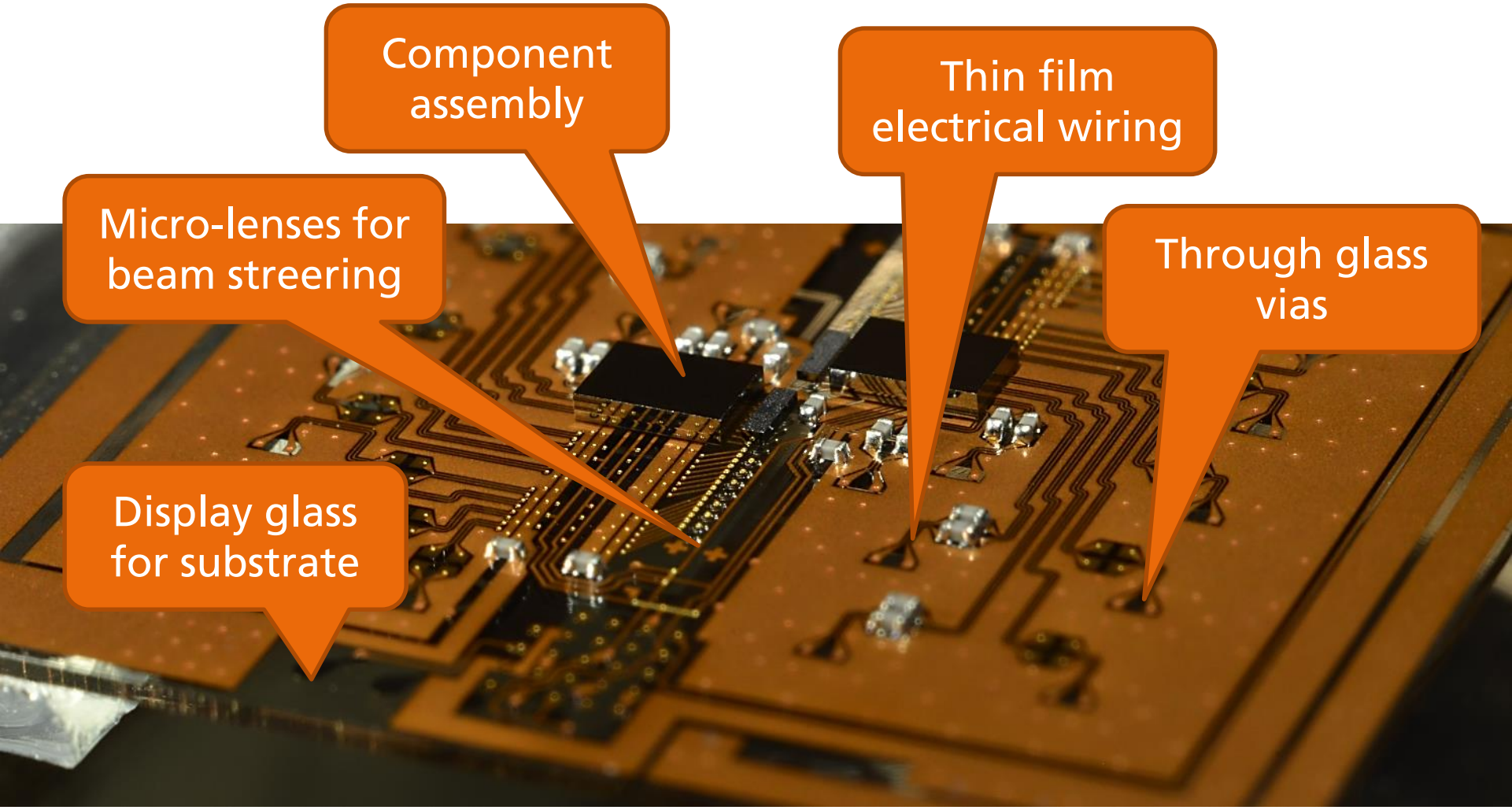
Photonic Packaging @ Fraunhofer IZM

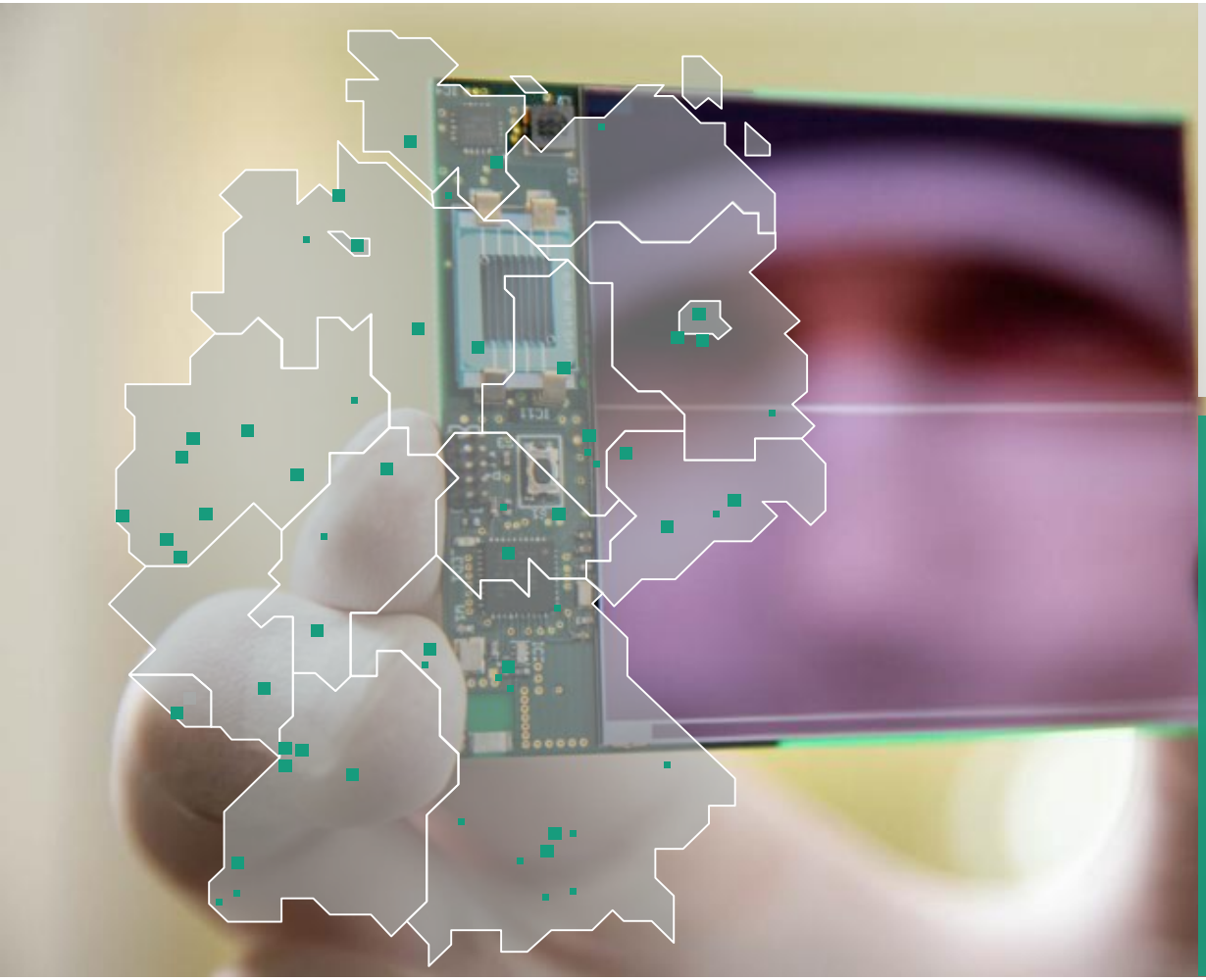


Name: Dirk Friebel, Dr. Henning Schröder

© Fraunhofer IZM

Fraunhofer IZM

Overview Fraunhofer Gesellschaft

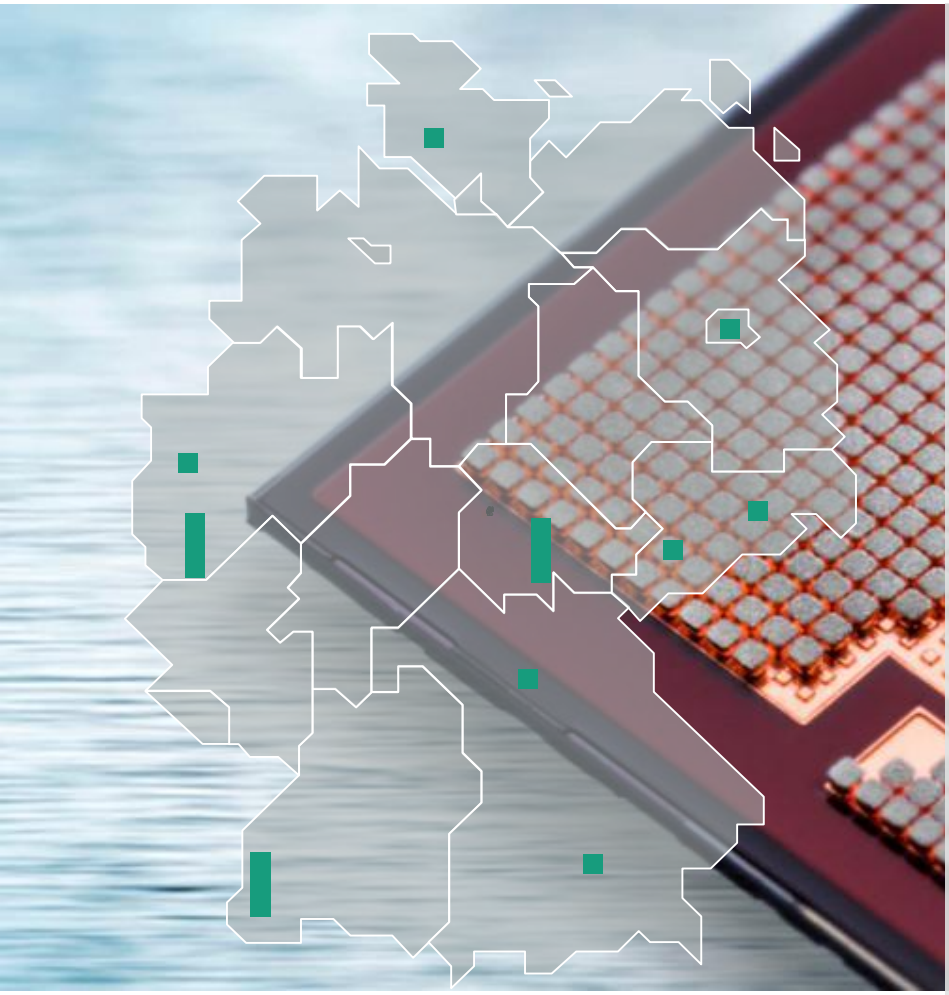


- 72 institutes
- 24,500 employees
- app. 2.1 billion € turnover
- More than 70% contract research

- Information Technology
- Light & Surfaces
- Life Sciences
- Microelectronics
- Production
- Defense & Security
- Materials & Components

Fraunhofer IZM

Overview Fraunhofer Group Microelectronics



Organization

- 18 institutes – 3,000 employees – 381 Mio € budget (2016)
  - More than 50% industrial contracts
  - 20% basic funding
  - 30% public projects / other revenues

Competencies:

Systems - Components - Technologies

Business Fields

- Ambient Assisted Living, Health & Well-being
- Energy Efficient Systems
- Mobility & Urbanization
- Smart Living

Fraunhofer IZM

Fraunhofer IZM – Facts

Figures 2017

- 30.2 Mio. € turnover
- 83 % contract research
- 388 employees
  (233 full time, 146 students, PhD, trainee)

Locations

- Berlin
- Dresden

Director

Prof. K.-D. Lang

University Cooperation

- Long-term contract with Technical University of Berlin
- Research Center Microperipheric Technologies
- Approx. 90 additional staff
- Joint use of equipment, facilities and infrastructure

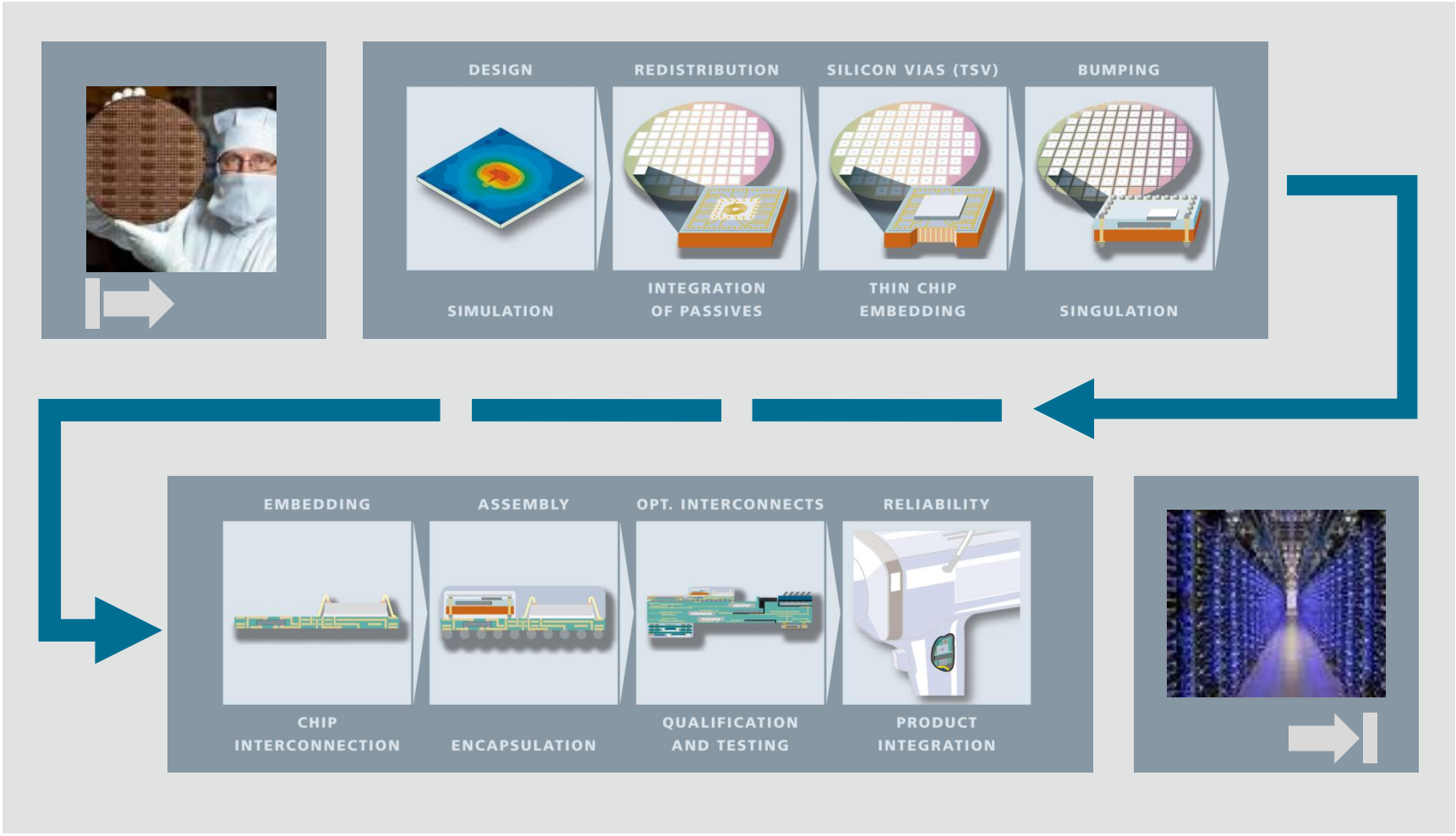
- Material characterization
- Process evaluation
- Reliability testing
- Failure analysis
- Sample production
- Training courses

© Fraunhofer IZM

Technische Universität Berlin

Fraunhofer IZM

Mission Fraunhofer IZM
Bringing microelectronics and photonics into application



© Fraunhofer IZM

Technische Universität Berlin

Fraunhofer IZM

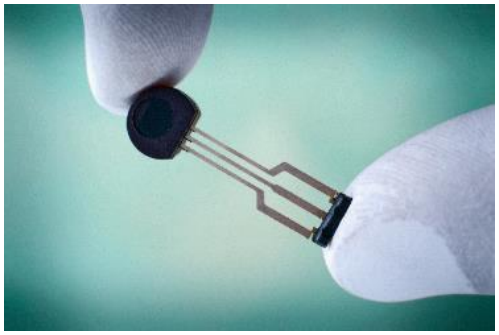
CORE COMPETENCIES

© Fraunhofer IZM

Technische Universität Berlin

Fraunhofer IZM

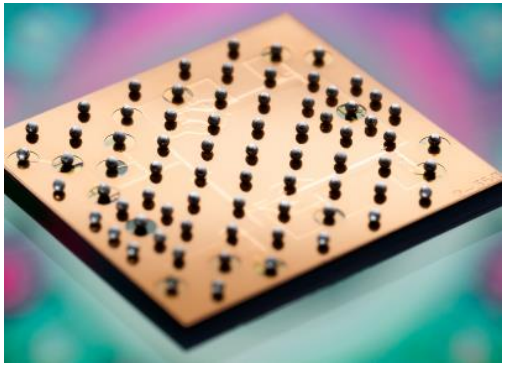
Technology Strategy: From Focus Chip Packaging. .



Specific Component Packaging

e.g. MEMS, Silicon Photonics, Sensors, Battery,...

. . towards System in Package



Advanced Assembly and Packaging

e.g. Embedding, DIE-Stacking, TSV, RDL, …

© Fraunhofer IZM

Application Strategy: From Microsystem Technology . .

Reference processes ready for industrialization

e.g. Fan-out Wafer and Panel Level Packaging with double sided redistribution layer and through-X-vias

. . towards Smart System Integration

Cyber Physical Systems

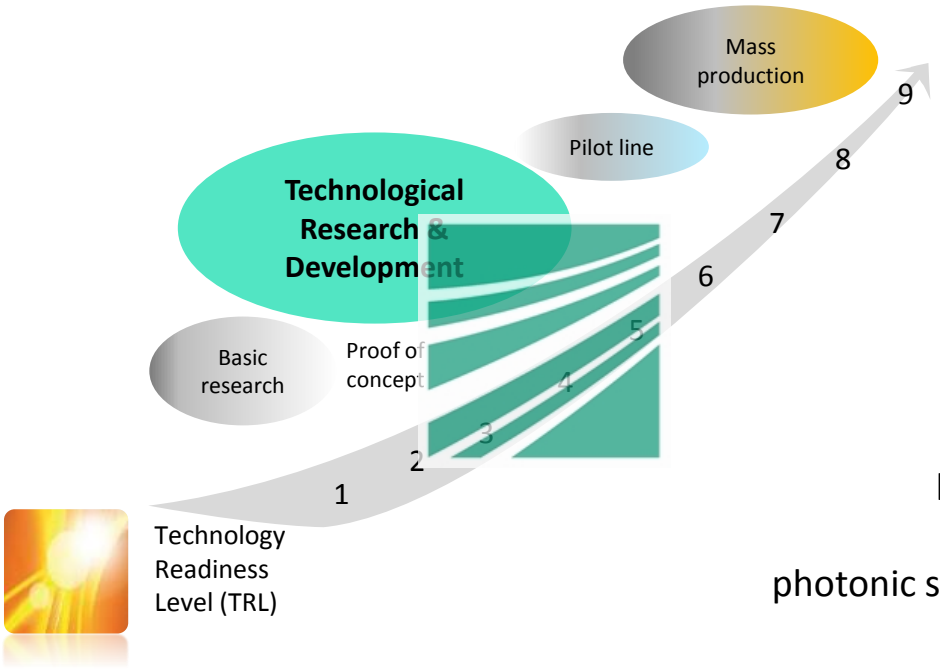
e.g. Smart system and smart sensor modules for connecting physical and digital world (sensing, processing storage and communication)

© Fraunhofer IZM

Technische Universität Berlin

Fraunhofer IZM

Fraunhofer IZM: Bringing photonics into application



- Communication
- Sensoring
- Lighting
- Quantumtechnology

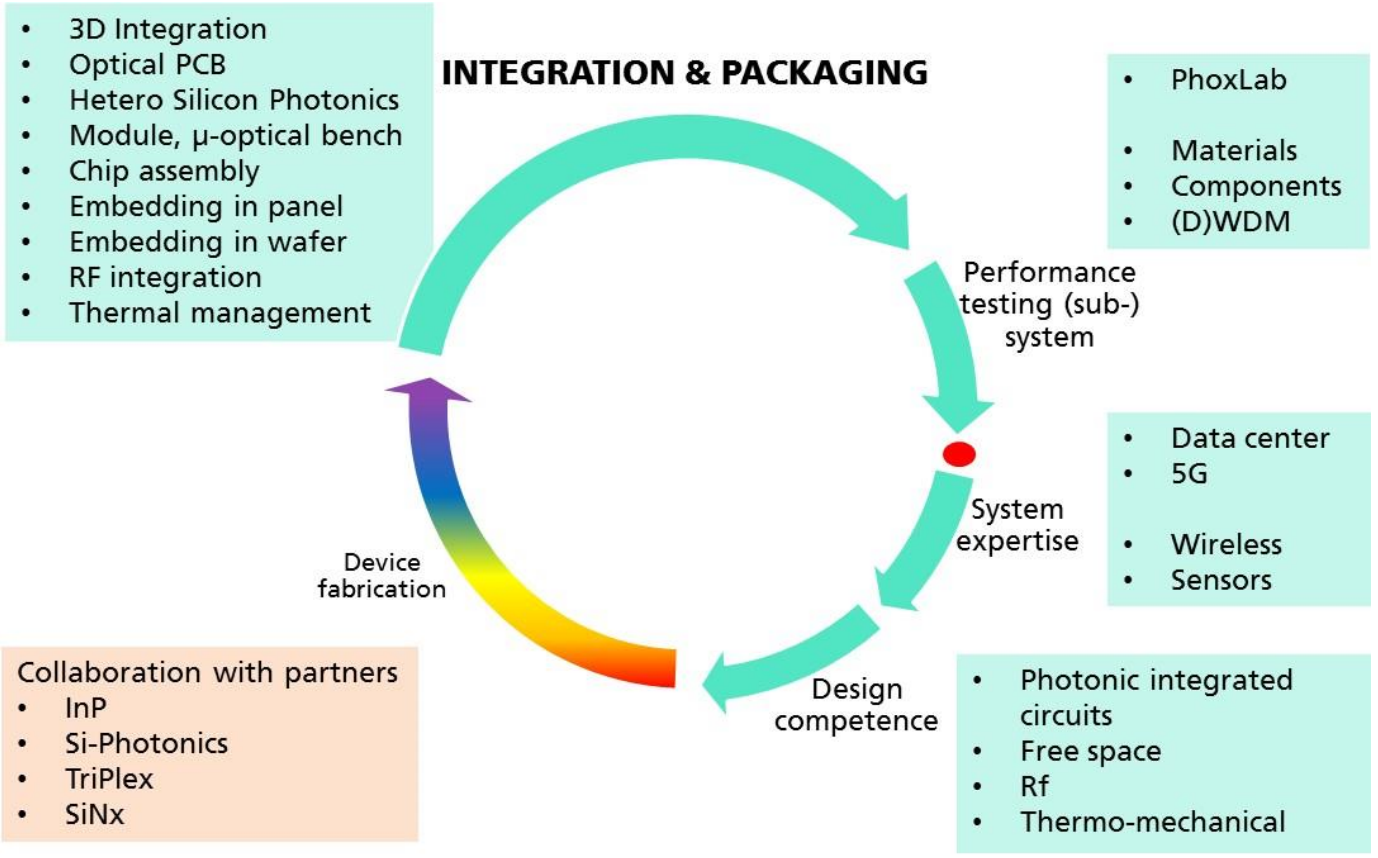
low cost,
high performance
high volume
photonic system integration
in
panel & wafer level

© Fraunhofer IZM

Technische Universität Berlin

Fraunhofer IZM

Photonics value chain addressed at Fraunhofer IZM

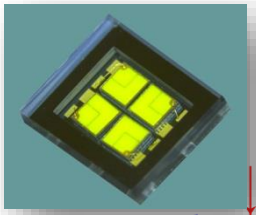


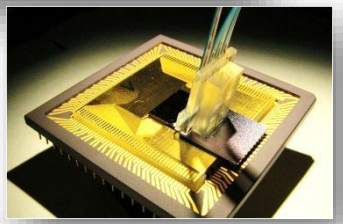
© Fraunhofer IZM

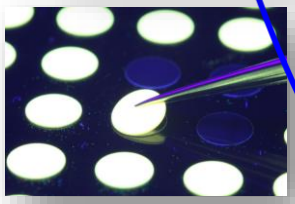
Technische Universität Berlin

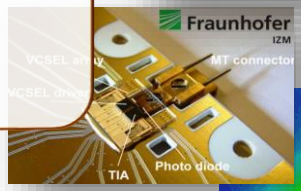
Fraunhofer IZM

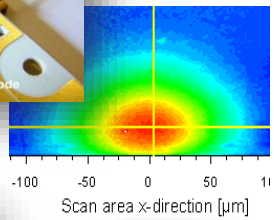
Photonik Packaging at Fraunhofer IZM

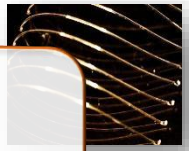


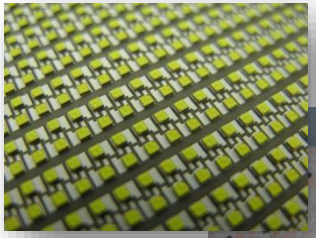


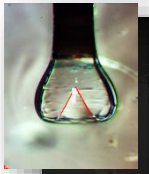












- Module design and assembly for LED light sources
- Secondary optics design/prototyping
- Color conversion
- Thermal Design and Analysis
- Failure Analysis

Lighting

Tele-/Datacom

- Design for packaging
- Automation for microoptics and Fiber assembly
- EOCB large panel integration
- glassPack o/e interposer
- Silicon Photonics design/integration
- HF up to 25 Gbit/s

Material Processing

- Power/Thermal management
- High Temperature Interconnection
- Beam shaping optics

Sensors

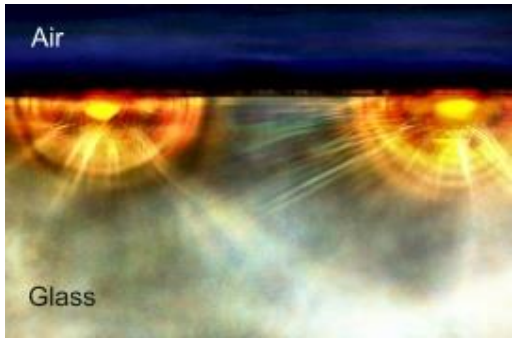
- Optical system design
- Prototyping
- System Test
- glassPack opto-fluidics
- Optical therapy heads
- Automated optical interconnect bonding

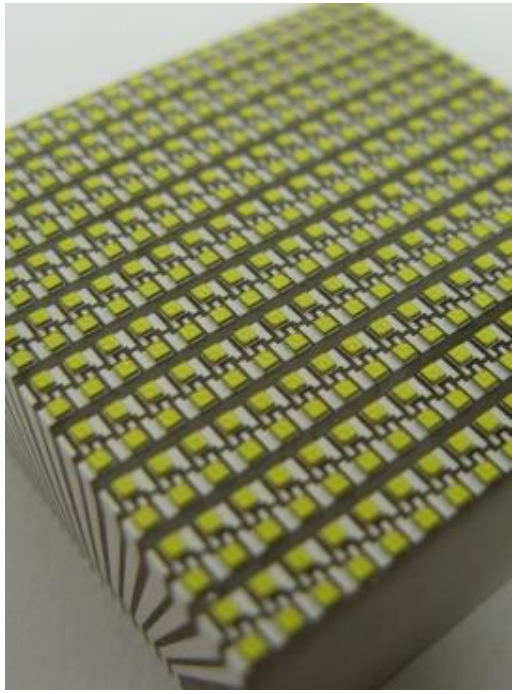
© Fraunhofer IZM

Technische Universität Berlin

Fraunhofer IZM

Application-oriented Development





Photonics – What we Do

- Solid state lighting, high bandwidth communication and sensing
- RF, microwave, antenna and plasmonic systems
- Photonic integration platforms (optical waveguide substrates, components, and interconnects)
- 3D integration, assembly, and packaging
- Reliability and thermal management

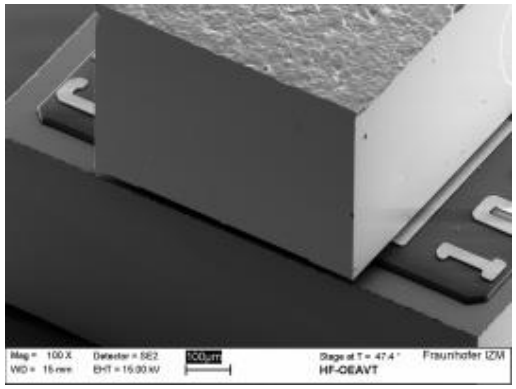
skip application ▪ back to overview

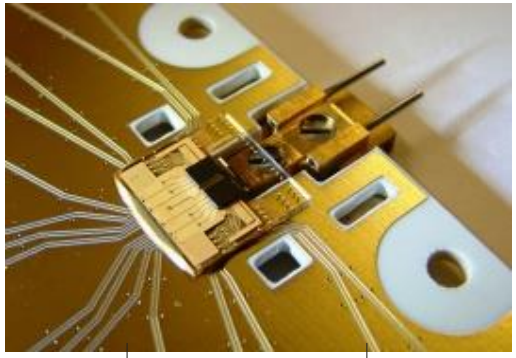
© Fraunhofer IZM

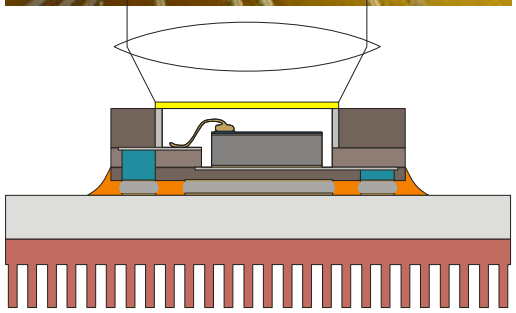
Technische Universität Berlin

Fraunhofer IZM

Application-oriented Development







Photonics – How We Do It

- Design with optical, thermo and thermo mechanical, and electrical simulation
- Soldering, sintering, thermo-compression, also with nano sponge, TLPB & TLPS, wire bonding
- Gluing, welding and splicing of high precision aligned optical components
- 2.5D and 3D wafer level processing including 3D structuring and through silicon vias
- Production like process flow development

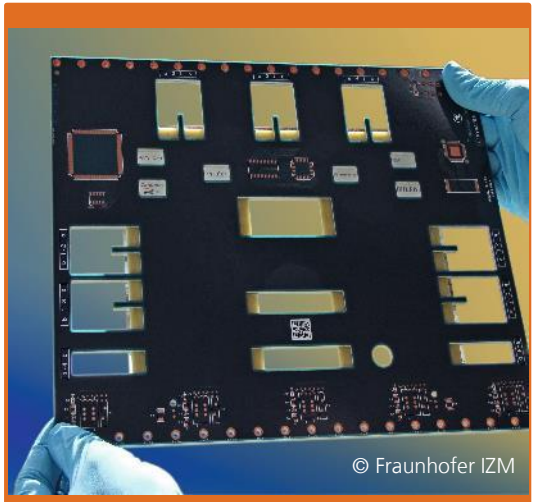
skip application ■ back to overview

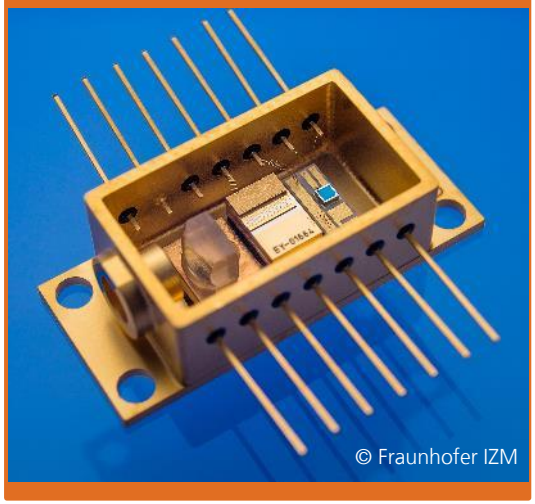
© Fraunhofer IZM

Technische Universität Berlin

Fraunhofer IZM

Photonics - Board and Module Integration





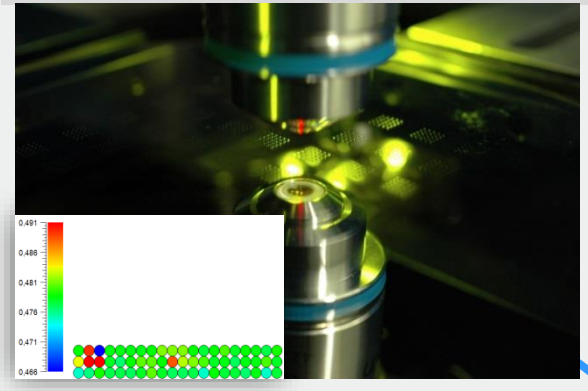
- **Glass-based Electrical-optical PCB**
  - Reliable low loss integrated optical NIR waveguides, (multimode/single mode) for telecom, datacom and sensors
  - Integrated micro-optics on large display glass panel
  - Design, manufacturing, test and connectorisation
- **Photonic Module Assembly**
  - Automated micro-optical assembly for optical engines, laser modules, e/o transceiver sensors
  - Micro-optical benches made of micromachined glass
  - Adhesive bonding and laser soldering
- **Fiber Optical Interconnects and Sensors**
  - Fiber-to-waveguide coupling, all fiber types
  - Optical sensors for biomarker detection, gas and aerospace (micro-resonators, gyroscopes, …)

© Fraunhofer IZM

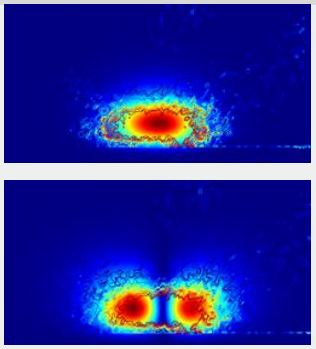
Technische Universität Berlin

Fraunhofer IZM

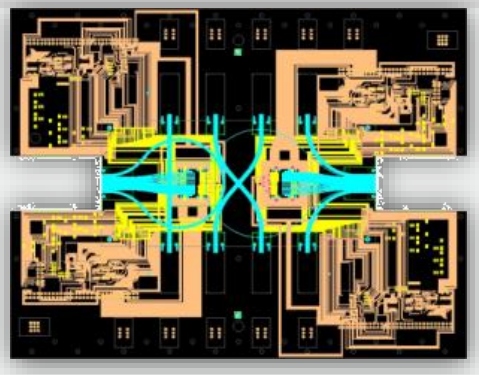
Micro Lens Array Fabrication & Measurement



MM/SM waveguide design



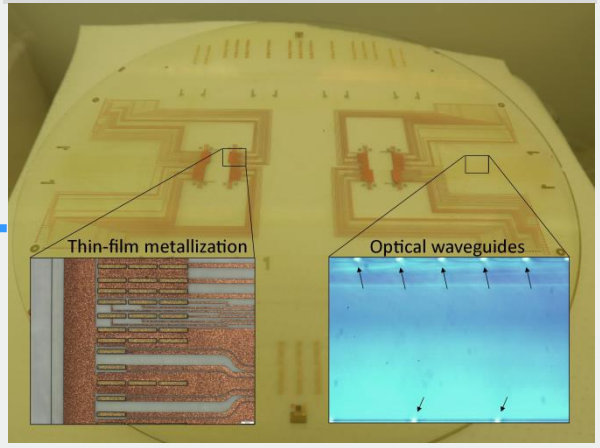
Electro-optical layouting



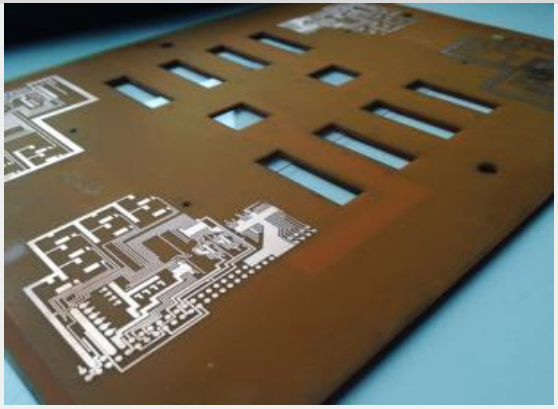
Coupling element assembly

Electro-Optical Circuit Board

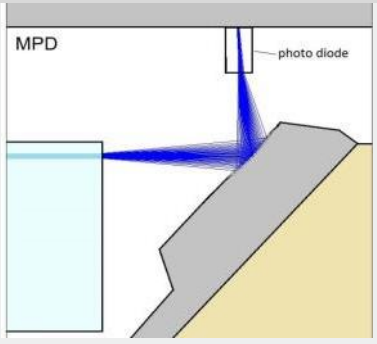
Functionalized glass wafer & panel



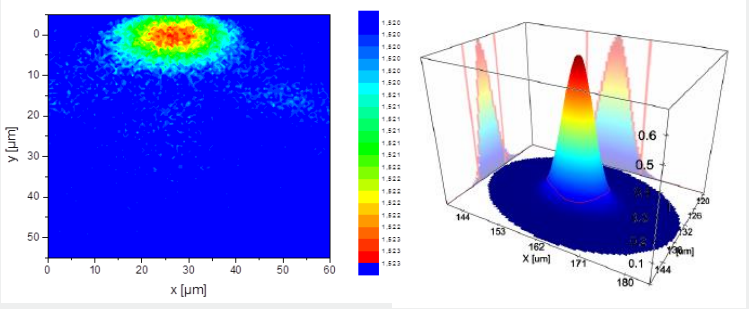
EOCB lamination



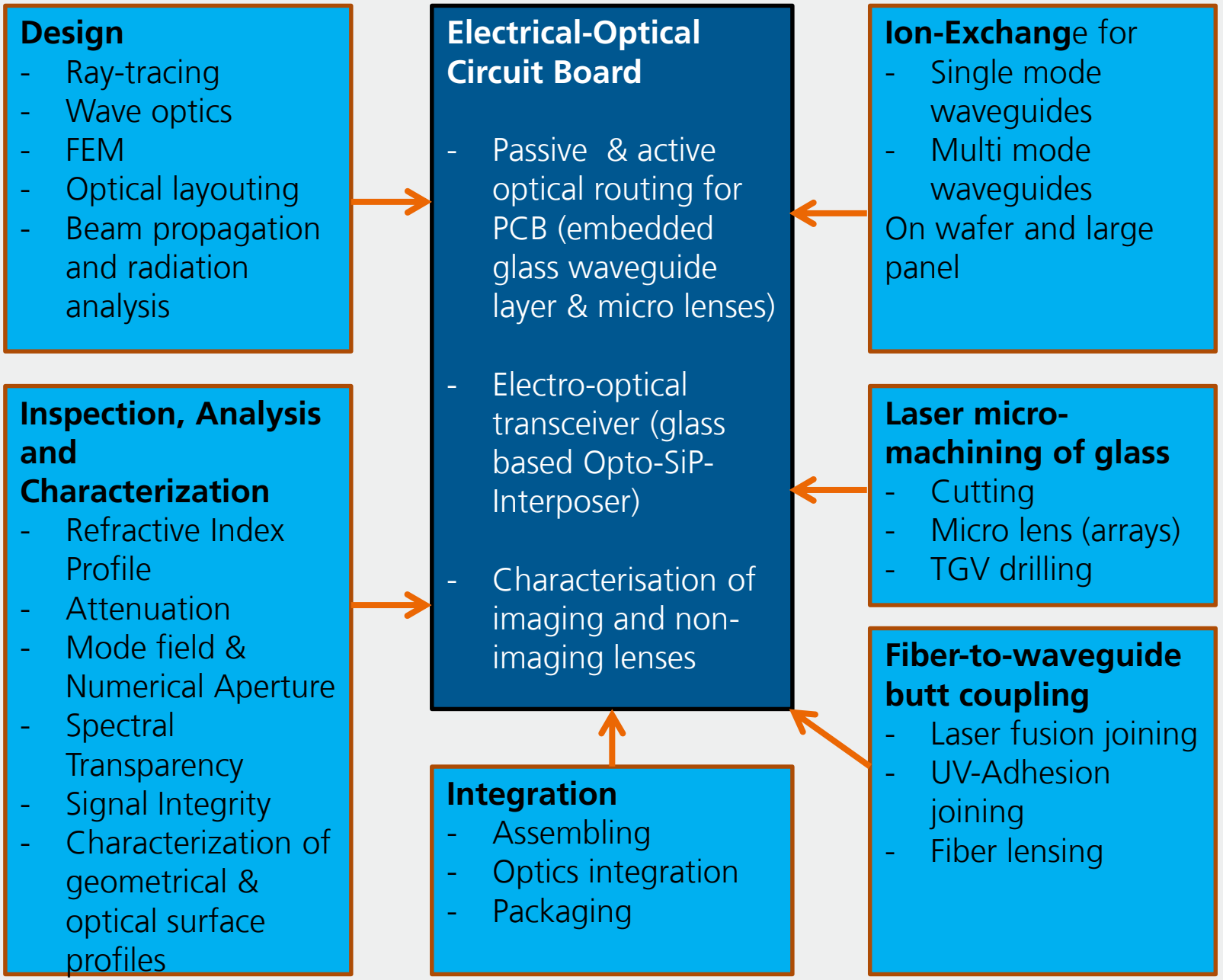
Coupling element simulation



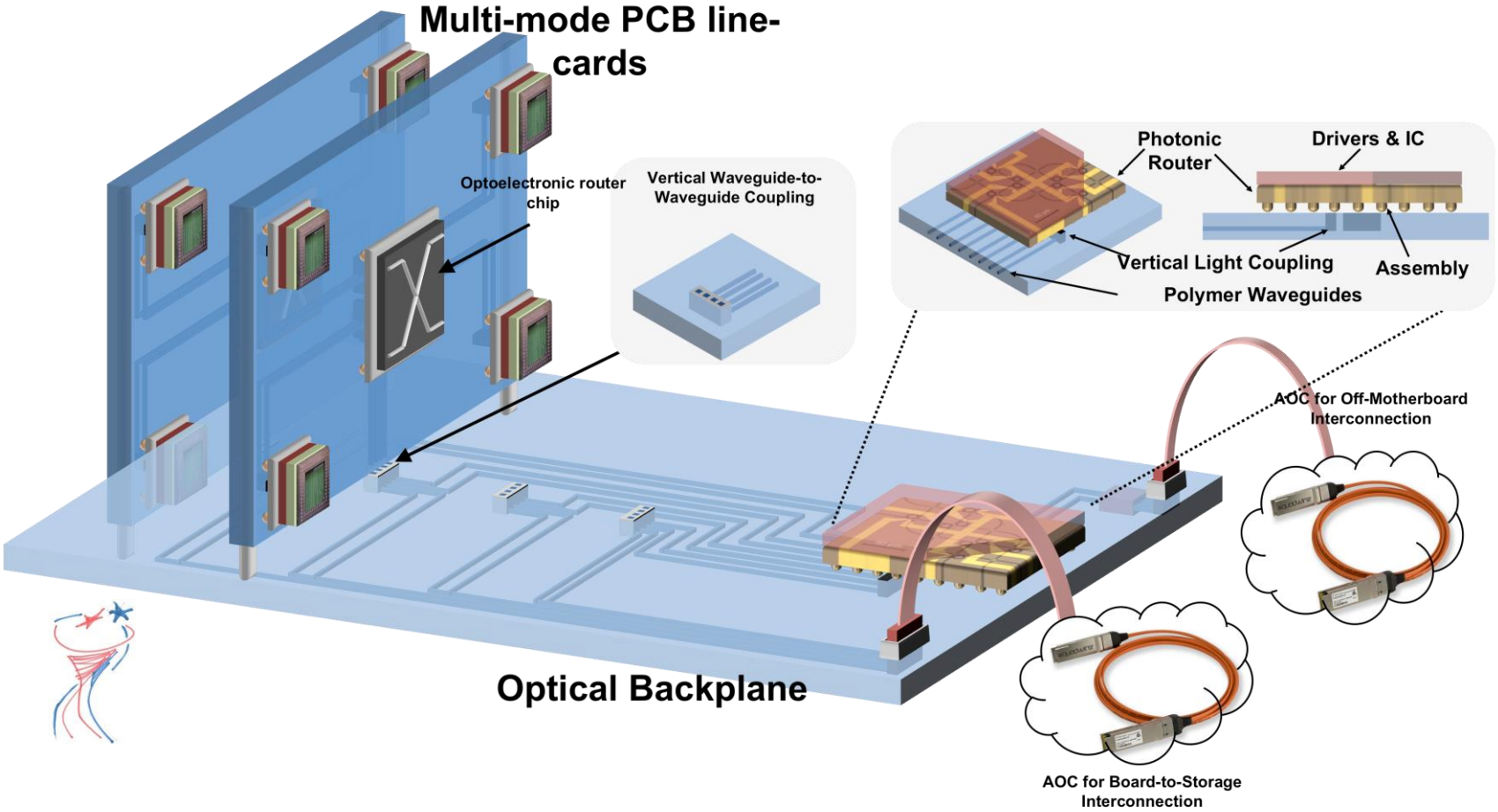
Optical characterization



Overview of EOCB



Tele- and Datacom
Complete Optical Chain



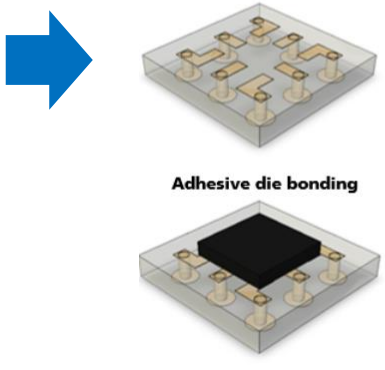
Intra Die | Die ⇔ Die | Die ⇔ Board | Board ⇔ Backplane | Router ⇔ Router

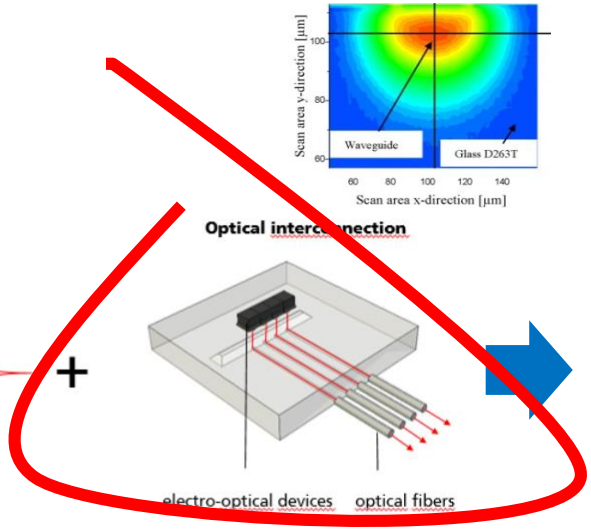
© Fraunhofer IZM

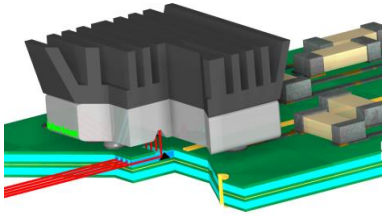
Technische Universität Berlin

Fraunhofer IZM

How does it looks like – ION EXCHANGE?







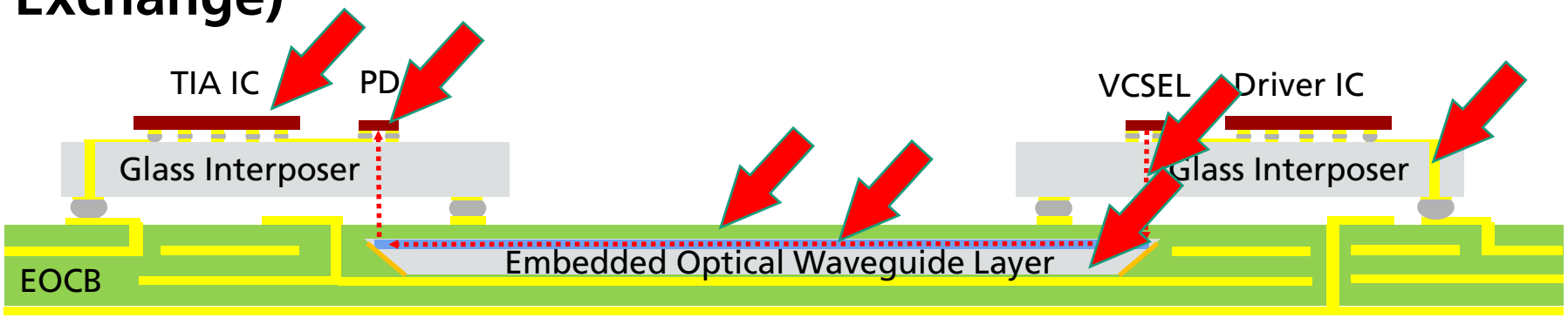
- delivered on large panel formate
- structured using mature techniques
- Isolator with very smooth surface
- Reliable at high thermal load and dimensional stabile
- Low loss buried optical waveguides can be realized

© Fraunhofer IZM

Technische Universität Berlin

Fraunhofer IZM

Why glass? Benefits of using glass for packaging (ION Exchange)

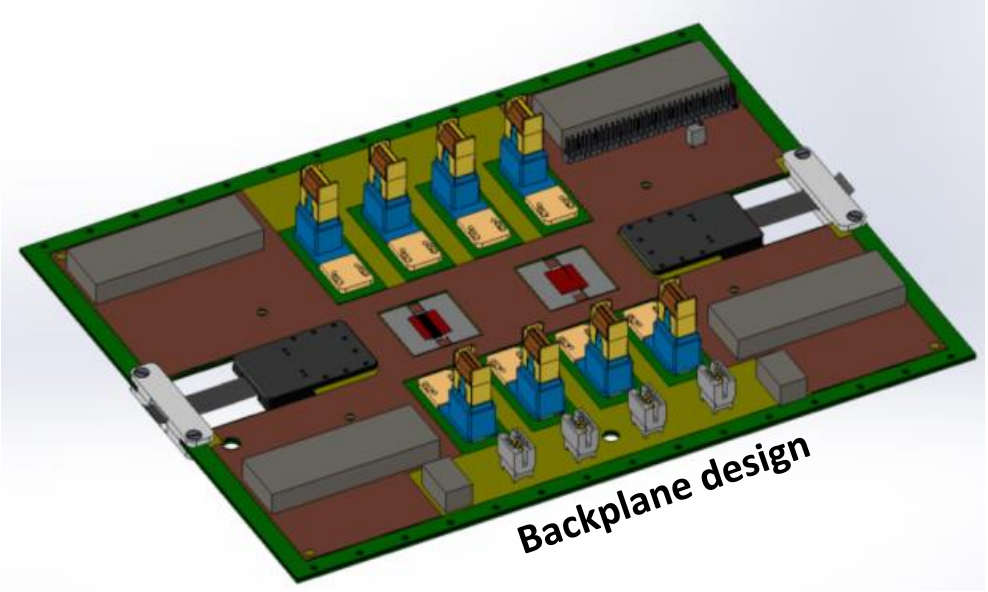


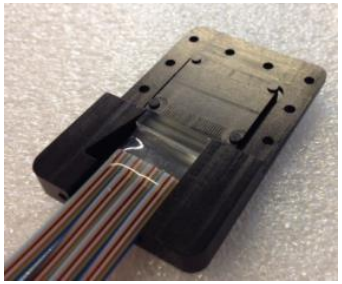
- CTE close to Si and III-V-components
- Through vias do not need passivation layer in contrast to silicon
- High thermal load and dimensional stability
- Transparent material – integration of optics
- Cost effective glass panels (e.g. display glass)

© Fraunhofer IZM

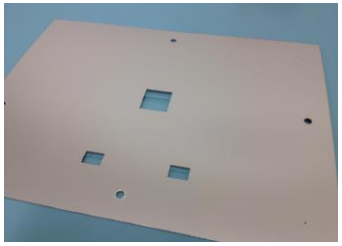
Glass single-mode optical on-board interconnects have shown high potential for next generation data centers

- Design and manufacturing of optical PCBs
- Single-mode optical waveguide integration in thin glass
- Embedding of thin glass using standard PCB processing
- Optical termination for chip-to-board, board-to-board and fiber-to board coupling





Fiber-to-board coupling



Glass panel embedding

PhoxTroT

Photonics for High-Performance, Low-Cost & Low-Energy Data Centers, High Performace Computing Systems: Terabit/s Optical interconnect Technologies for On-Board, Board-to-Board, Rack-to-Rack data links

Autoren: L. Brusberg, B.Sirbu, D. Dionyssis, B. Schild, D. Pernthaler, C. Herbst, M. Queisser, M. Neitz, H. Schröder, M. Wöhrmann, M. Töpper, D. Jäger, Y. Eichhammer, H. Oppermann, T. Tekin

© Fraunhofer IZM

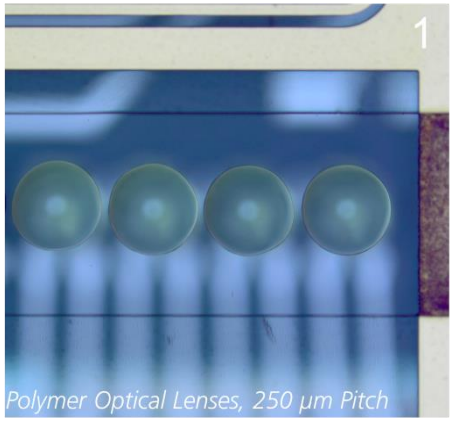
Technische Universität Berlin

Fraunhofer IZM

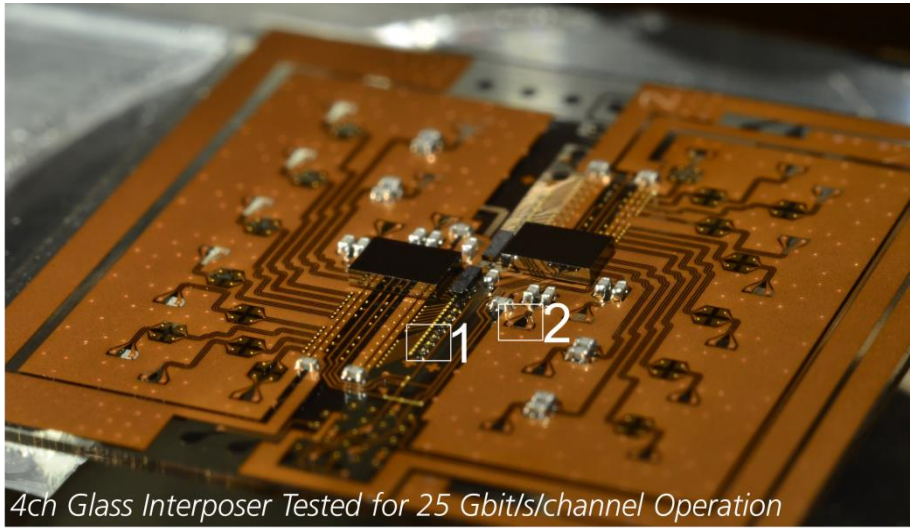
Hybridly Integrated Parallel Optics On-Board Transceiver

Glas-Interposer for OBT– Simulation, Fabrication, Characterization

- Glass Substrate Enables Low HF & Optical Losses
- Hermetically Filled Through-Glass Vias in Ø200 mm Glass Wafer
- Lens Design for High Coupling Tolerances & Easy Manufacturing
- Monolithically Integrated Fresnel or Additive Polymer Lenses
- 12ch High-Frequency Optimization for >25 Gbit/s/channel
- Flip-Chip Assembly for Easy Thermal Packaging



Polymer Optical Lenses, 250 µm Pitch



4ch Glass Interposer Tested for 25 Gbit/s/channel Operation

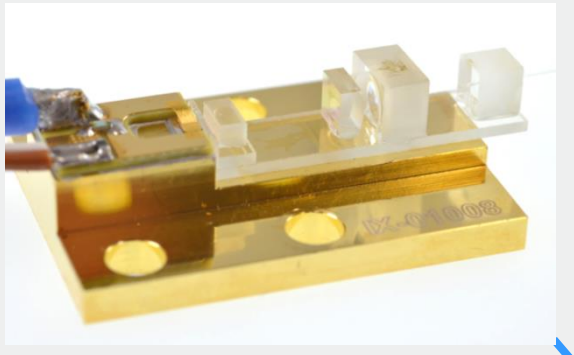
TGV in 300 µm Glass

© Fraunhofer IZM

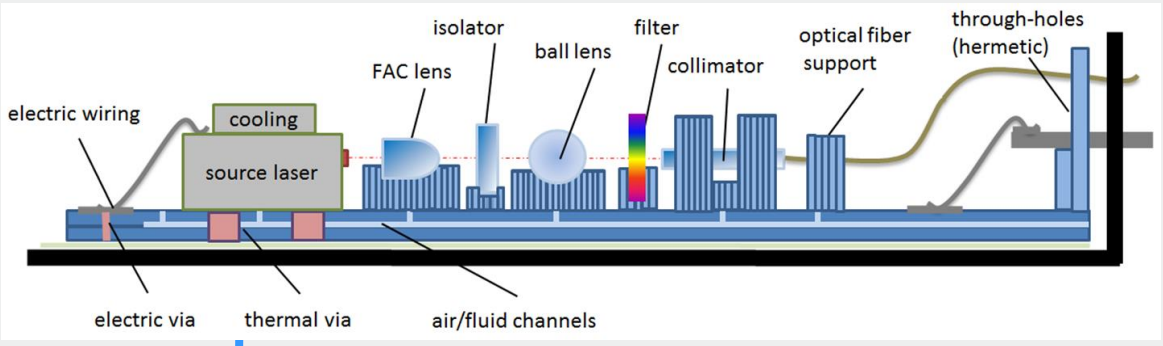
Technische Universität Berlin

Fraunhofer IZM

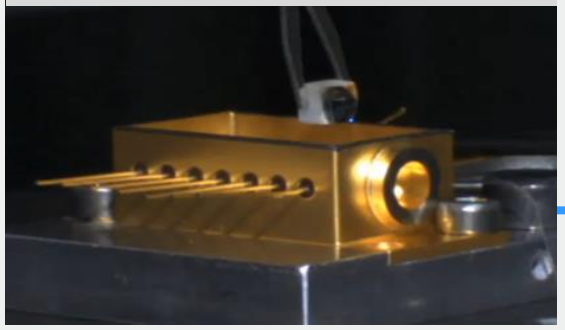
Complex Fiber Coupling Assemblies



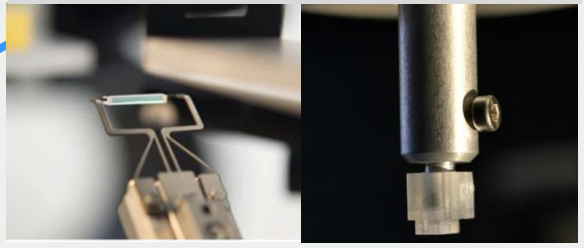
Easily Customizable Ultra Stable Glass Mounting Platform



Automated Laser Assembly

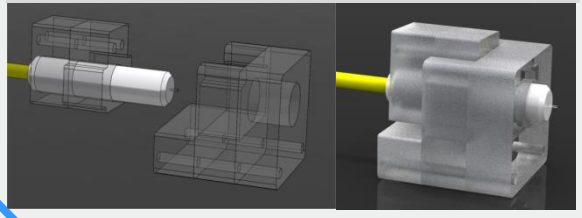


Universal Gripping Tools



Photonic Assembly

Customized Optical Collimators

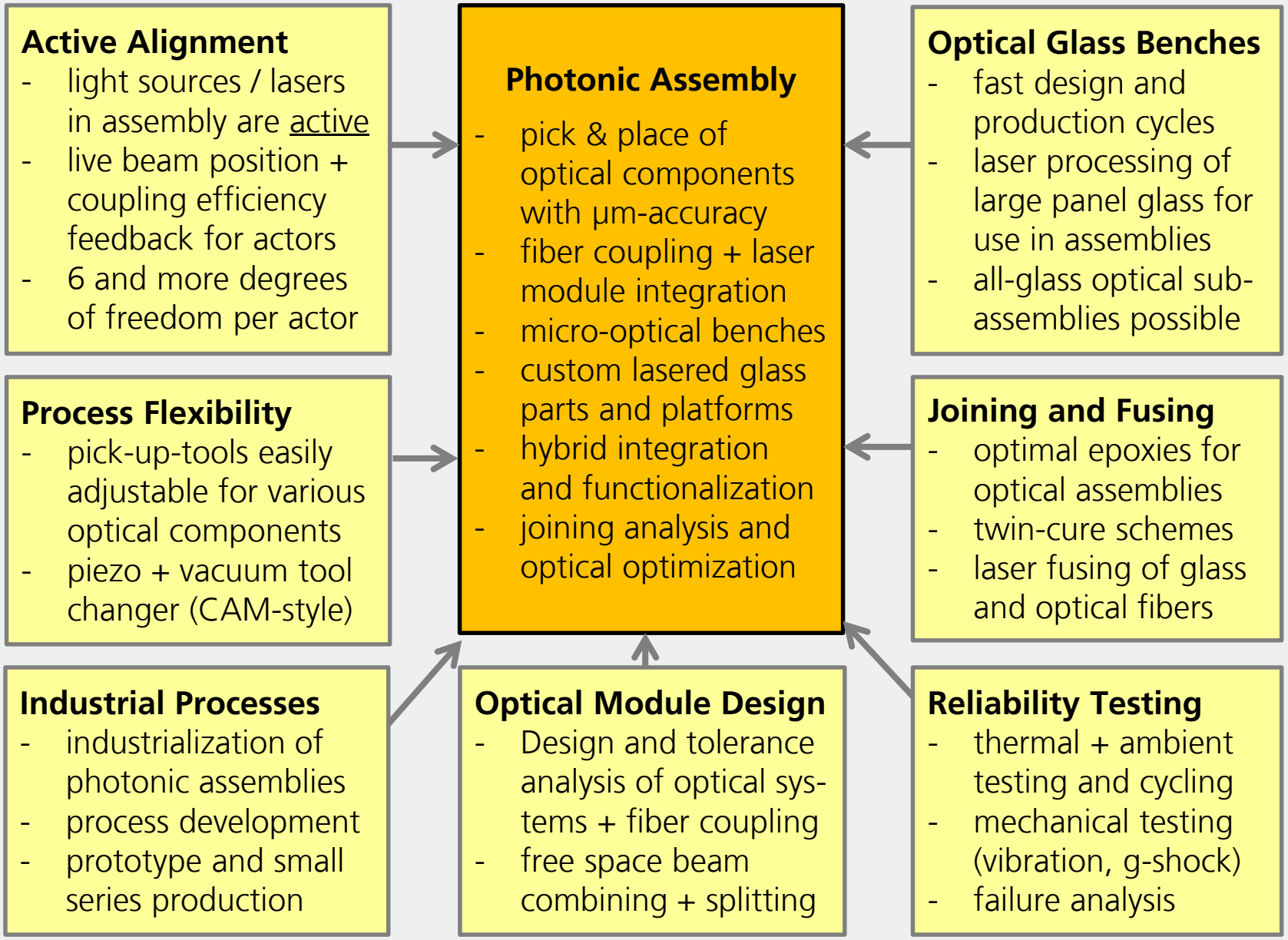


Programmable Active Alignment

Mounting of Optical Interposers

Laser Structured Glass Parts

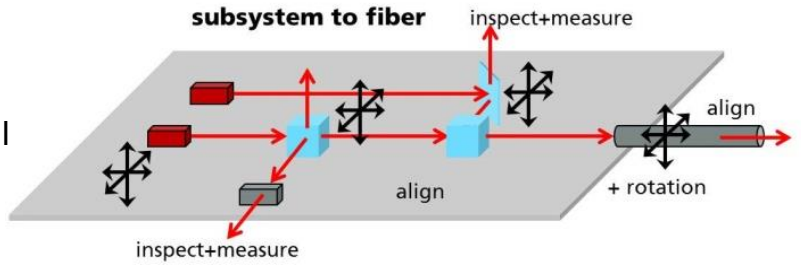
OIT – Photonic Assembly



Assembly turns into the manufacturing bottleneck for high precission and reproducibility requirements

Requirements

- µm… sub-µm precission and high complexity
- Specific relibility for automotive, space, comm, medical
- yield
- cost



?

Manuel

- flexible
- Cost effective?
- active and passive alignment

Automatic

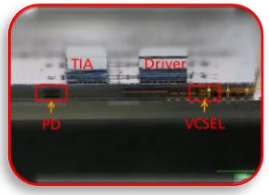
- High volume
- High reproducibility
- active and passive alignment

© Fraunhofer IZM

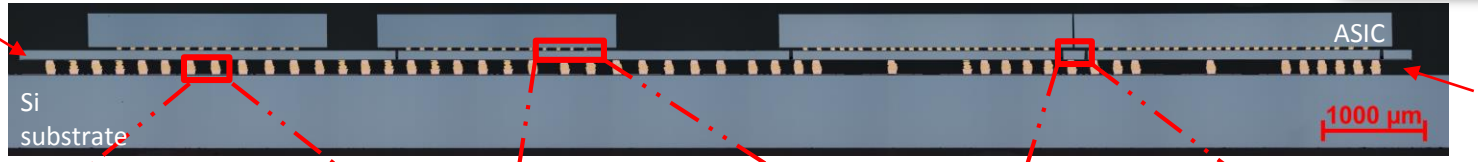
Technische Universität Berlin

Fraunhofer IZM

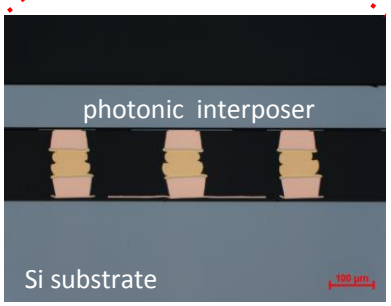
World's first 3D packaged Silicon Photonics Interposer



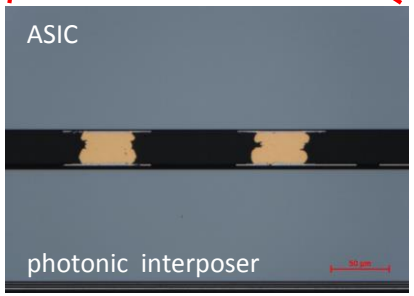
photonic interposer



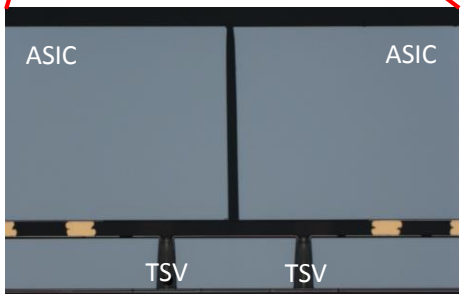
photonic components



- WG-Side to substrate
- Optical components to WG-side
- Optical connection between optical components and interposer



- Electronic components to TSV-side



- Electronic components to TSV-side
- TSV-side to WG-side (TSVs)

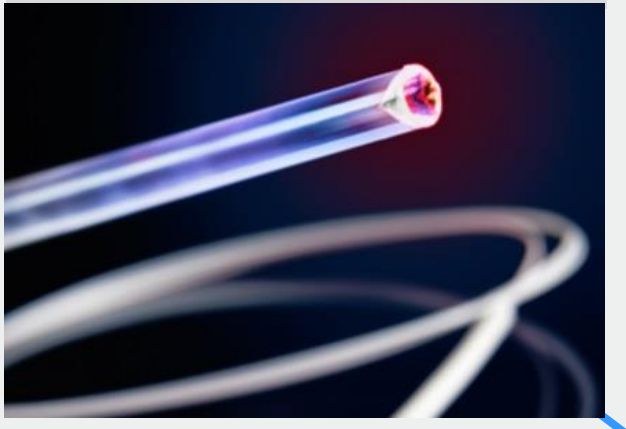
WLSI/IMP

© Fraunhofer IZM

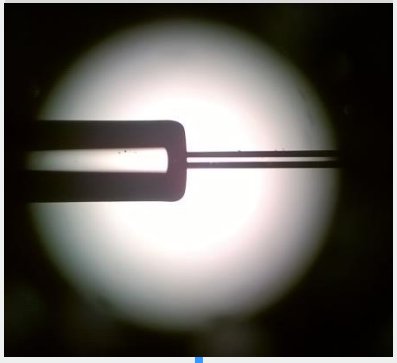
Technische Universität Berlin

Fraunhofer IZM

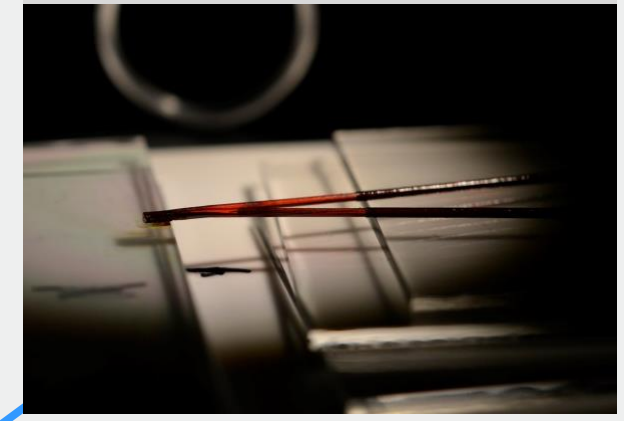
Structuring glass fiber tips



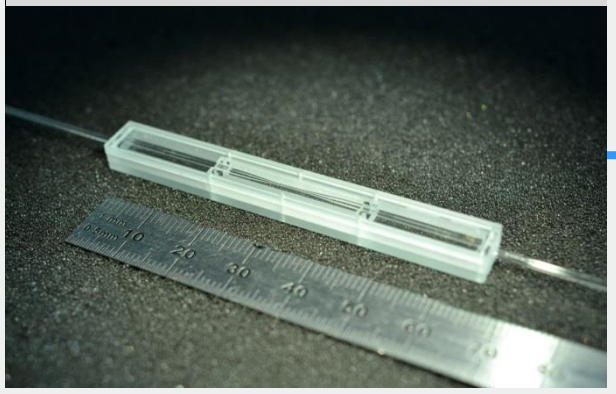
Splicing glass fibers



IR-fiber components

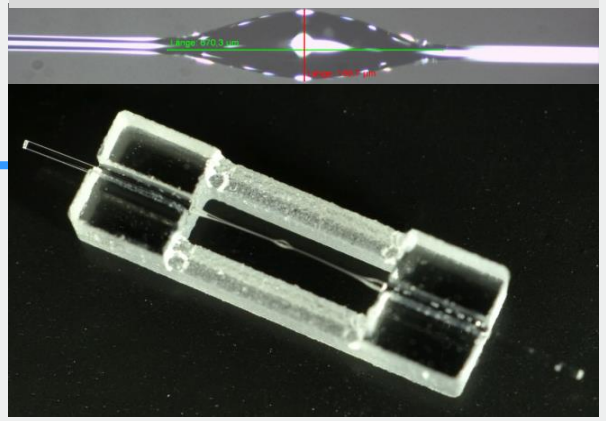


Large-core MM couplers

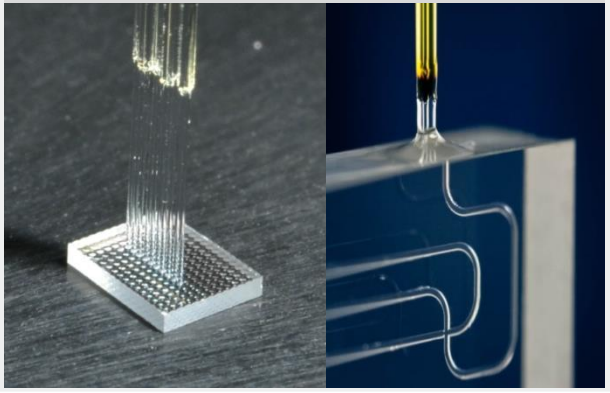


Fiber Optic Interconnects and Sensors

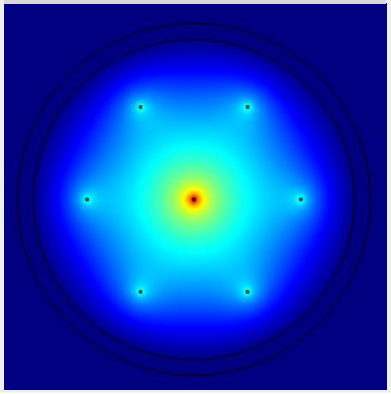
Laser-structured bottle resonators



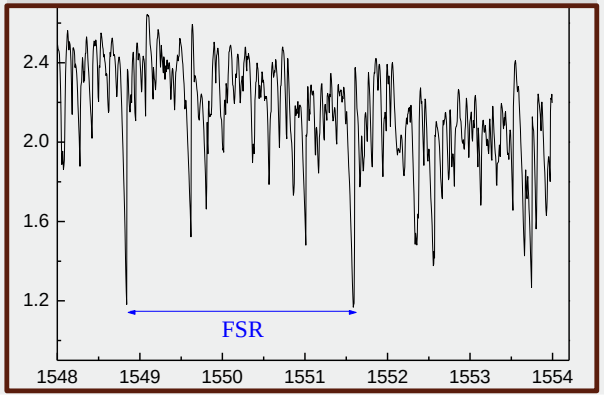
Fusing fibers/capillaries to glass chips

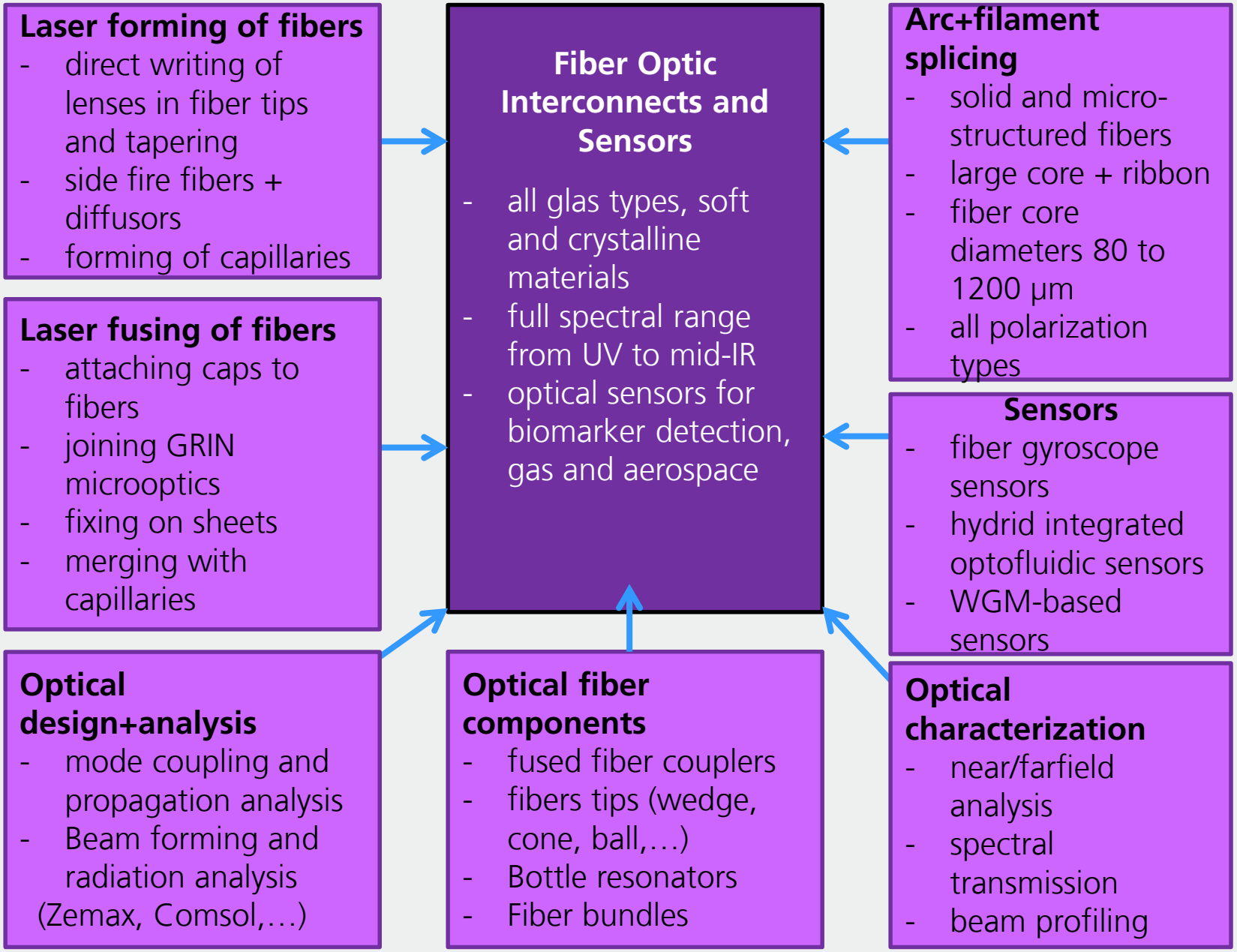


Design/Analysis



Optical characterization

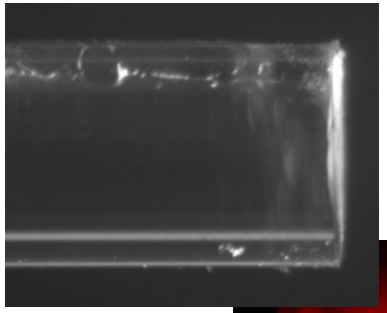



Laser forming of fibers
- direct writing of lenses in fiber tips and tapering
- side fire fibers + diffusors
- forming of capillaries
Laser fusing of fibers
- attaching caps to fibers
- joining GRIN microoptics
- fixing on sheets
- merging with capillaries
Optical design+analysis
- mode coupling and propagation analysis
- Beam forming and radiation analysis (Zemax, Comsol,…)
Fiber Optic Interconnects and Sensors
- all glas types, soft and crystalline materials
- full spectral range from UV to mid-IR
- optical sensors for biomarker detection, gas and aerospace
Optical fiber components
- fused fiber couplers
- fibers tips (wedge, cone, ball,…)
- Bottle resonators
- Fiber bundles
Arc+filament splicing
- solid and micro-structured fibers
- large core + ribbon
- fiber core diameters 80 to 1200 µm
- all polarization types
Sensors
- fiber gyroscope sensors
- hydrid integrated optofluidic sensors
- WGM-based sensors
Optical characterization
- near/farfield analysis
- spectral transmission
- beam profiling

Laser processing of fiber tips

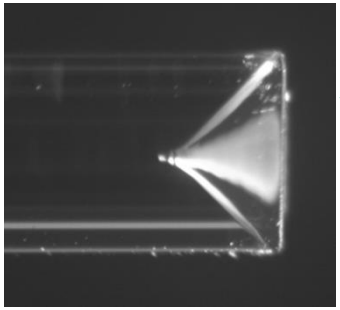
Contactless shaping (concave, convex, etc.) of optical fibers to change its radiation characteristics

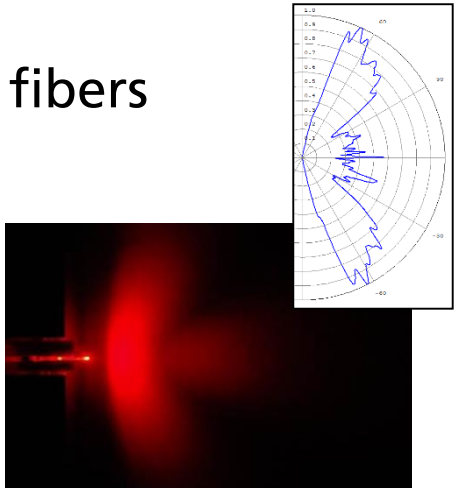
- Inverse cone for radial radiation



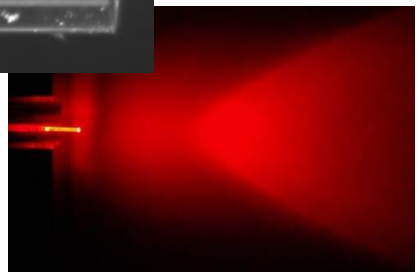
Cleaved, untreated fiber tip

Laser processing

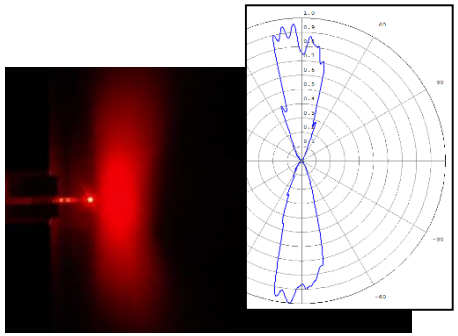




Radial radiation ≈ 80%
(simulated maximum ≈ 94%)

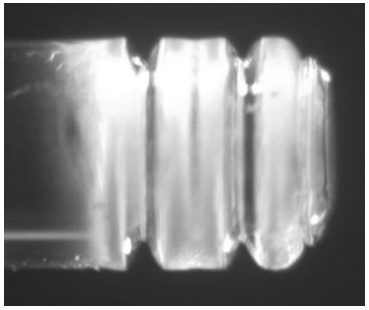


Screening principle, top view



Additionally metallized cone

- Another structuring sample

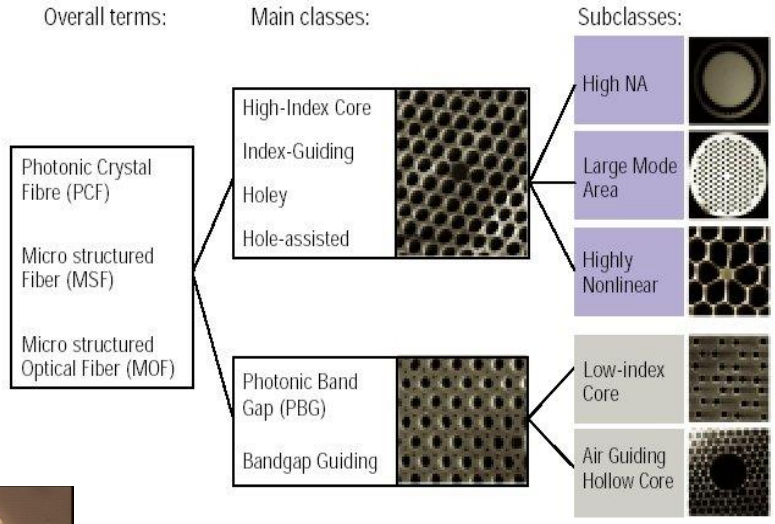


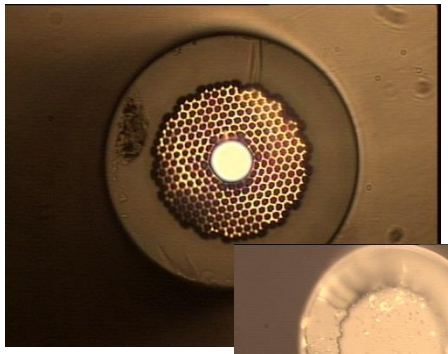
© Fraunhofer IZM

Technische Universität Berlin

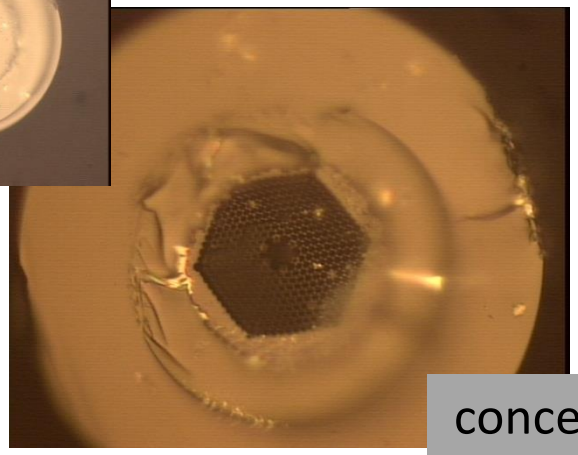
Fraunhofer IZM

Structured Fiber Packaging

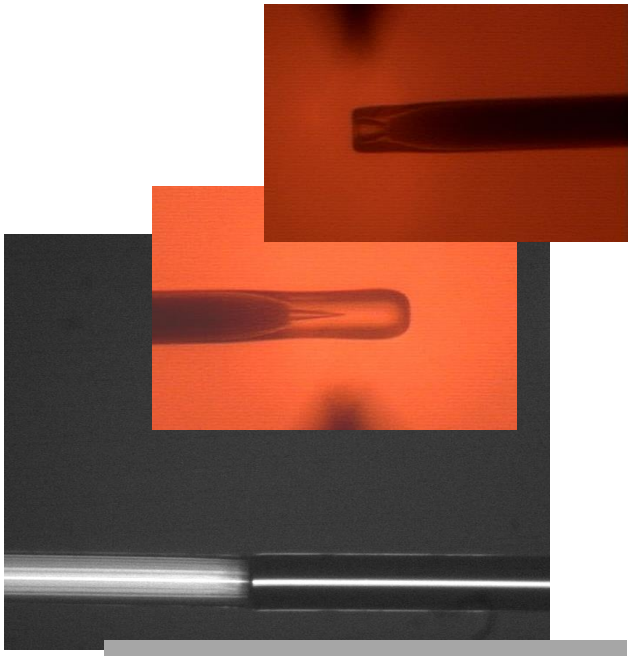




fiber cut



concentric splicing



Partly and no collapsing

OIT Capabilities

- Splicing
- Lensing
- Alignment
- Characterisation

© Fraunhofer IZM

Technische Universität Berlin

Fraunhofer IZM

Optical Bottle Microresonators

Packaged glass bottle resonators for sensing applications

Motivation:

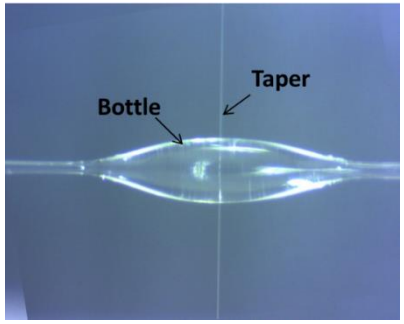
- No existing package for ultra-high sensitive fiber-based microresonators

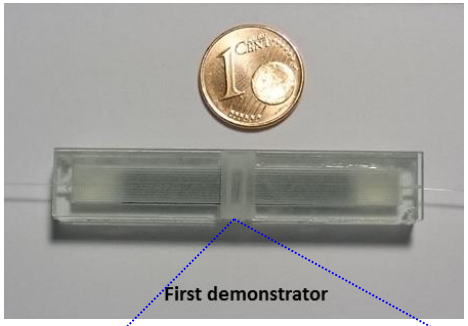
Goal:

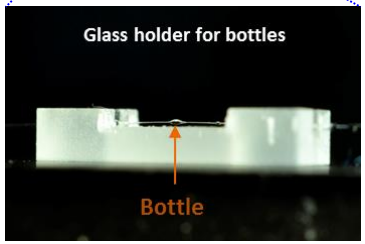
- Fabrication and package of bottle microresonators and tapers

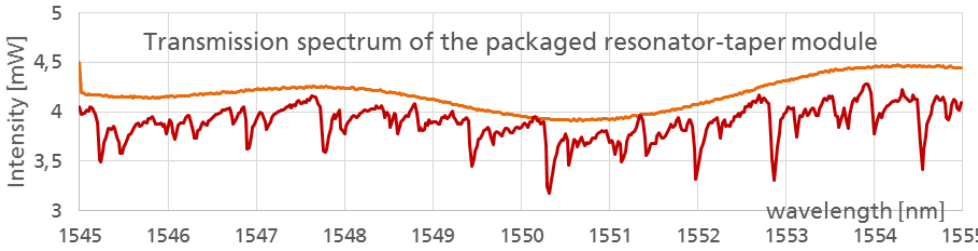
Results:

- Bottle-shaped glass fibers using a laser-assisted pull setup
- Compact stacked glass package for the bottle-taper coupling system
- *Applications:* Miniaturized optical biosensors, and gyroscopes









SPONSORED BY THE
Federal Ministry of Education and Research

Jonas Herter, Valentin Wunderlich, Christian Janeczka, Vanessa Zamora

© Fraunhofer IZM

confidential

Technische Universität Berlin

Fraunhofer IZM

Novel Glass Etching Process

Molten salt etching technology to develop fiber optic components

Motivation:

- Molten salt is a stable etchant vs. Hydrofluoric (HF) acid
  - No generation of microcracks in etched fibers

Goal:

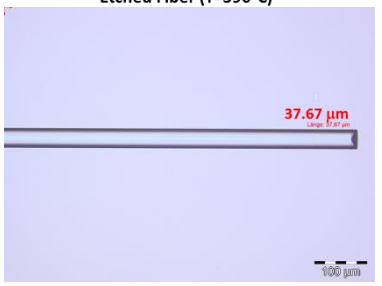
- Developing etch process and construction of a lab station for etching glass fibers in a reliable way

Results:

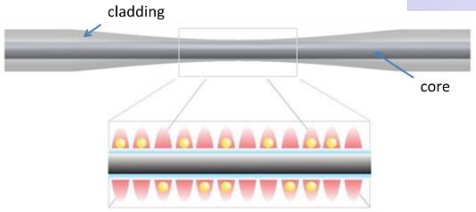
- Etched SM and MM fibers with final diameters around 55 µm
- *Applications:* Development of fiber optic components such as fused couplers, fiber tips and narrow fibers for telecom and sensing

Completed construction of the labreactor

Etched Fiber (T=390°C)



Application: Evanescent sensors



Norbert Arndt-Staufenbiel, Christian Janeczka, George Havlik, Vanessa Zamora

© Fraunhofer IZM

Berlin Founder Garage of the 21st Century

START:FACTORY
advanced tools
for your ideas

@HALLE16.BERLIN

© Fraunhofer IZM

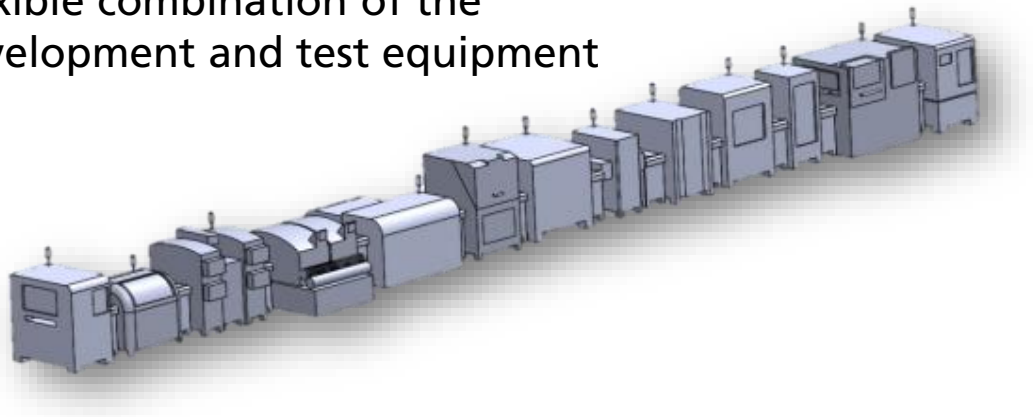
START:FACTORY advanced tools for your ideas

Funded by: Bundesministerium für Bildung und Forschung
EFRE ...Aufschwung durch Europa!
Technische Universität Berlin
Fraunhofer IZM

COMPONENTS

Development Space

- Individually equipped
- Located in refurbished oversea containers
- Flexible combination of the development and test equipment



Technology Coaching, Training & Mentoring

- Spaces for coaching, customer events, team meetings, trainings, concept discussions & presentations
- Comprehensive program around electronic packaging for products

Prototype Production

- Flexible production line for ultra fast prototyping in small batches – **High Mix Low Volume**

© Fraunhofer IZM

Thank you for your attention!

Fraunhofer Institute for
Reliability and Microintegration IZM

Head of Marketing & Business Development
Dirk Friebel

Gustav-Meyer-Allee 25
13355 Berlin
Germany

+49 30 46403-100
info@izm.fraunhofer.de
www.izm.fraunhofer.de

For more information please contact:
Georg Weigelt
+49 30 46403-279
georg.weigelt@izm.fraunhofer.de

© Kai Abresch FAIRNET GmbH

© Fraunhofer IZM

Technische Universität Berlin

Fraunhofer IZM