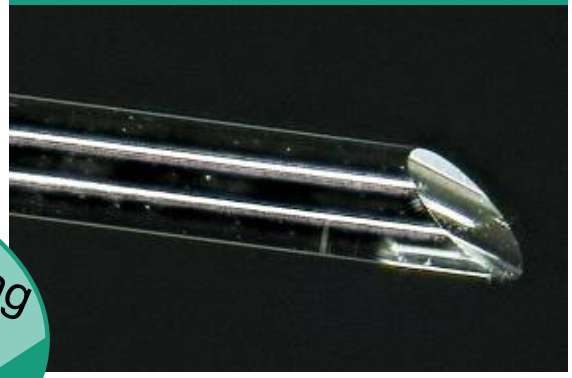
From Manufacturing over Assembly to System integration

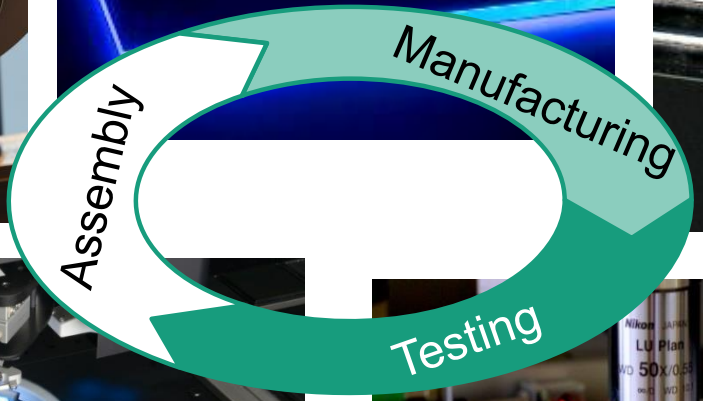
Glass Optics

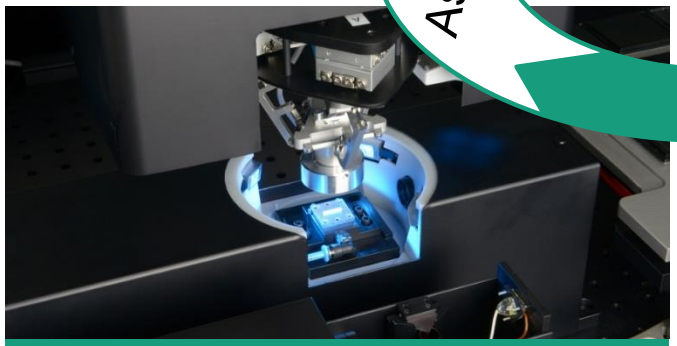
Polymer Optics



Fiber Optics







Automated assembly of Optics

Evaluation of Optics

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Optics in Aachen

Organisational overview

Fundamental Basic research — **RWTH Aachen University**

Leading edge applied research — **Fraunhofer Institute for Production Technology**

Technology leading spin-off companies

AIXTRON

COHERENT | DILAS

SON X

COHERENT | rofin

AIXEMTEC

polyscale

laserline

aix tooling

INGENERIC

oculavis

fionec
fiber optic sensor technologies

INNOLITE

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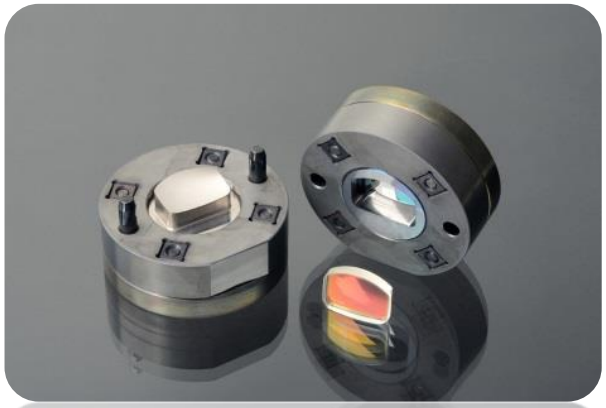
Two examples: Precision glass molding and precision assembly

For both technological fields, Aachen is one of the leading industrial supplier regions of the world



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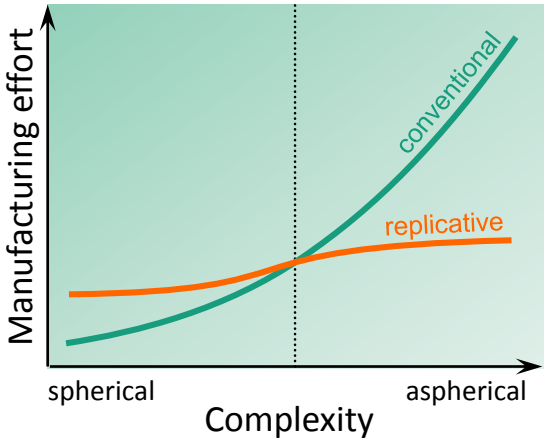
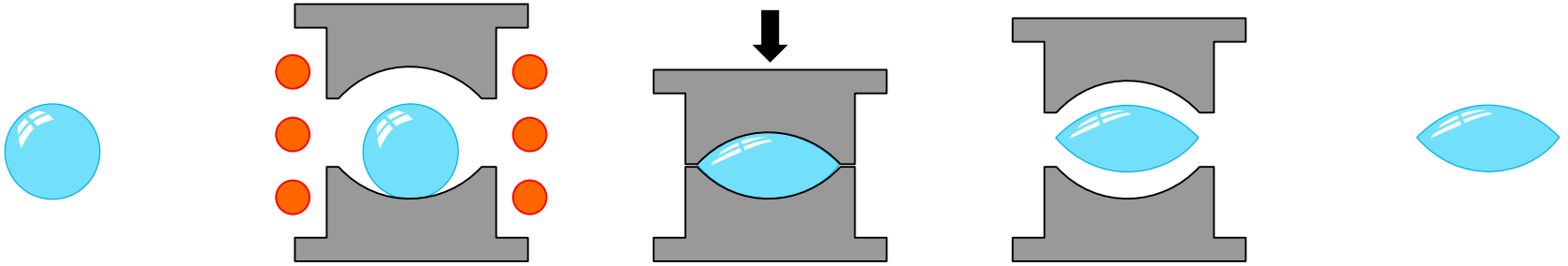
Why replicative optics manufacturing?



- Conventional grinding and polishing of optics is a well-established technology for manufacturing spherical high-precision optics
- More complex geometries, e.g. aspheres or miniaturized optics demand a much higher manufacturing effort
- Increasing demand on highly precise, complex shaped optics made of glass require innovations in manufacturing technology

Approach: Replicative Glass Optics Manufacturing



Blank/Preform → Heating → Molding → Cooling and Removal → Ready-to-use Glass Optic

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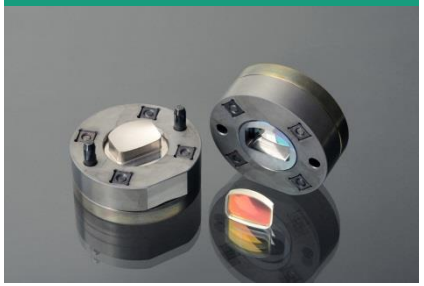
Product Spectrum & Scope of Application

Aspherical Optics

Freeform Optics



Lighting Optics

Diffractive Optics

Micro Optics

Infrared Optics

Cylindric Lenses

Lens Arrays

Wafer Optics

- Wide range of possible geometries
- Accuracies can be adjusted according to the field of application:
  - Imaging
  - Lighting
  - Laser Optics
- High reproducibility/ repeatability as a consequence of the molding process

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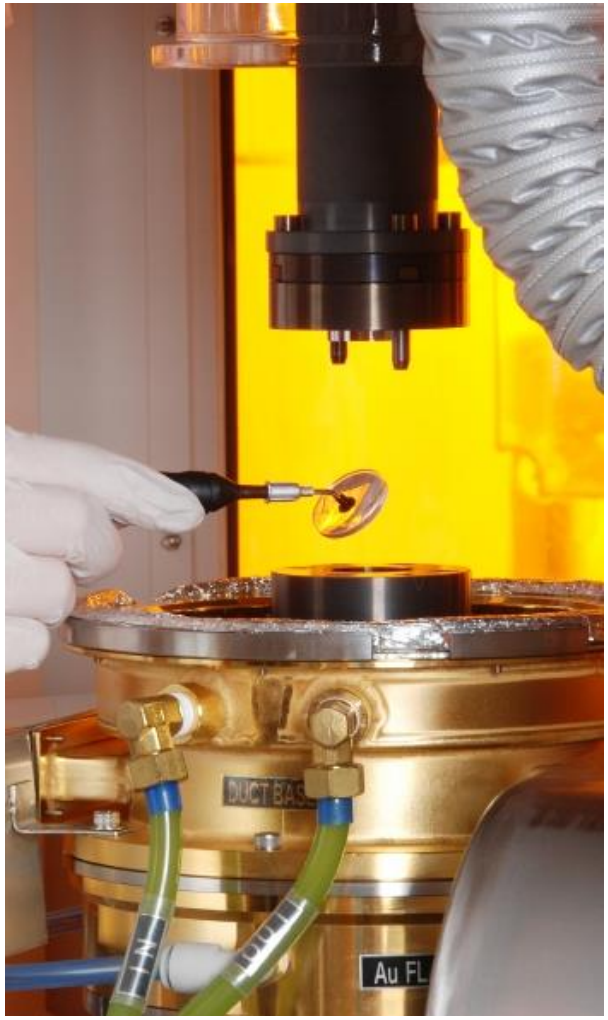
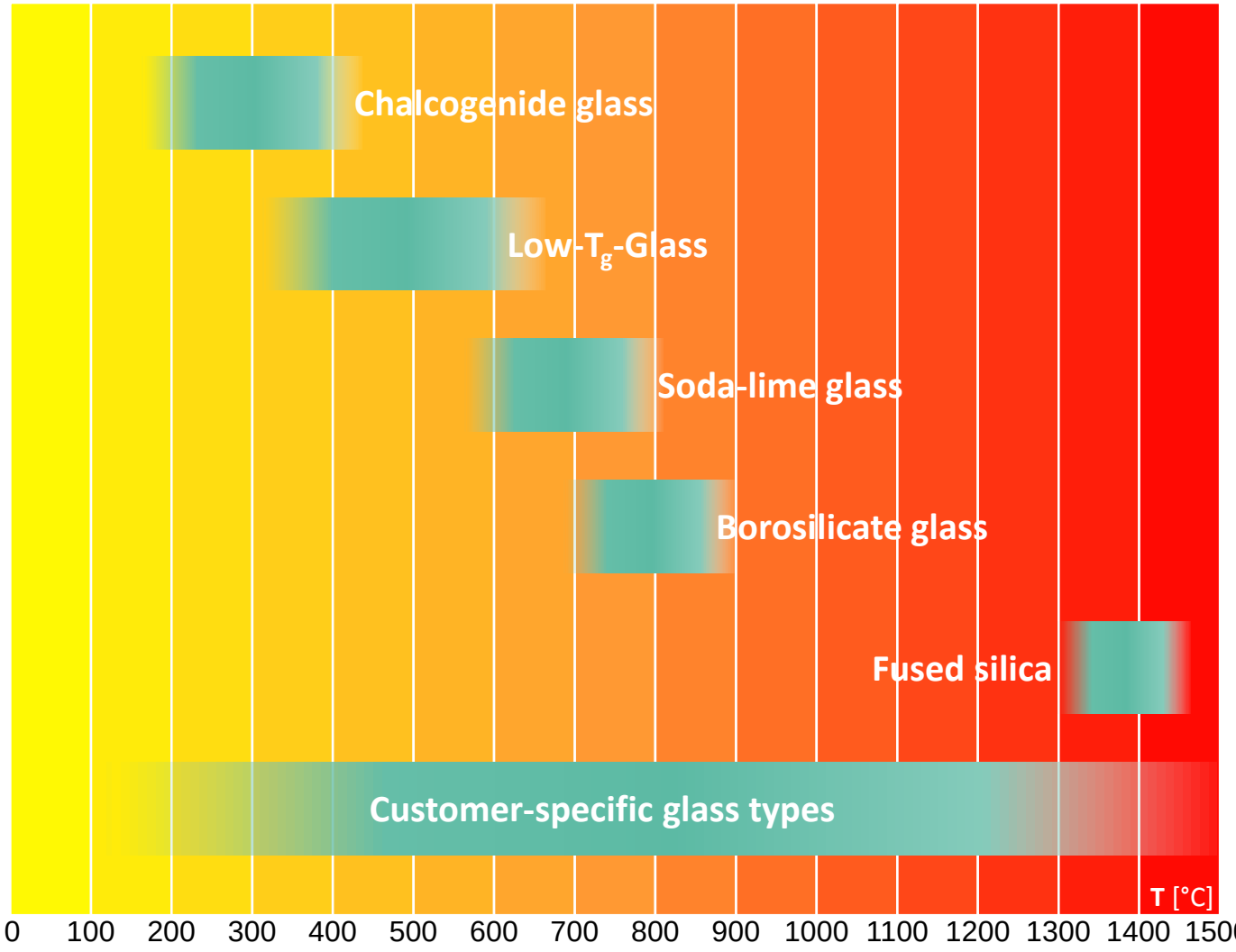
Precision Glass Molding

Glass Types and Molding temperatures





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Precision Glass Molding

Considering the entire Production Process Chain

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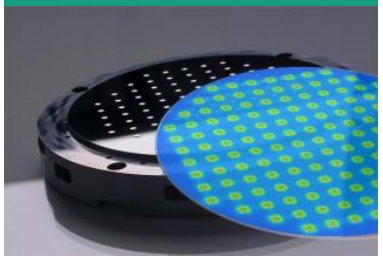
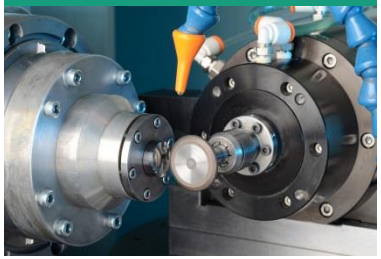
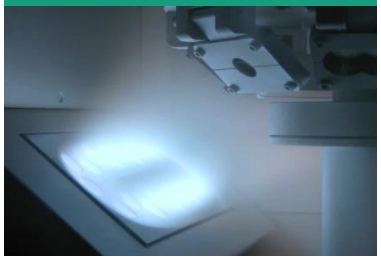
Simulation



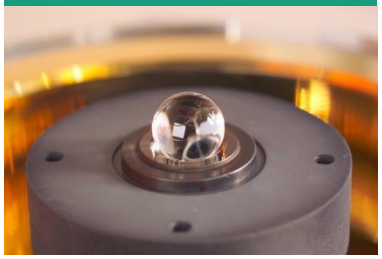
Tool Manufacturing



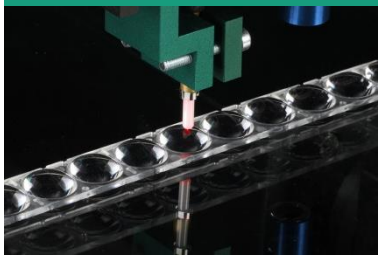
Coating



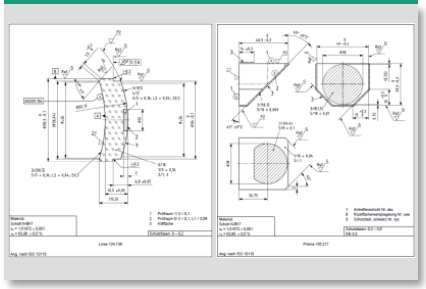
Molding



Metrology



Optical Design



»Based on your optical design we develop technologies for an efficient production of optical components«

»We cover the entire process chain from simulation to qualification of the optics«

Ready-to-use Optic

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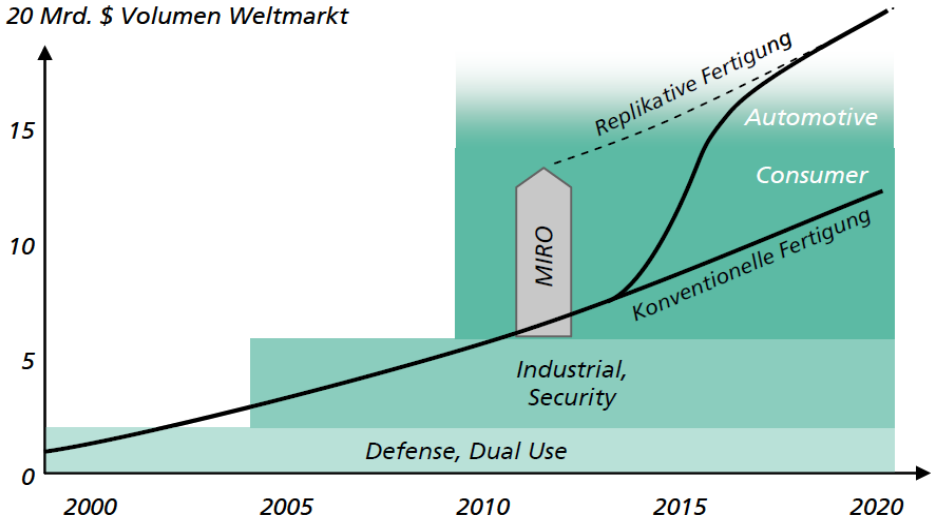
Precision Glass Molding
Project Overview »MIRO«

- Project target: “Mass production of infrared optics by means of Precision Glass Molding” – MIRO (BMBF V.I.P.)
- Approach:
  - Qualifying Precision Glass Molding of IR optics consisting of chalcogenide glass by using simulation and molding experiments
  - Development of wear protection coatings for mass production



- Results:
  - Validated FEM model for simulating glass molding of IR glasses
  - Qualified tool coating for mass production of IR optics
  - Novel wide angle IR optic as technology demonstrator

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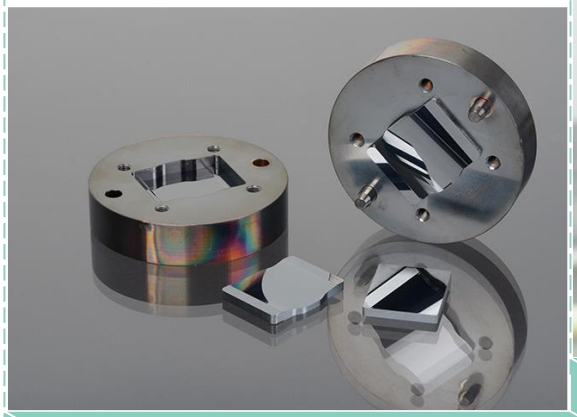
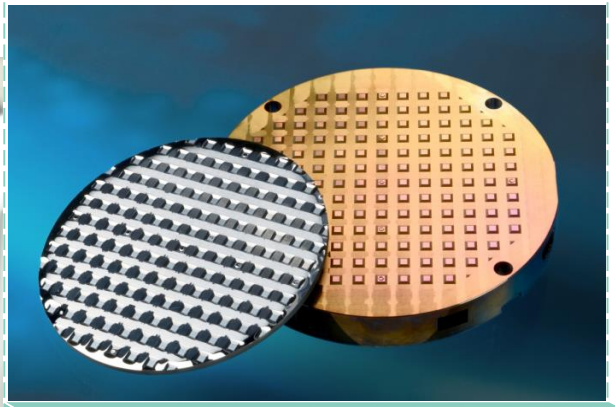
Project Overview »SKALIR« 2017 - 2020

- Project target: “Scalable replication of infrared lenses”
  - Cost reduction for precision molded infrared optics by a factor of 5 – 10 due to scalable mold concepts.

Single-Cavity	Multi-Cavity	Wafer Level
■ Complex geometries and large diameter lenses feasible	■ Rotational symmetric lenses smaller Ø20 mm	■ Lenses smaller Ø5 mm





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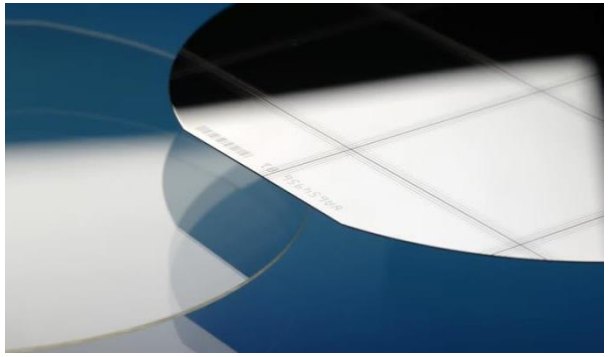
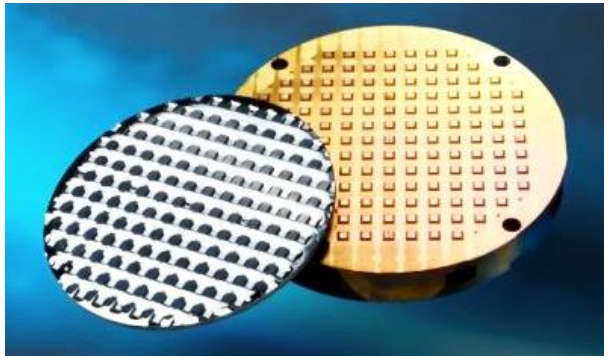
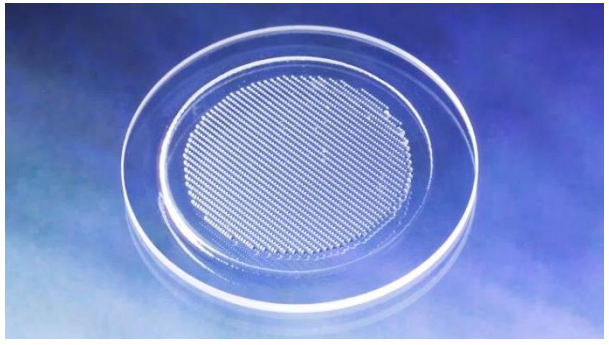
Project Overview »Wafer-Level Glass Molding«







- Project target: Precision Glass Molding of thin glass Wafers for various fields of application
  - Manufacturing of structured surfaces (e.g. arrays)
  - Durable bonding of glass and silicon in terms of encapsulating and isolating power electronics and MEMS
- Approach: Development of novel tool concepts for Wafer-Level Glass Molding
  - Focused on low form error and high parallelism
  - Qualifying tool materials and coatings to avoid glass adhesions
- Results:
  - Demonstrators of fully structured wafers and 3D-glass-silicon-compounds
  - Simulation model for Wafer-Level Glass Molding

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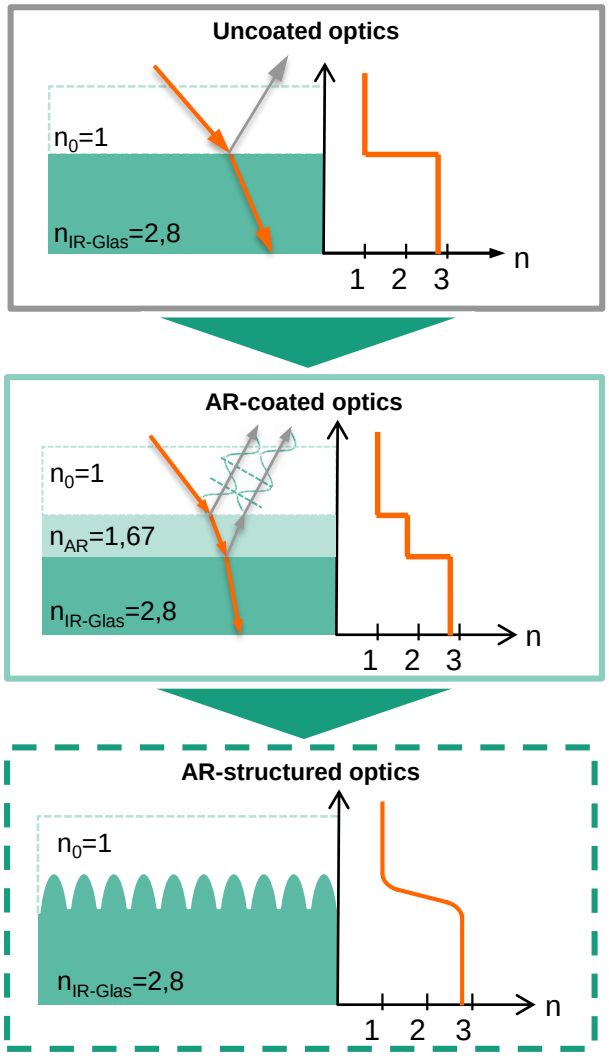
Project Overview »Anti-Reflection Surface Structures«



- Project target: Increasing the transmittance of molded chalcogenide glass optics in the infrared range
  - Cost- and energy-efficient production of highly transmissive IR optics
- Approach: Integrated molding of antireflective micro- and nanostructures by means of precision glass molding
  - Substitution of additional antireflective coatings by simultaneous moth-eye structuring
  - Reduction of reflections due to a smooth transition of the refractive index
- Results:
  - Process chain for the production of moth-eye structured optics
  - FEM model for molding AR structures
  - Demonstrators for typical applications in the IR range

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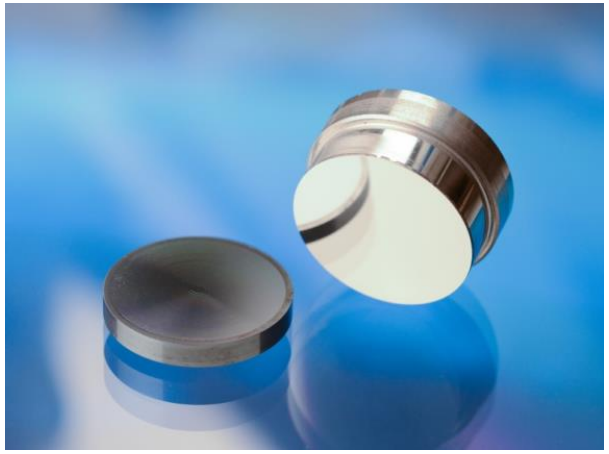
Project Overview »Technology Transfer«



- Project target: Technology Transfer in Precision Glass Molding
  - Integrating the technology into the manufacturing environment of the customer
  - Extension of manufacturing technology by complete transfer of the process chain
- Approach:
  - Workshops and training
  - Process development for demonstrator optics
    - Low-T_g glass asphere, diameter > 60 mm
    - Chalcogenide glass IR optic
- Results:
  - Successful transfer of the developed processes to the facilities
  - Support during ramp up phase for serial production
  - Assistance for measurement qualification

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Fraunhofer IPT‘s Precision Assembly and Automation Group

- Building of numerous prototype assemblies in our lab
  - Supporting the customers from idea over first prototype to consumer product
- Transfer production from lab environment to industrial level production
- 6 generations of assembly machines in the last years
  - e.g. fully automated DOE Assembly Turn-Key solution in the field
  - 30s-60s cycle time, 24/7 production
- Contract manufacturing for optical systems in mid-volumes
- OEM components in automotive industry: Over 800.000 assembled automotive driving assistance cameras with Fraunhofer IPT Micro Manipulator Technology
- Commercialized through spin-off company Aixemtec GmbH

➢ Our enabler is the know-how in assembly of optical systems combined with industrial automation

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Our enabler is our reconfigurable precision assembly machine

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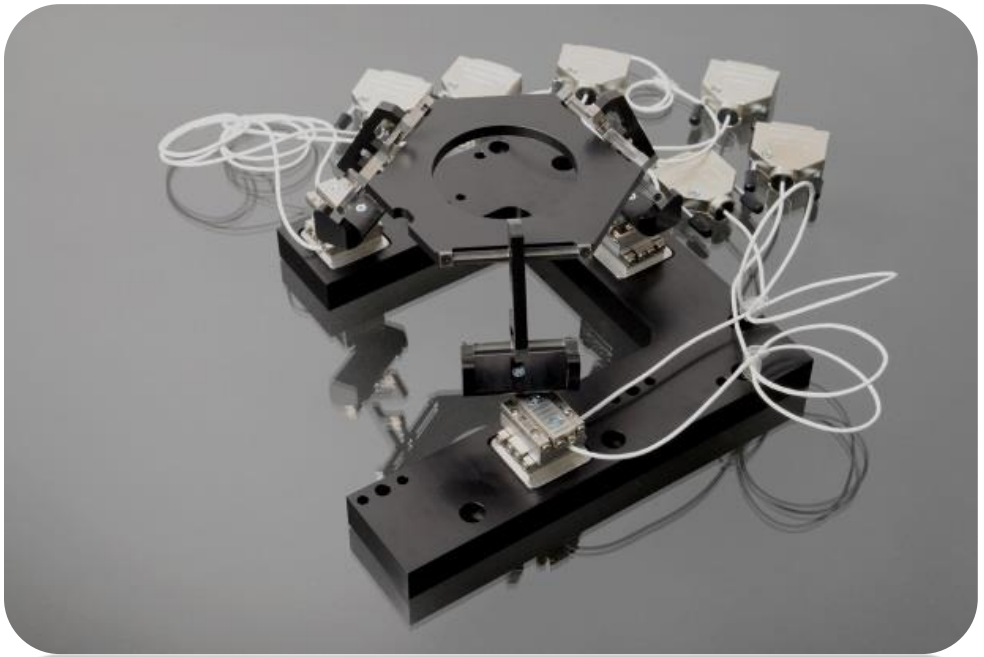
Key Component Micro Manipulator Commander6

- 6 degrees of freedom
- Step resolution
  - 10 nm (X, Y, Z)
  - 5 µrad (Ψ, Θ, Φ)
- Since 2014: Assembly of 800.000 automotive driving assistance cameras



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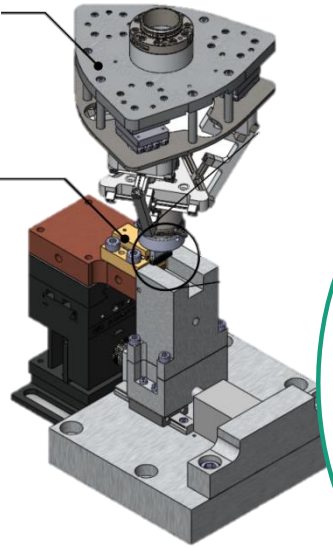
Precision limitations of individual process building blocks

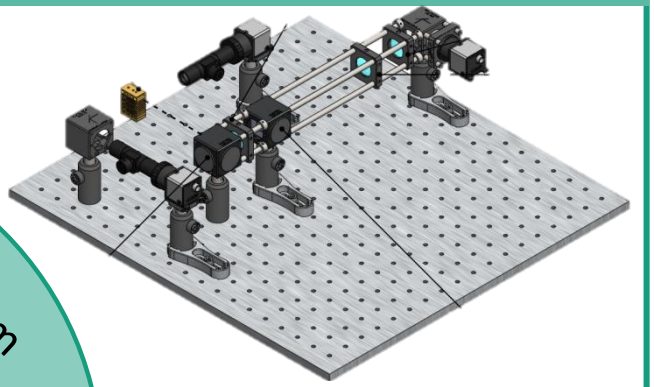
Handling & Micro Manipulation

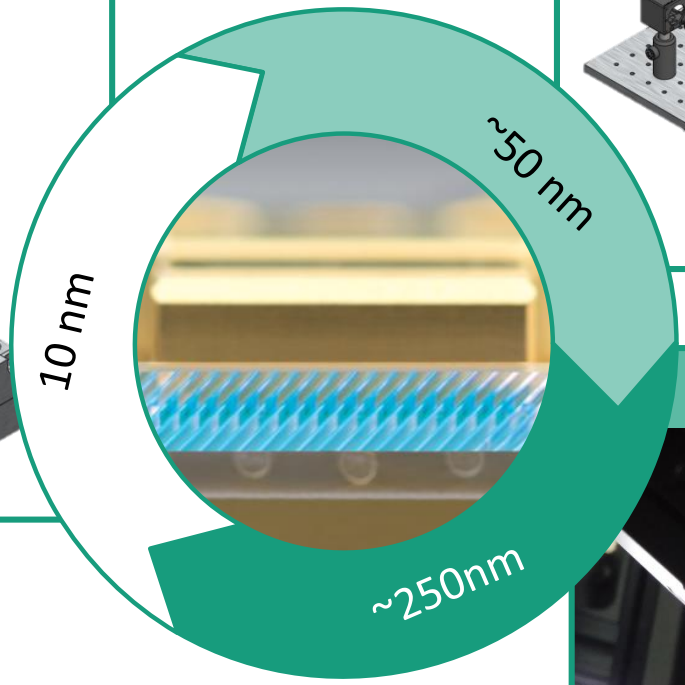
Commander 6

Diode laser

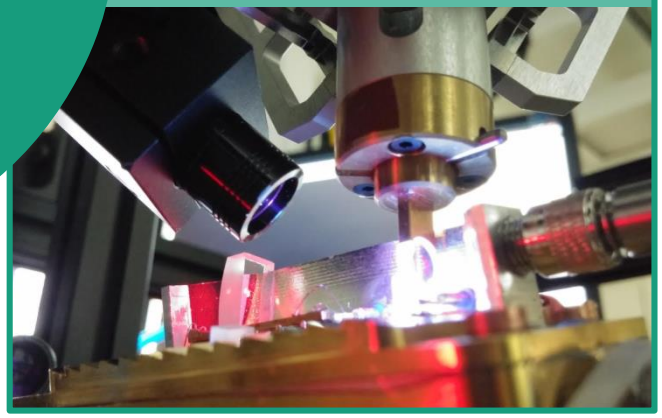


Metrology





Bonding



- UV-curing bonding is the quality limiting process step

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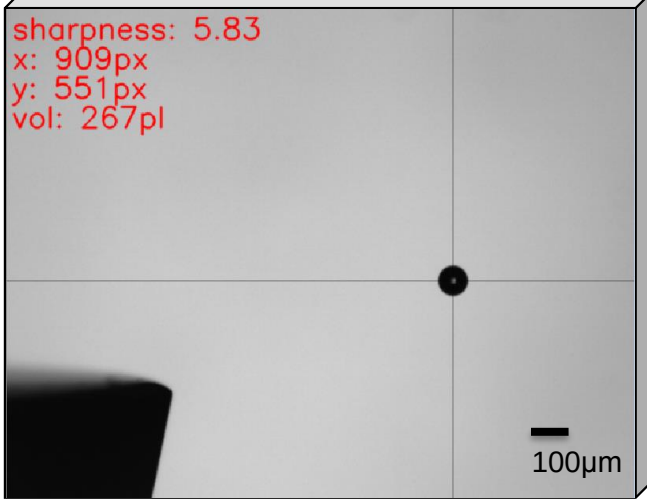
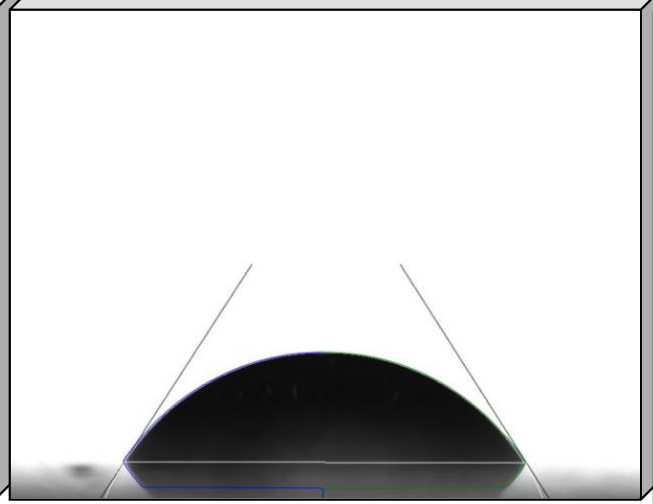
Robust and automated precision adhesive bonding

Core processes for robust precision adhesive bonding

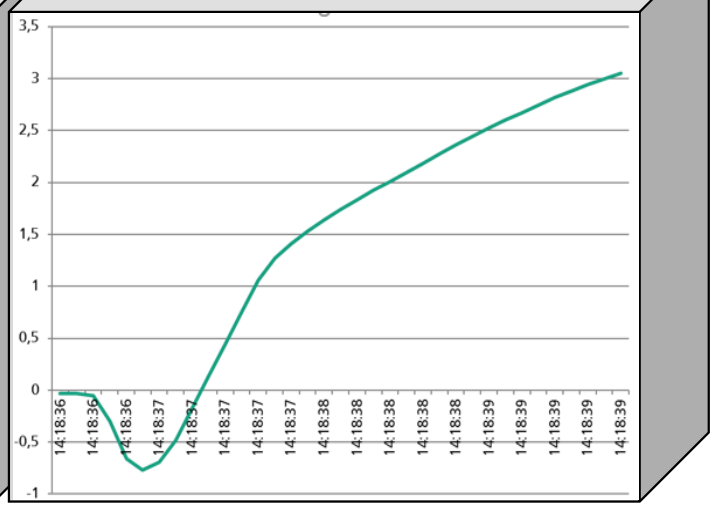
Precision dispensing



Shrinkage measurement



Defined UV-curing



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Precision dispensing – standard solution commercially availlable

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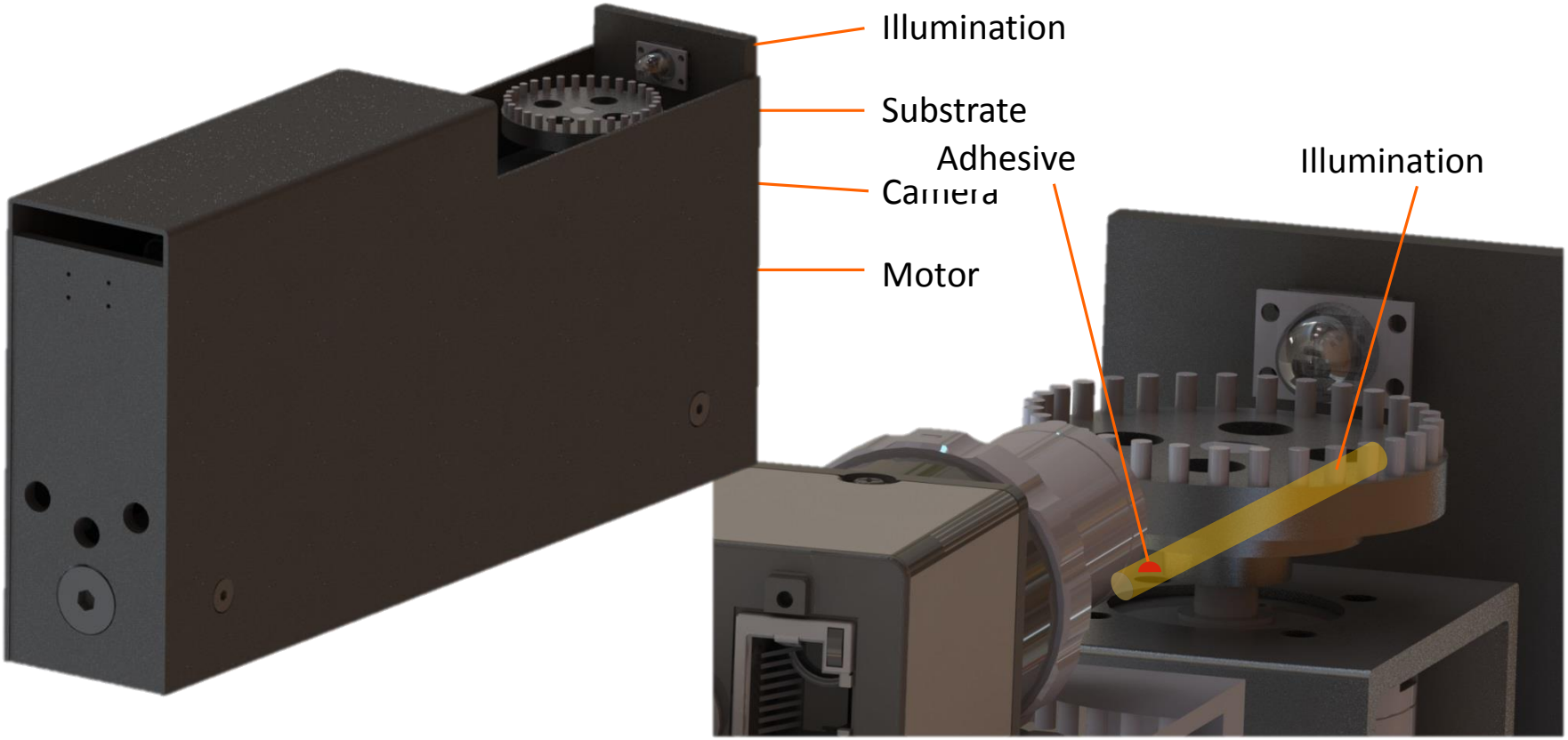
Shrinkage characterization



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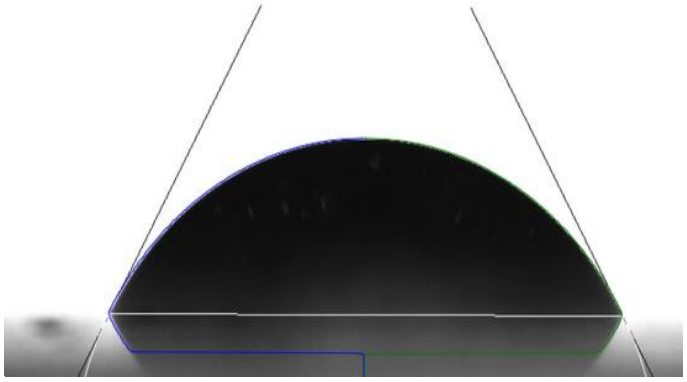
Shrinkage characterization

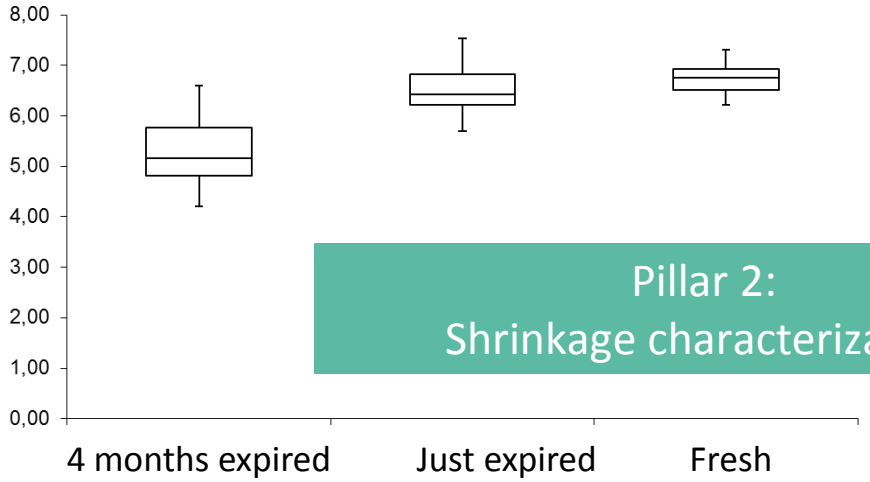
Drop-shape analysis (DSA)

- Detection of contact angles before and after curing
- Calculation of volumetric shrinkage
- Qualification of adhesives
- Comparison of different adhesives through standardizes measurement



Exemplary measurements:

- Same adhesive at three ages
  - Adhesive degenerates
  - Reproducibility declines
  - Process robustness decreases



Pillar 2:
Shrinkage characterization

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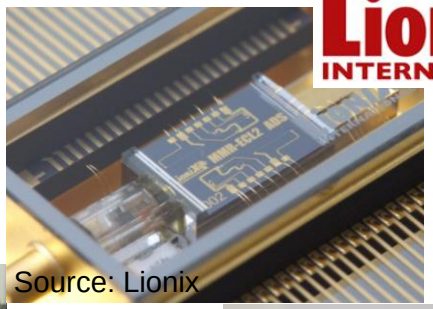
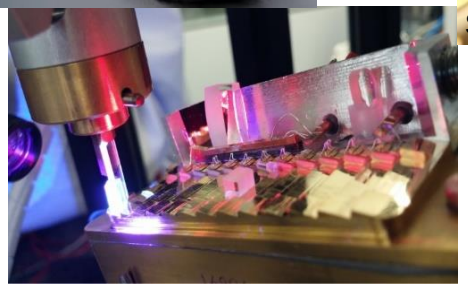
Precision Assembly

Recent and ongoing projects from various fields of applications

- Silicon Photonics
  - Chip Testing
  - Fiber assembly
  - Chip coupling
- Lasersystems
  - Active alignment of FAC-lenses
- Automotive applications
  - Headlight systems
  - LiDAR systems
  - Driving assistance cameras
- Imaging systems
  - Endoscopes
  - Camera lens (Lens-Barrel)
  - Single lenses in ring
- Consumer electronics
  - Gesture recognition
- Related topics
  - Microfluidic systems
  - Roll-to-Roll

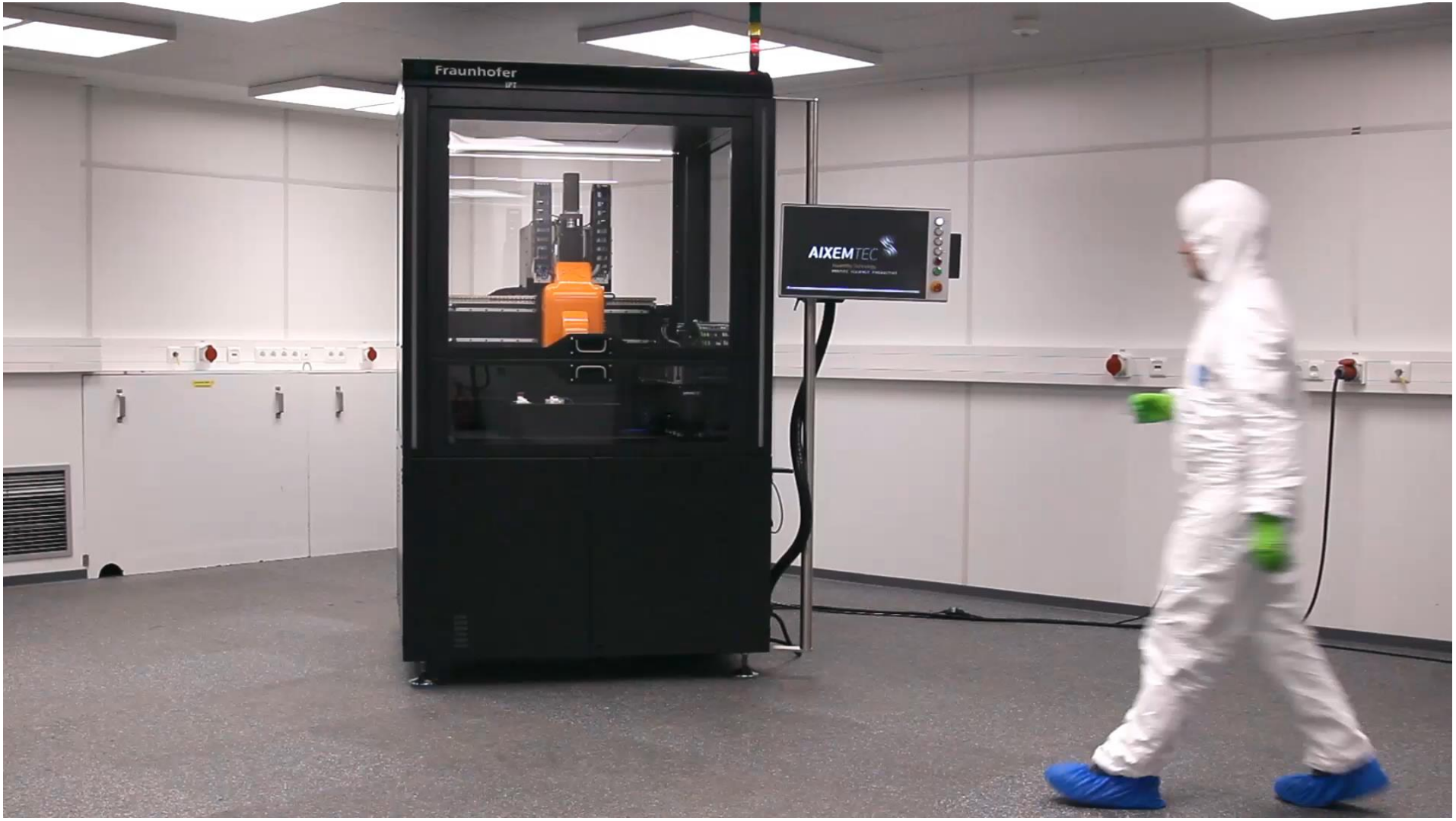
Source: IBEO


Source: Lionix



Prototyping	Small Series	Volume Production
Fraunhofer IPT	AIXEMTEC	phix PHOTONICS ASSEMBLY

Active alignment machine for PM-Fiber systems



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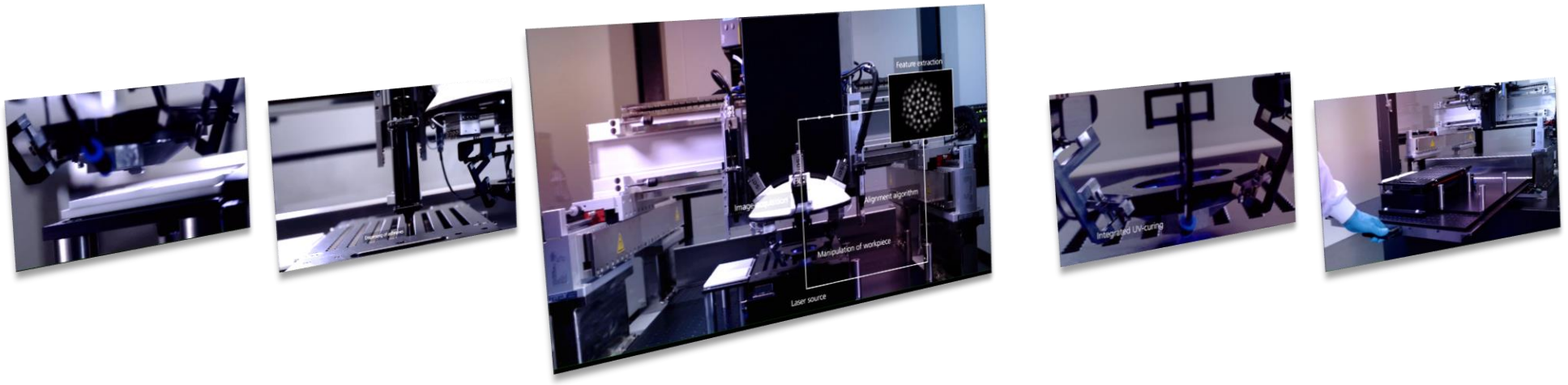
Process steps overview



feeding → adhesive application → focus alignment → pre alignment → feature alignment → shrinkage offset → curing → discharge

30 seconds per module – 2 hours autonomous production – 2 minutes loading time

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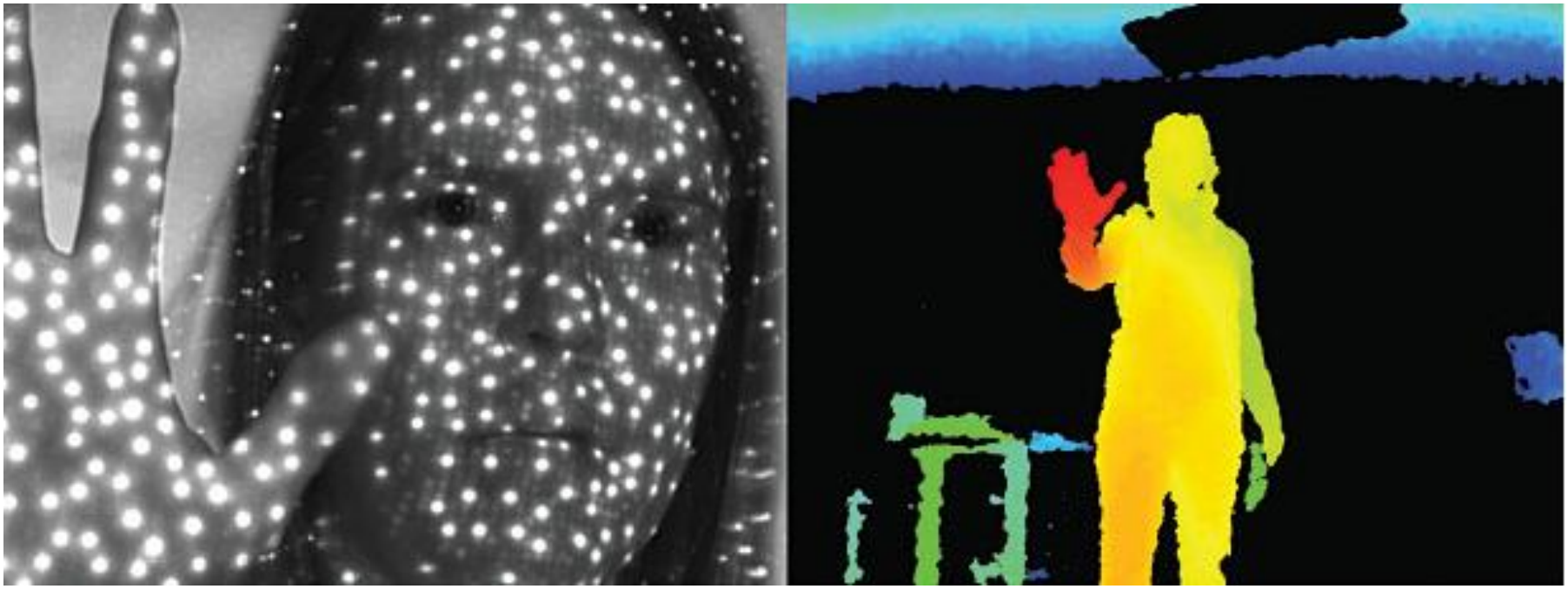
Active alignment for the tolerance compensation in DOE Assembly

Automated Assembly of structured light emitter for gesture recognition

- Core component for gesture recognition
- Assembly of large projection angly systems (Projectionangle >80°)
- Sample applications Microsoft Kinect, Google Glass



Quelle: http://www.qualitymag.com/articles/91010--d-imaging-enters-the-machine-vision-world

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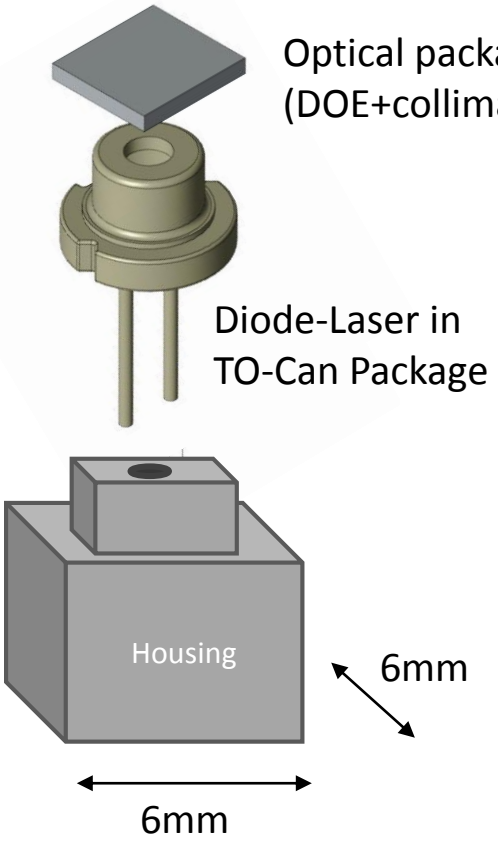
Active alignment for the tolerance compensation in DOE Assembly



Product design and assembly challenges of structured light emitter

- Projector consist basically of 3 elements: DOE+Collimator
- Large tolerances of the single components make active alignment necessary – major tolerances are:
  - Laser position within TO-Can Package
  - Manufacturing tolerances of housing
  - Assembly tolerances between housing and TO-Can package
- Overall tolerances lead to glue gap of > 200 µm
- Position requirements of the DOE < 1 µm
- Correction of 6 degrees of freedom
- Shrinkage compensation of adhesive required

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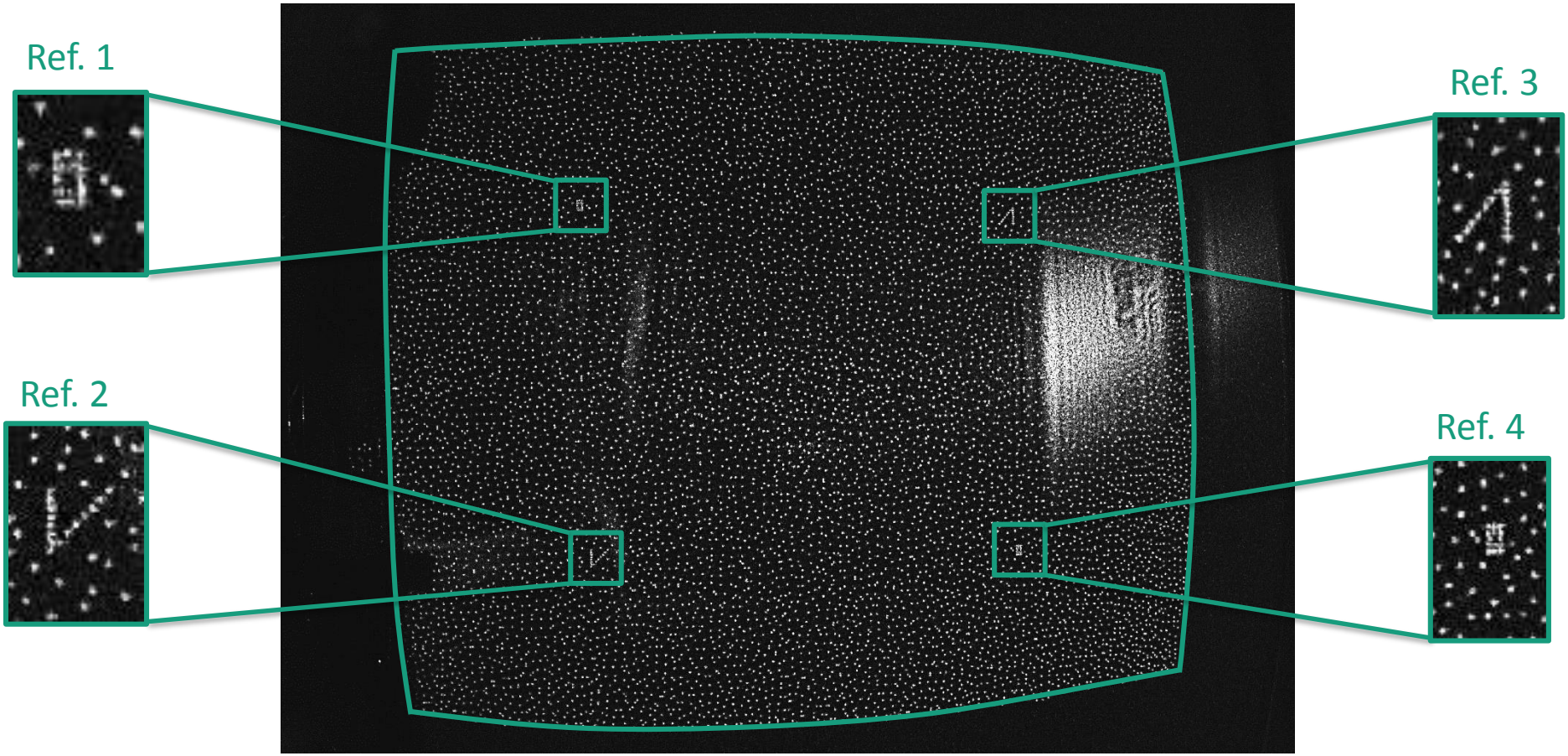
Precision measurement system, SotA: Measurement on a screen



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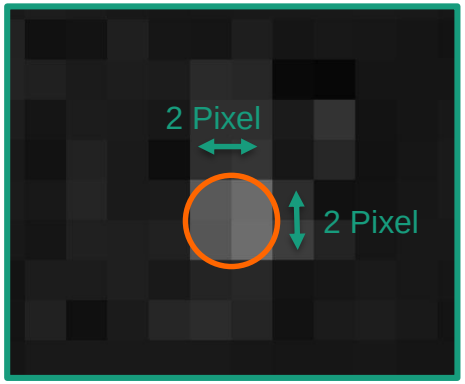
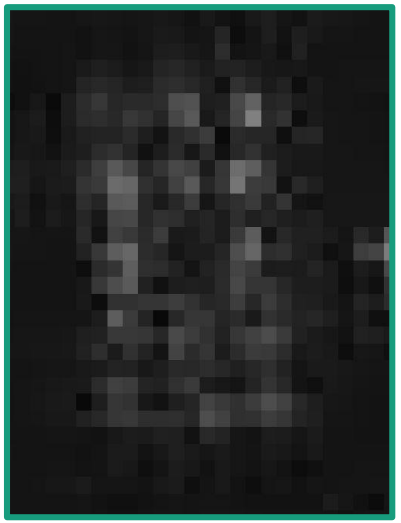
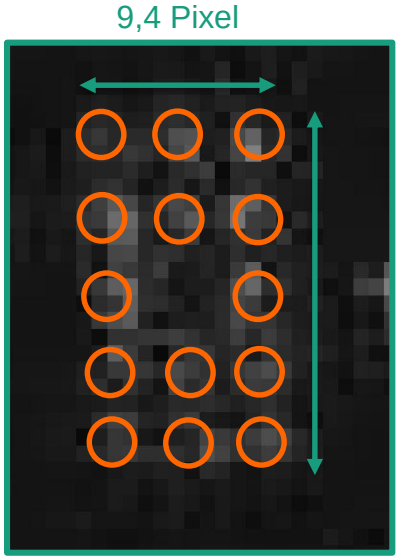
Resolution of single spots on a screen







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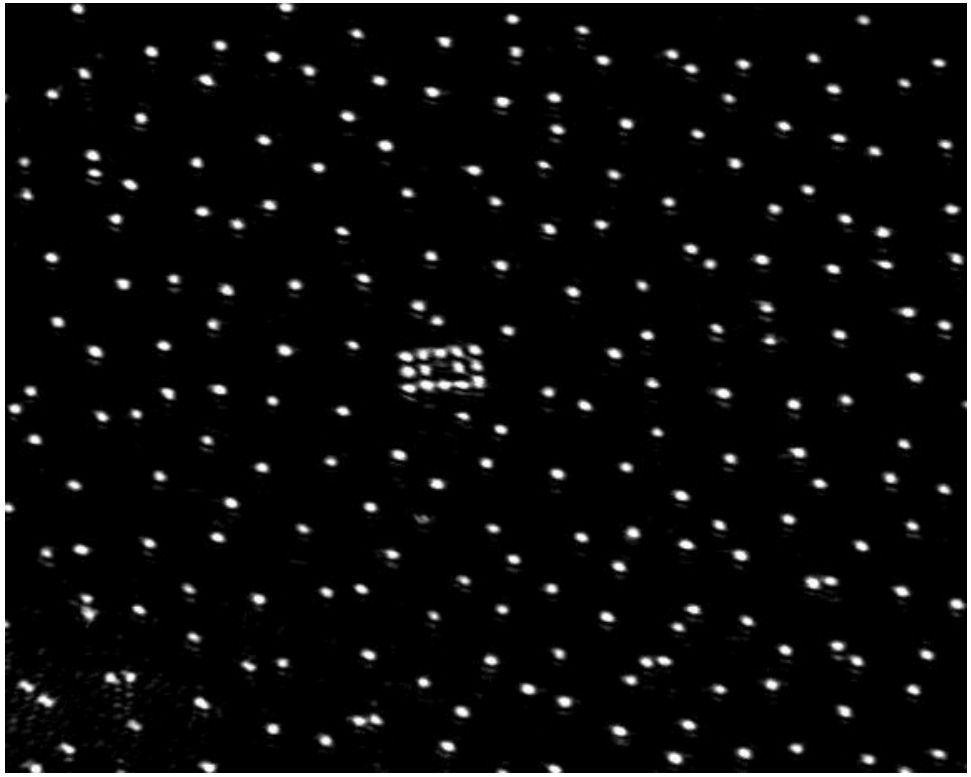
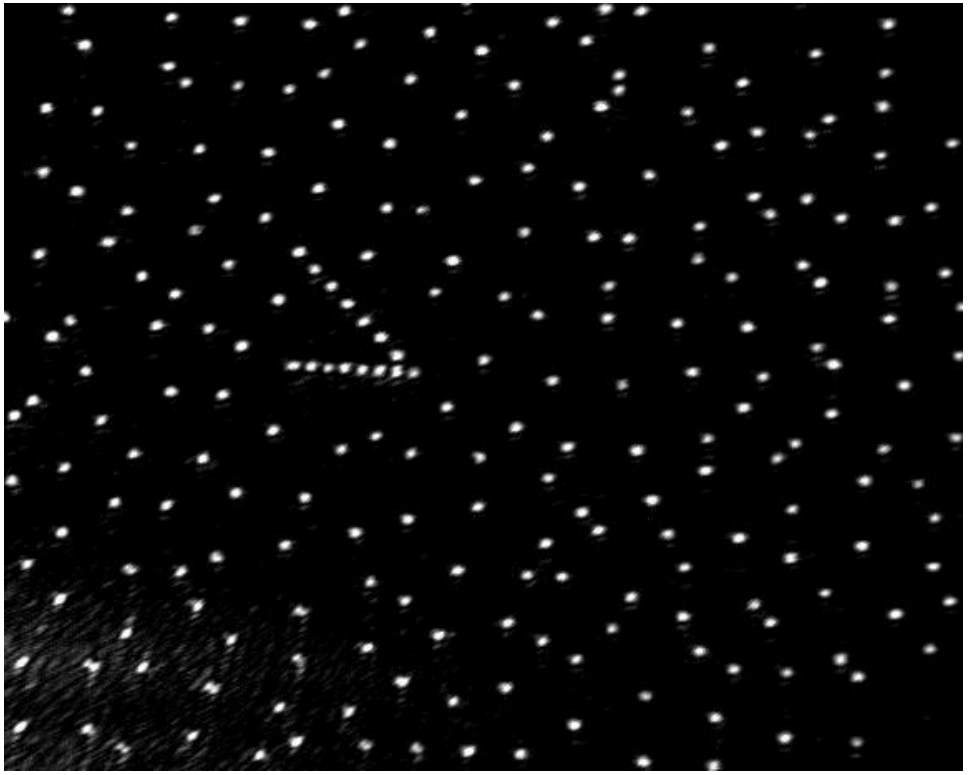
Imaging section of whole FOV resulting in a higher resolution (x10!)

Camera Image



Camera Image



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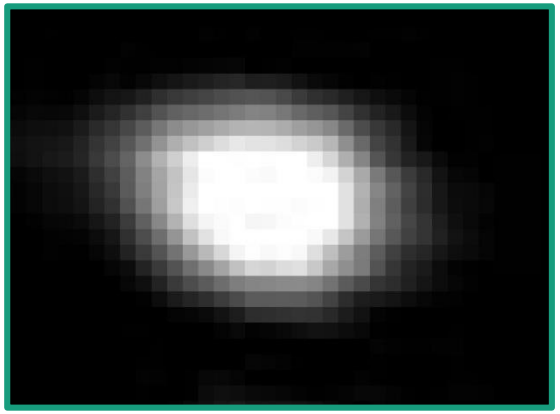
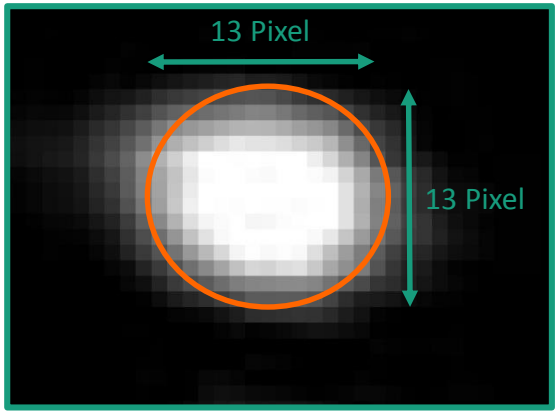
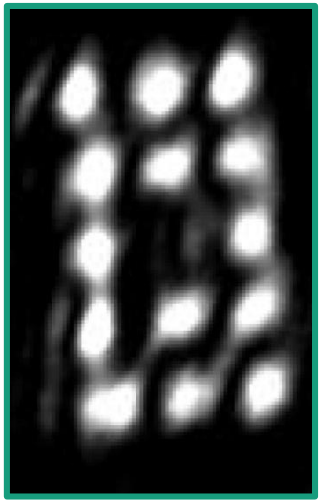
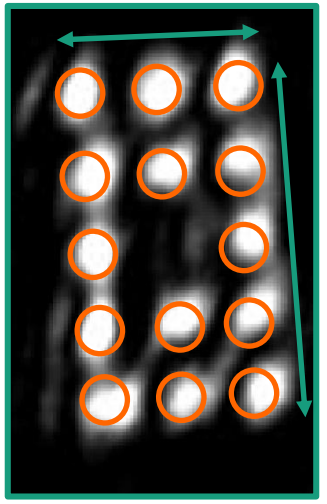
Sample measurement of 2 mm spots with our measurement system









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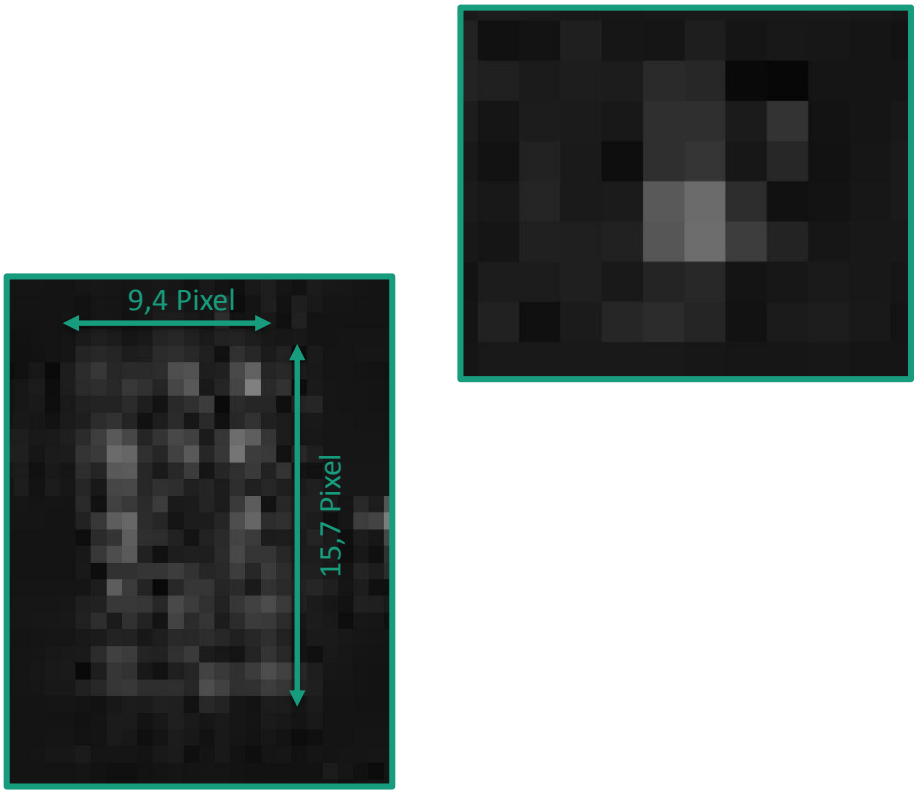
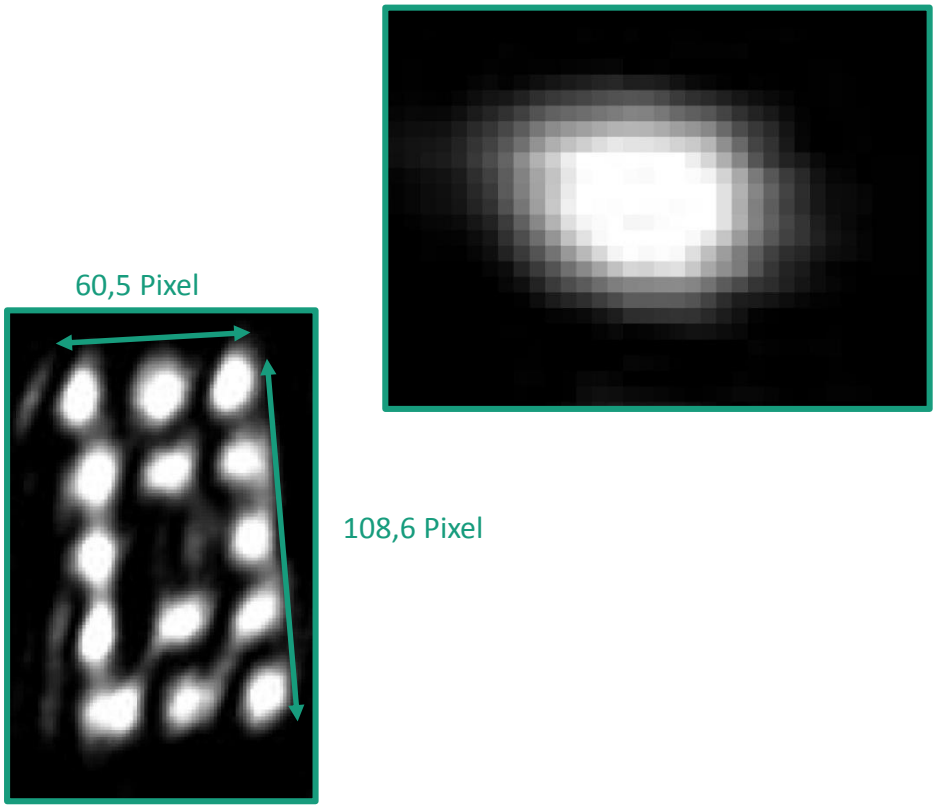
Comparison: State of the art vs. IPT measurement system

State of the art: Screen system



High resolution Fraunhofer IPT system



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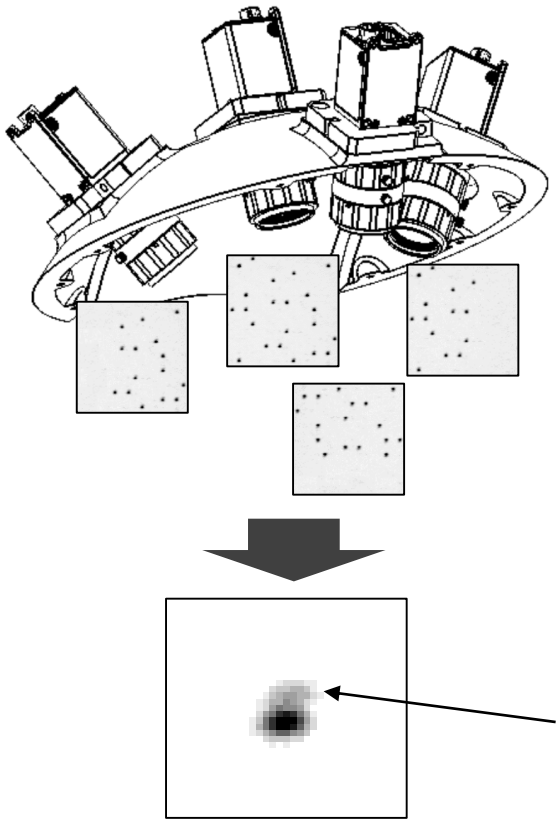
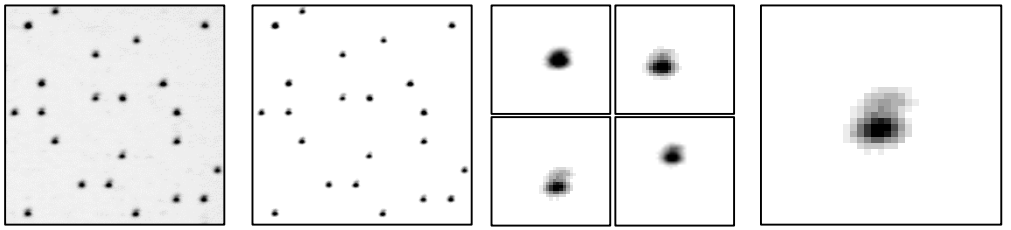
Basic information on the measurem. system and alignment algorithm



- Integration of measurement system into micromanipulttor
- Basis for feature description: average spot appearance



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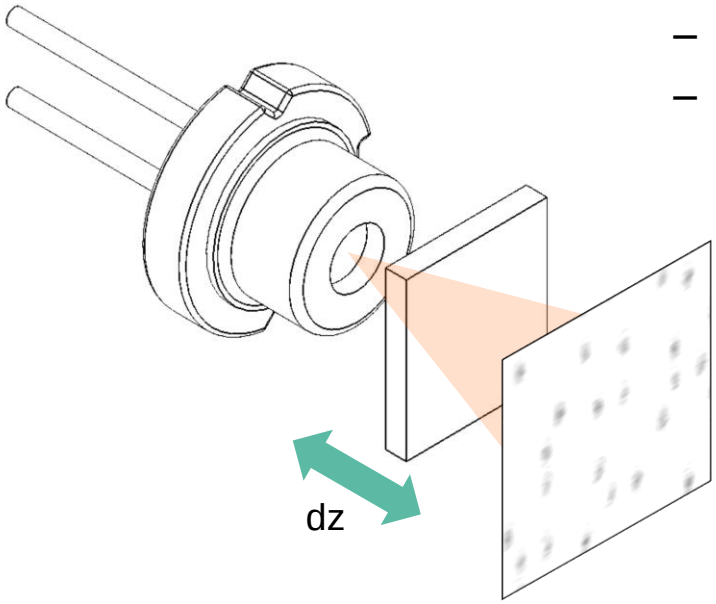
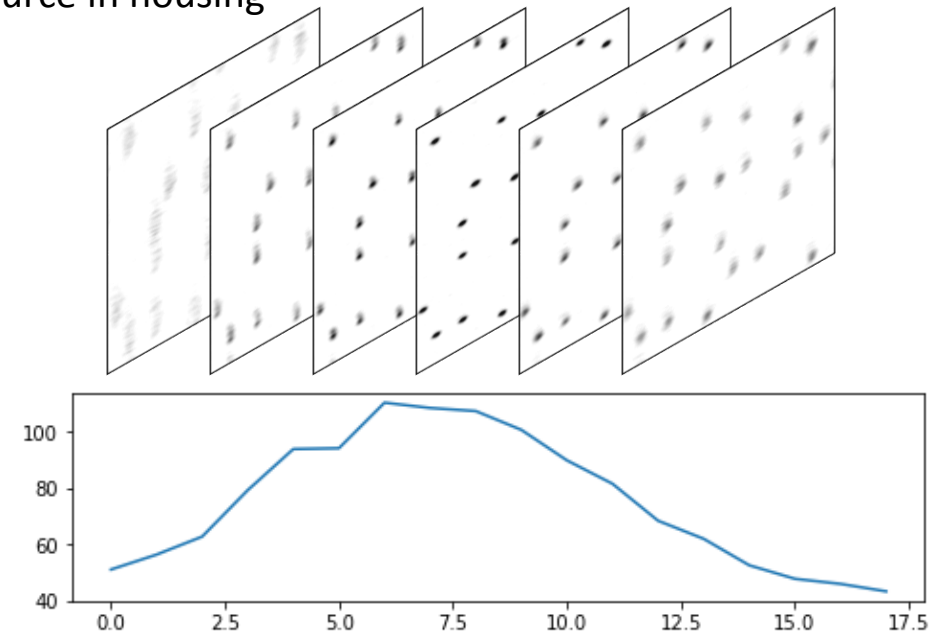
SPIE LASE 10085-33: Focus alignment

- Active focus alignment compensates tolerances from upstream processes
  - Laser source in housing
  - TO-Can





focus function

feeding | adhesive application | **focus alignment** | pre alignment | feature alignment | shrinkage offset | curing | discharge

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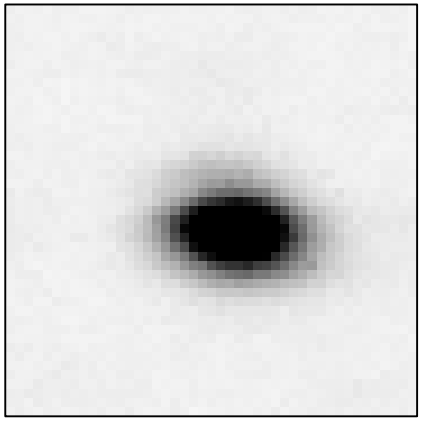
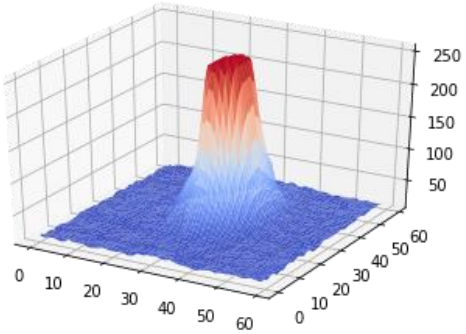
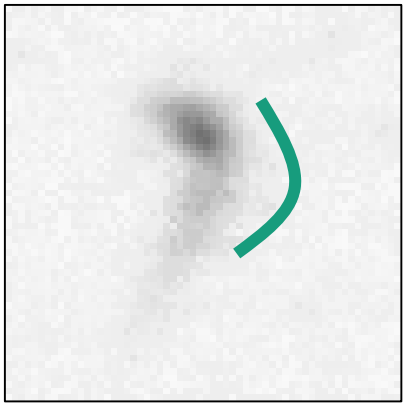
Feature alignment: Misalignment effects



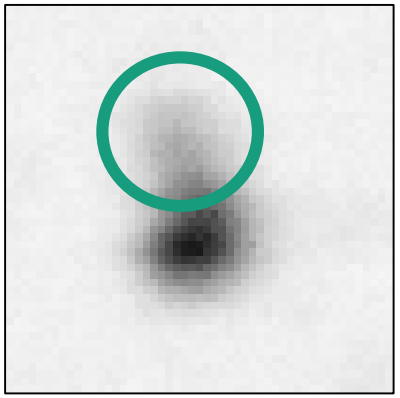
optimal spot appearance



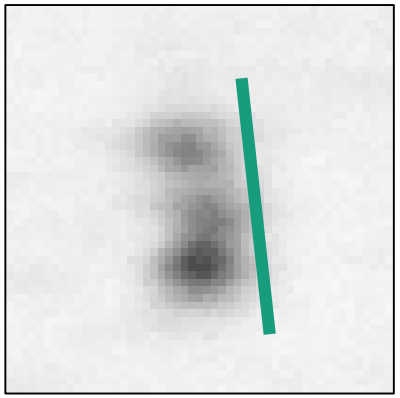
intensity distribution



sickle: dy



shift: dx



angle: rz

feeding | adhesive application | focus alignment | pre alignment | **feature alignment** | shrinkage offset | curing | discharge

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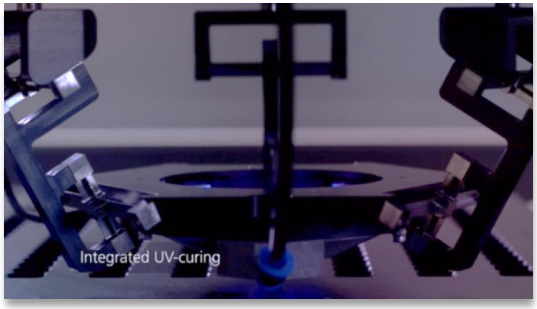
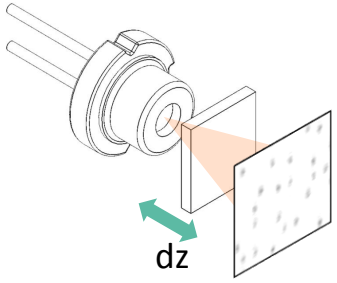
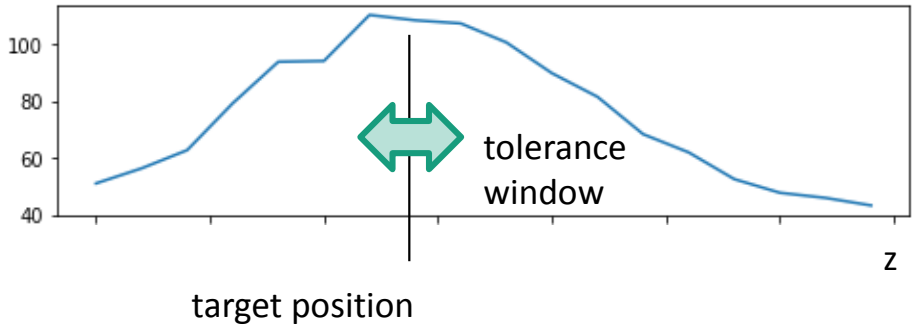
Shrinkage compensation to secure alignment result



- Shrinkage compensation strategy:
  Statistical process control
  - Shrinkage quantifiable due to focus evaluation.

Focus quantified and mapped during focus alignment





target position

feeding | adhesive application | focus alignment | pre alignment | feature alignment | **shrinkage offset** | curing | discharge

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Outlook – How can we get started?

Three Stages of successfull launch of new products

Stage 1

Product development consulting
Design for manufacturing/assembly
Prototyping and feasibility studies

Stage 2

Contract manufacturing for mid-volume
Production for developer kits

Stage 3

Commercialization e.g. through our spin-offs

aix tooling | sonox | INGENERIC
fionec fiber optic sensor technologies | AIXEMTEC Assembly Technology | INNOLITE

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