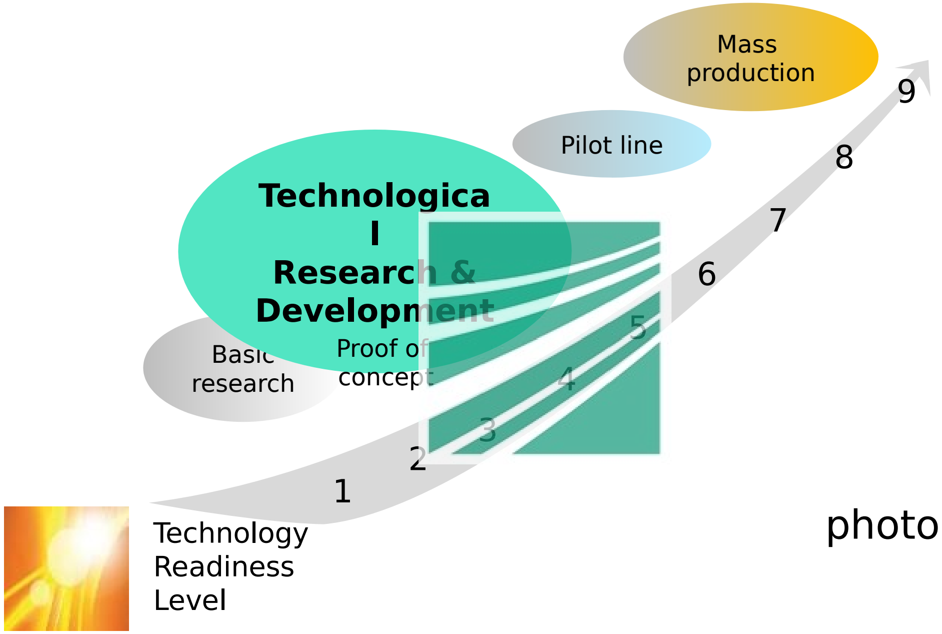
Strategies for glass based photonic system integration

Henning Schröder



- COMMUNICATION
- Quantumtechnology
- Lighting
- Sensoring
- Material Processing

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

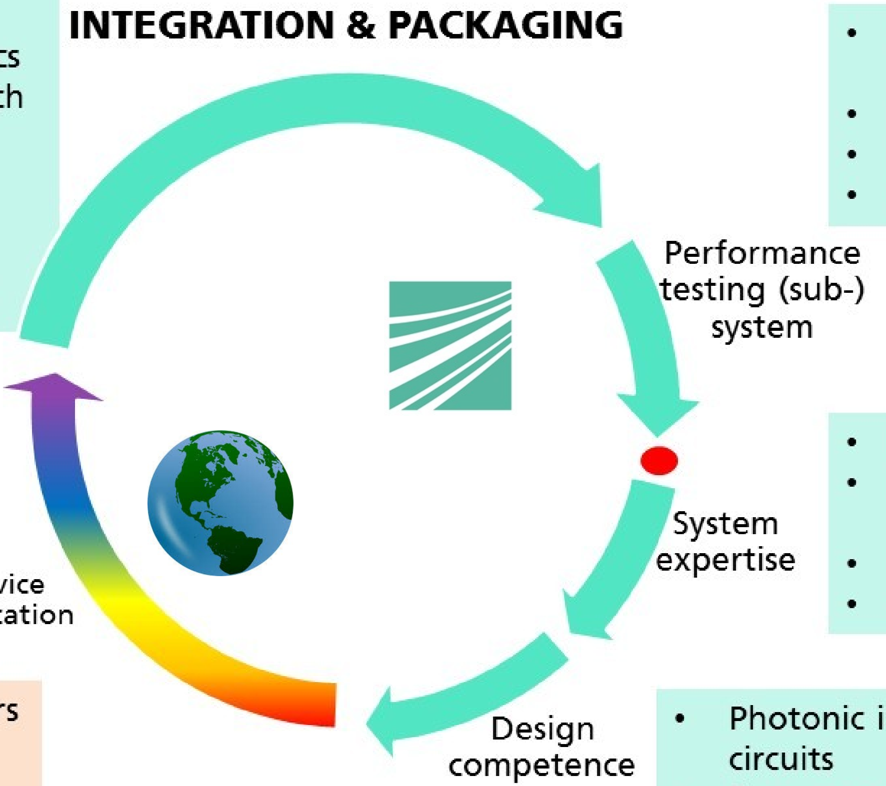

10th Anniversary Symposium of the Photonics Society of Poland combined with the International Day of Light 2018

Friday, 18th May 2018

Warsaw University of Technology, Physics Building,
75 Koszykowa St, Warsaw 00-662

Photonics value chain addressed at Fraunhofer IZM

- 3D Integration
- Optical PCB
- Hetero Silicon Photonics
- Module, µ-optical bench
- Chip assembly
- Embedding in panel
- Embedding in wafer
- RF integration
- Thermal management



- PhoxLab

- Materials
- Components
- (D)WDM

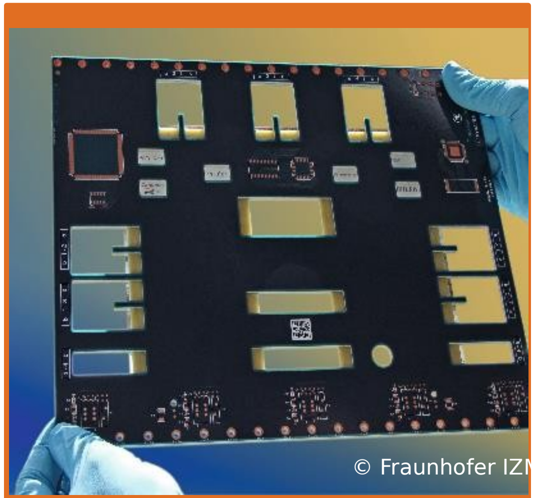
- Data center
- 5G

- Wireless
- Sensors

- Photonic integrated circuits
- Free space
- Rf
- Thermo-mechanical

Collaboration with partners
- InP
- Si-Photonics
- TriPlex
- SiNx

Photonics - Board and Module Integration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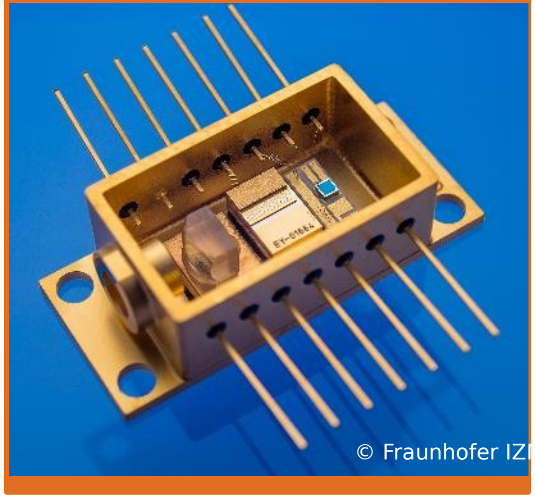
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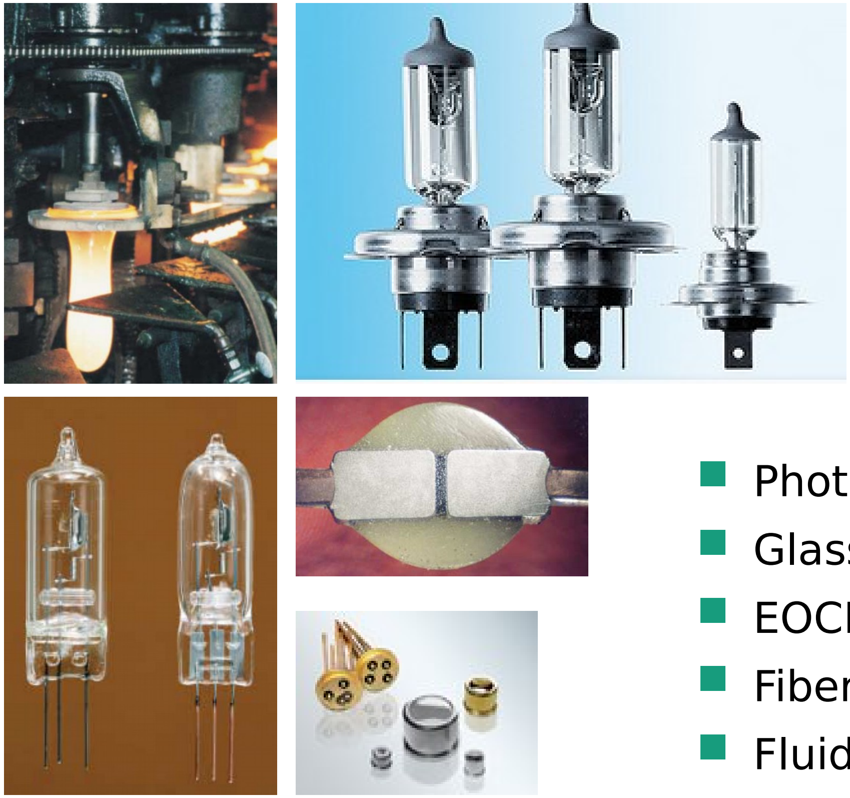
- Glass-based Electrical-optical PCB
  - Reliable low loss glass integrated integrated optical NIR waveguides, (multimode/single mode) for telecom, datacom and sensors
  - Integrated micro-optics on large display glass panel
  - Design, manufacturing, test and connectorisation
- Photonic Module Assembly
  - 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 (glass packaged micro-resonators, gyroscopes, . . .)

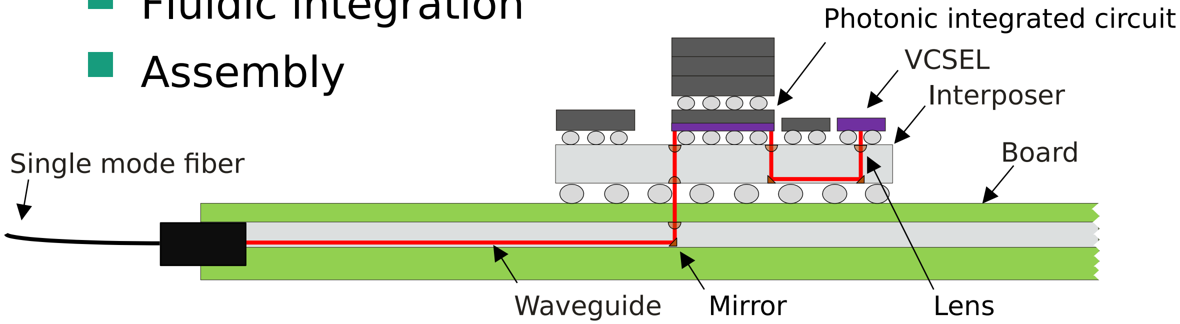
What I am not talking about



www.schott.com

But I am talking about

- Photonic system integration and micro-optics
- Glass based interposer and TGV
- EOCB = panel size integration using thin glass
- Fiber optical interconnects
- Fluidic integration
- Assembly



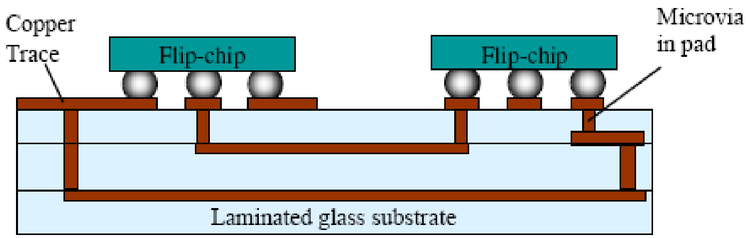
Outline

- **Motivation** for glass in photonic packaging
- Photonic **system integration technologies**
  - PCB level: EOCB, integrated optical waveguides, lamination, assembly of connectors
  - Interposer level: lens arrays, (TGV, soldering, thin film)
- **Interconnection technologies**
  - Optical fiber direct fusing
  - Fluidic interconnects
  - Assembly using active alignment and glass made building blocks

Glass Based Electrical Systems today?

Loughborough University, UK

research activities only



Excimer laser drilliing,
electroless copper plating and direct bonding experiments
(Xiaoyun Cui et al, Proc. Of. EPTC 2008)

- Research without any optical or fluidic integration
- single technologies for single applications, i.e.

Intelligenz in Glas

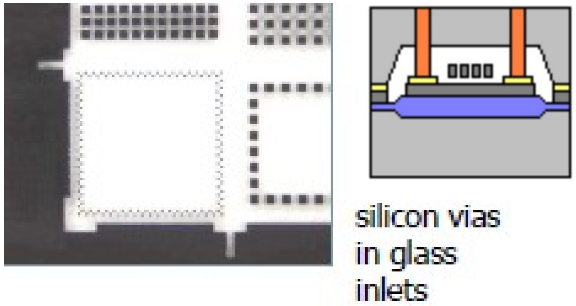
IMPAtouch®, Glastouch, kapazitiv

Unsere patentierte Technologie IMPAtouch® bietet die Integration von Elektronik, Sensorik und moderner Glastechnologie.

FELAM GLASLINE

FELAM GLASLINE steht für die Fertigung moderner Eingabesysteme aus Glas. Bei FELAM GLASLINE handelt es sich um eine patentierte Technologie, die 2002 mit dem Innovationspreis der deutschen Wirtschaft ausgezeichnet wurde.

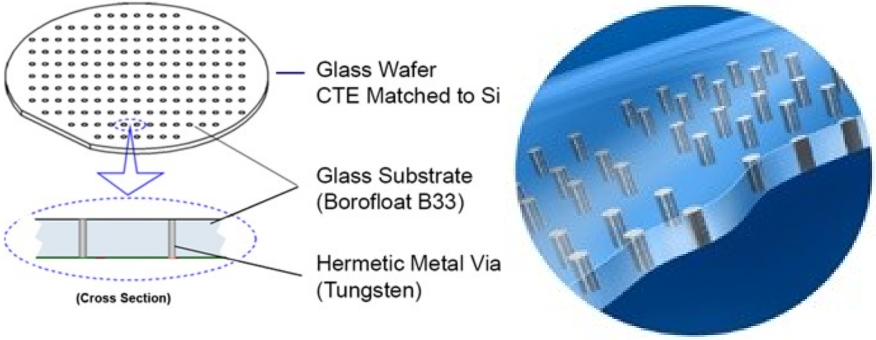
Planoptik, Germany



Silicon vias in Borofloat33 glass wafer
(

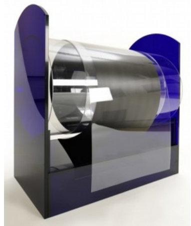
www.planoptik.de)

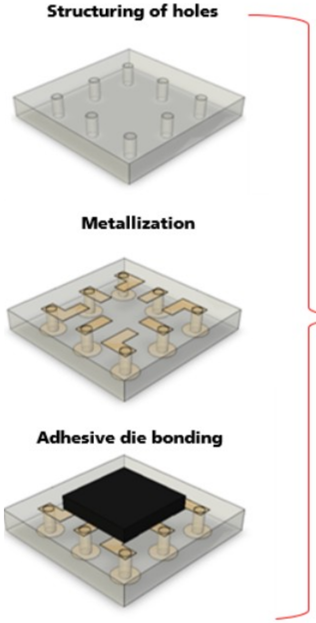
NEC/Schott, Japan

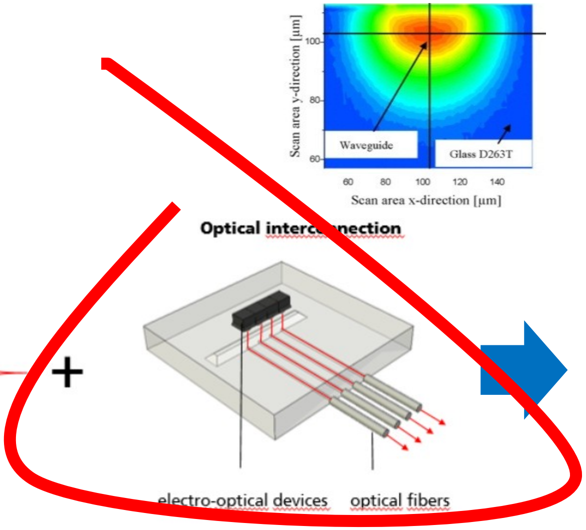


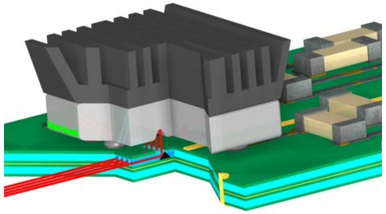
100µm thick metal pin in 500µm Borofloat33 glass wafer
(http://www.nec-schott.co.jp)

We at Fraunhofer IZM believe…
…that thin glass has enormous potential for the future…



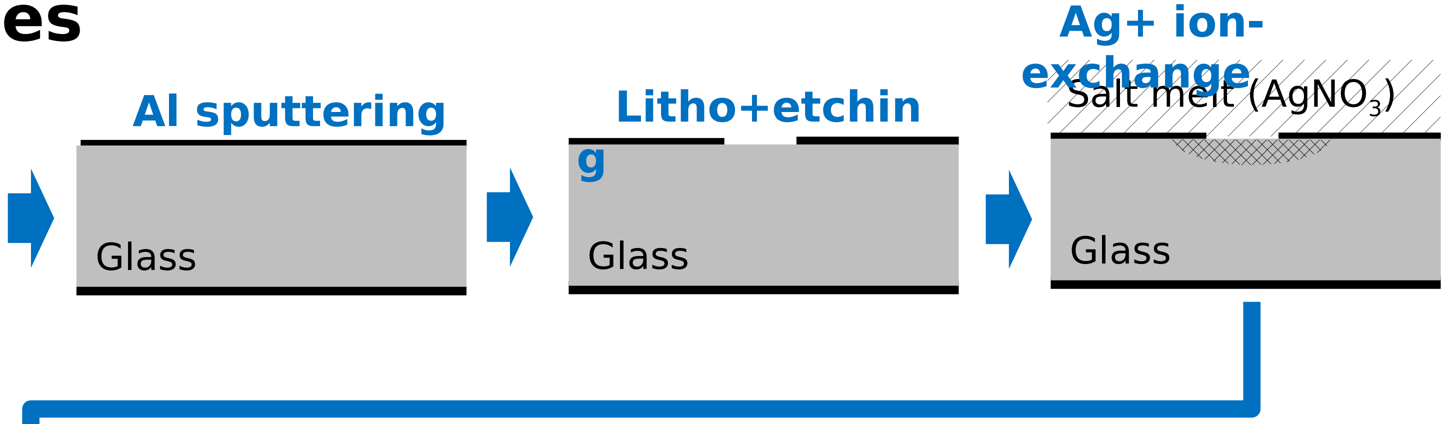






- delivered on large panel formate
- structured using mature techniques
- Isolator with very smooth surface
- Reliable at high thermal load and dimensional stab
- Low loss buried optical waveguides can be realize

Thermal ion exchange technology results in graded index buried multimode optical waveguides



Al sputtering

Glass

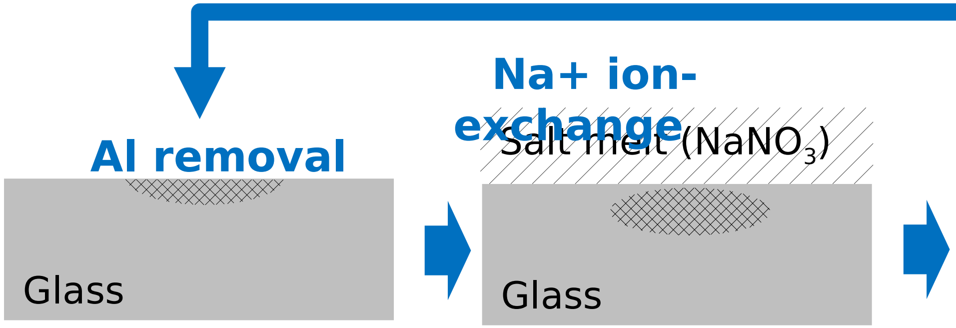
Litho+etching

Glass

Ag+ ion-exchange

Salt melt ($AgNO_3$)

Glass



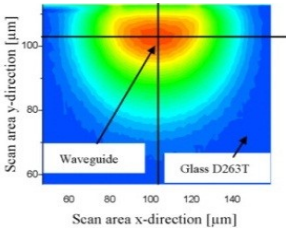
Al removal

Glass

Na+ ion-exchange

Salt melt ($NaNO_3$)

Glass

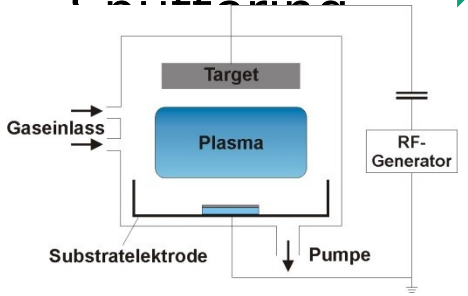


Cross section refractive index profile of MM-GI-WG

Glass waveguide panel (199 x 160 mm)

Thin film metalisation and Cu plating enables electrical wiring

Cu-Sputtering

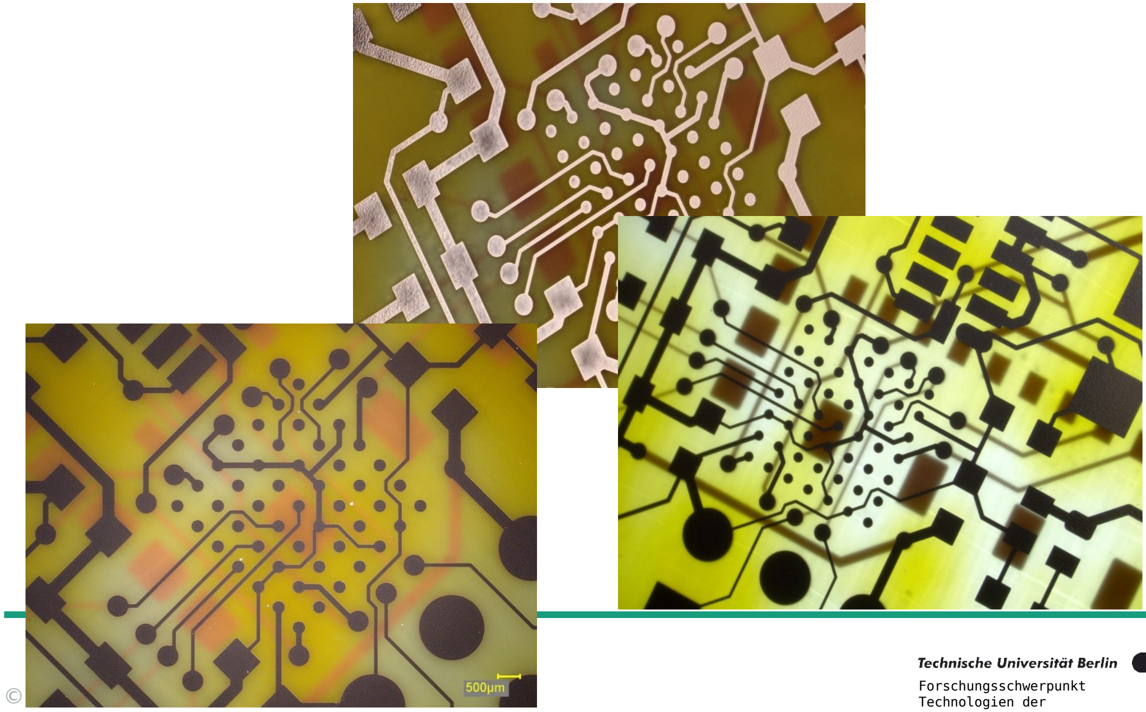


Laser drilling

Cu plating

LDI patterning

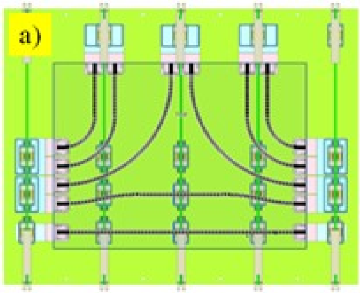
etching



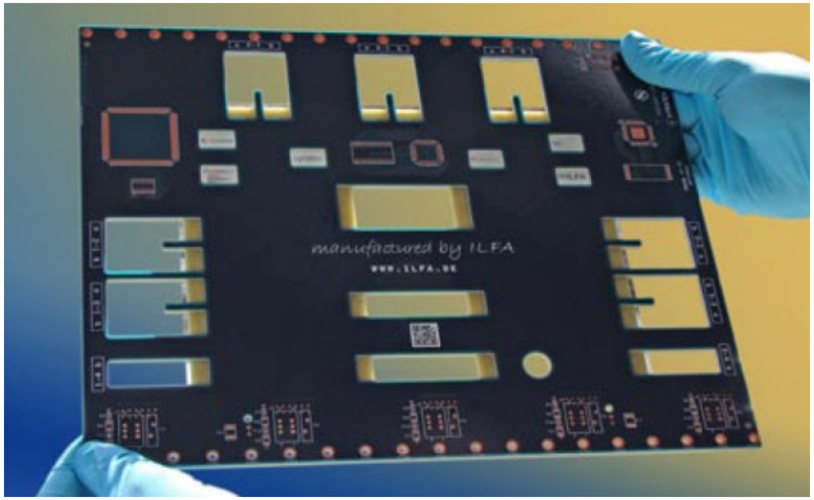
MM e/o backplane demonstrato

EU collaborative project SEPIANet

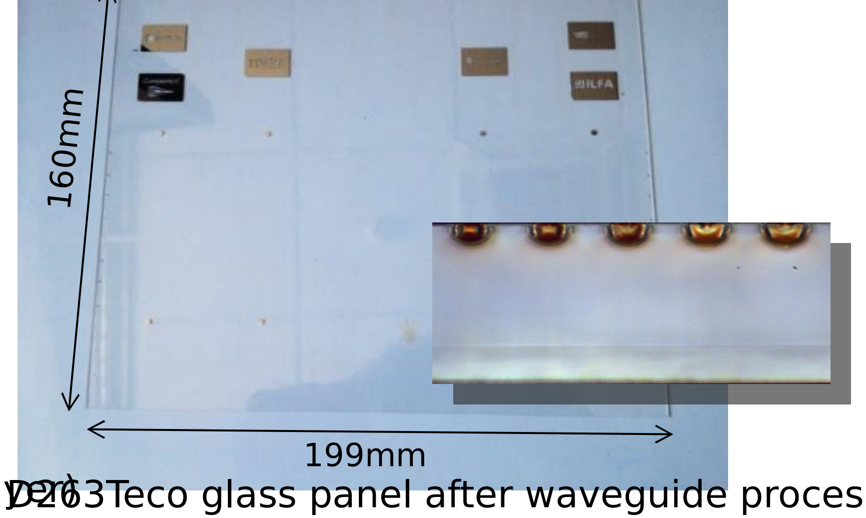
- Backplane fabrication (281x233mm²)
  - Design ☾ XYRATEX
  - Glass panel fabrication ☾ IZM
  - Backplane fabrication ☾ ILFA



Backplane design



Electro-optical backplane (1x o-Layer, 4x e-Layer)



D263Teco glass panel after waveguide process

Largest glass made Electro-Optical Circuit Board

Up-scaling glass waveguide panel process and waveguide termination by fiber flex

Multi-mode glass waveguide panels

- Development of lithography and etching on large glass panels having area of 420x470mm^2

Improving waveguide performance

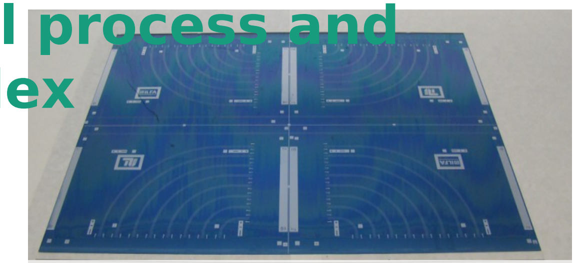
- Lower propagation and bend loss in aluminum silicate glass

LEOCB fabrication

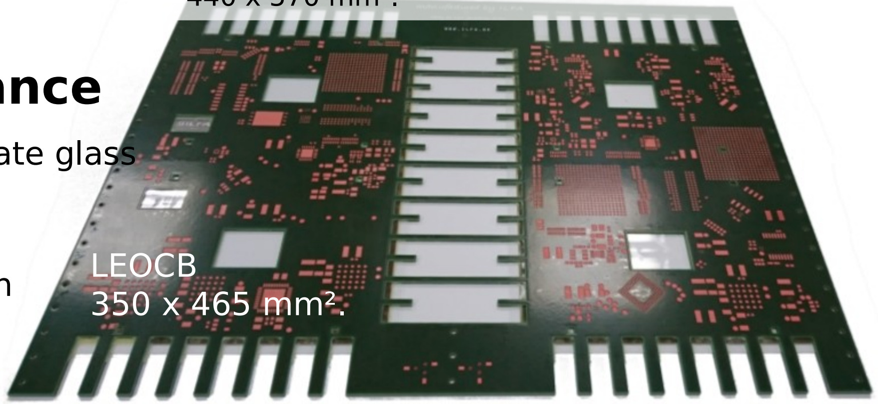
- Cooperation with SEGATE for dual-star board design
- Cooperation with ILFA for fabrication

Passive fiber flex assembly for waveguide termination for standard MT interface

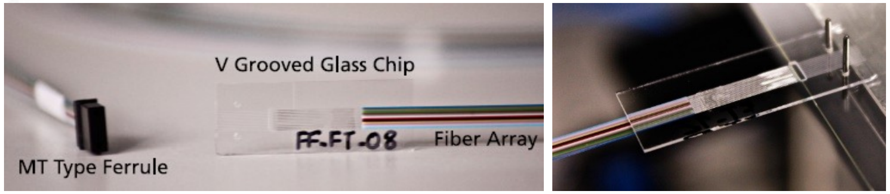
Patent pending



Developed photoresist on aluminum deposited glass panel with area of 440 x 570 mm^2.



LEOCB
350 x 465 mm^2.



Flex-ridge waveguide interface design, assembled on glass

- L. Brusberg, C. Herbst, C. Frey, J. Röder, F. Faridi, H. Schröder

Glass body photonic interposer can be EOCB integrated by assembling and embedding

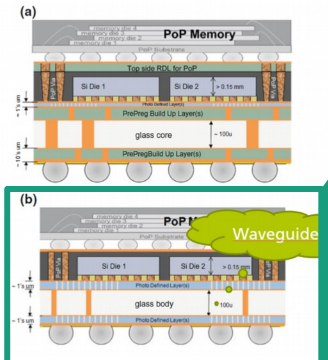
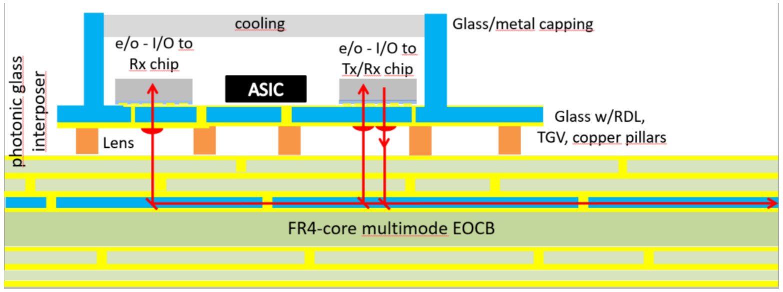


Fig. 2.9 Concept Low-Cost (Glass) Interposer (LCIg) SiP package—a cartoon illustration of two concept Low-Cost Glass Interposer (LCIg) SiP constructions, showing a cross-sectional and a top-down view of a Split Die Glass Core Substrate package (**a**), and a Glass Body package (**b**), identifying the generic order-of-magnitude dimensions and showing a PoP'ed memory

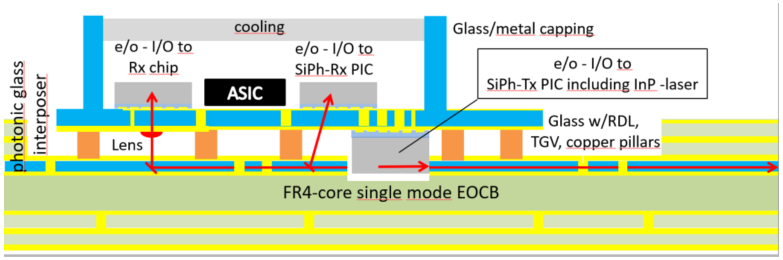
Glass body

With integrated optical lenses

assembled on EOCB



Embedded in EOCB



Source(s): ...
Author(s): Dr. Henning Schröder (IZM) et al.
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Forschungsschwerpunkt
Technologien der
Mikroperipherik

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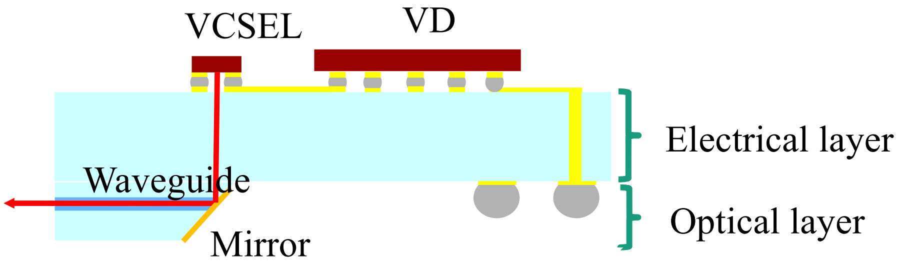
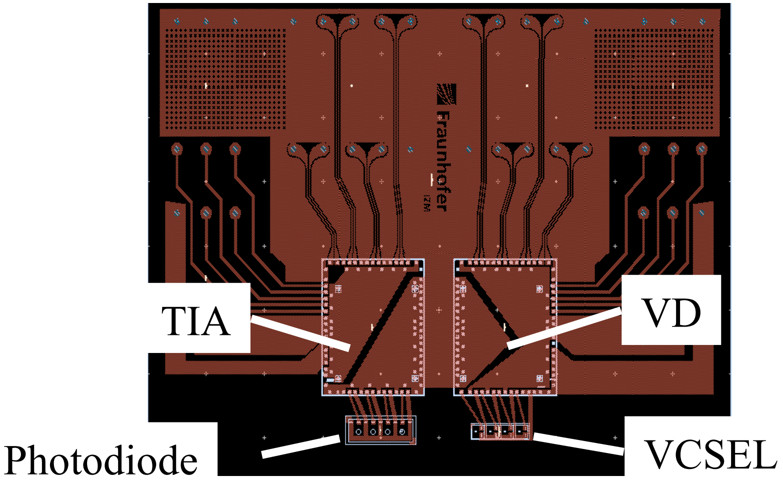
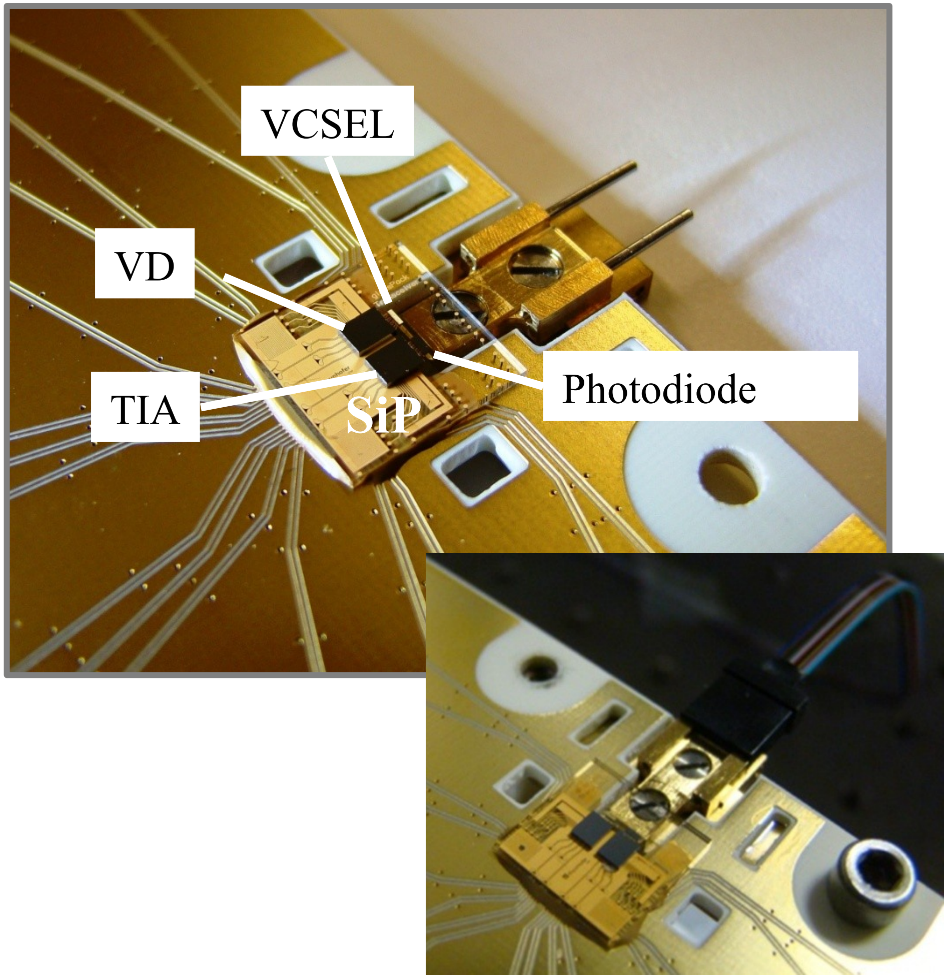
IZM

Electro-optical Transceiver technology







FEATURES

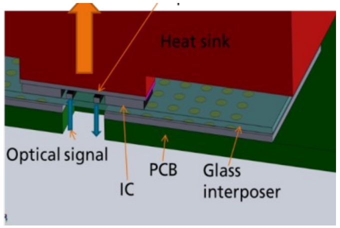
Datarate: 4x10Gb/s

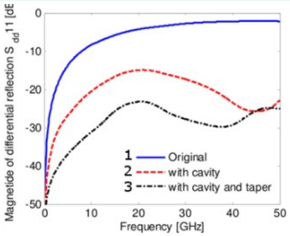
Wavelength: 850nm

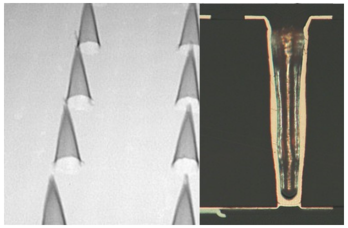
Fiber interface: MT-fiber ribbon cable

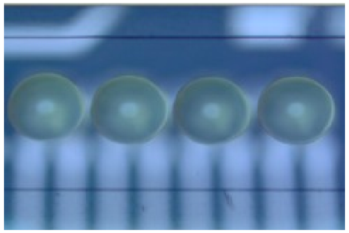
Hybrid glass interposer for Mid-Board-Engines with high RF and optical performance

Process steps

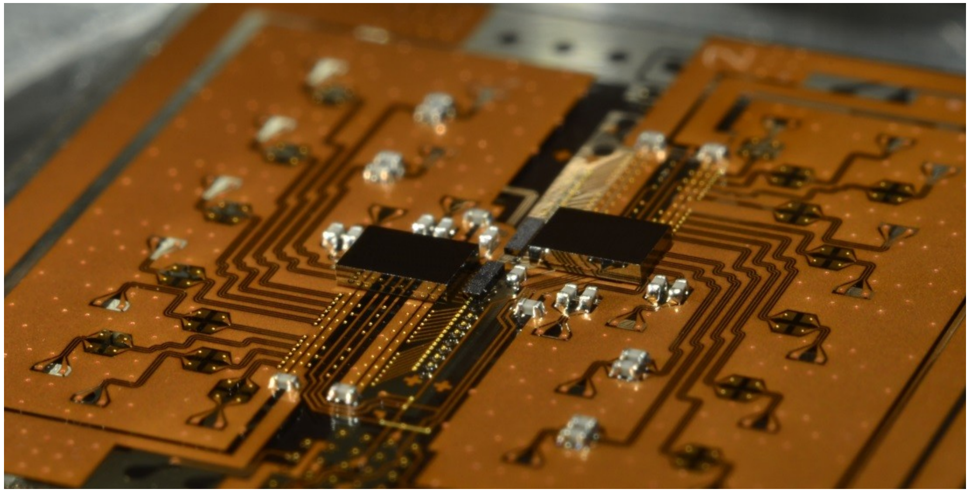






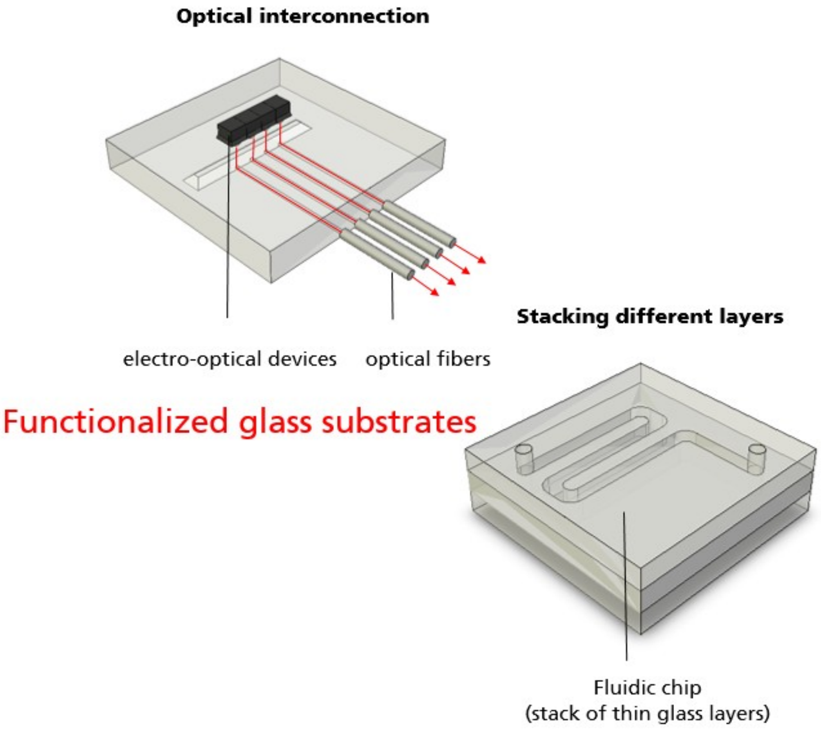


First Hybrid Glass Interposer for Mid-Board-Optical Engines



- Effective interposer cooling method
- Working 25 Gbit/s/ch
- Simple wafer level process for TGV processing
- Collimated beam for standardized connectorization
- Very low optical losses (0.5 dB Rx, < 2 dB Tx @ 2mm)
- Up to 12 ch TRx with < 1.6 dB losses possible

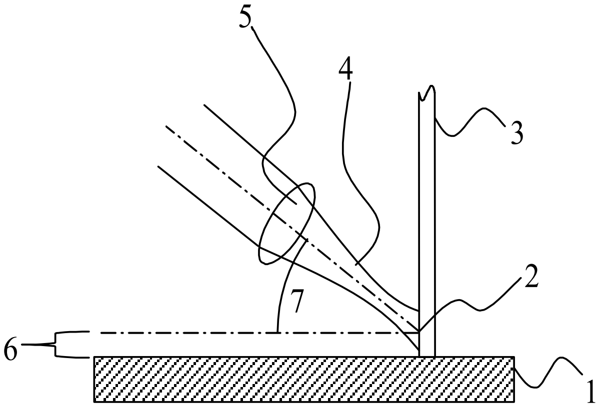
Outline

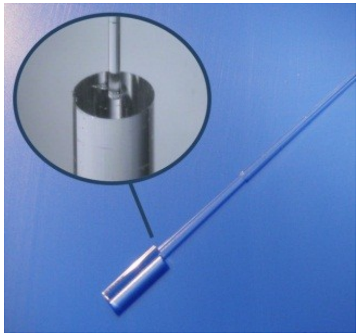


- **Motivation** for glass in ph
- Photonic **system integra**
  - PCB level: EOCB, integrated c lamination, assembly of conn
  - Interposer level: lens arrays,
- **Interconnection technologies**
  - Optical fiber direct fusing
  - Fluidic interconnects
  - Assembly using active alignment and glass made building blocks

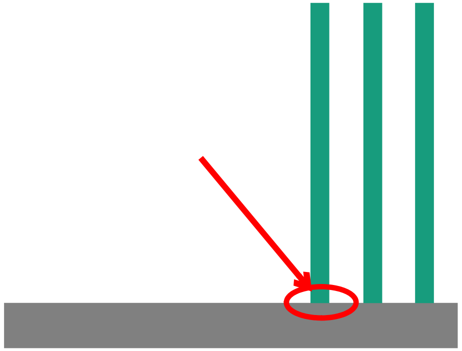
Joining fibers and capillaries in tight arrays to substrates

- patented optical fiber to bulk glass laser bonding (fused silica to B33 glas)
- also usable for tight fiber arrays + capillaries

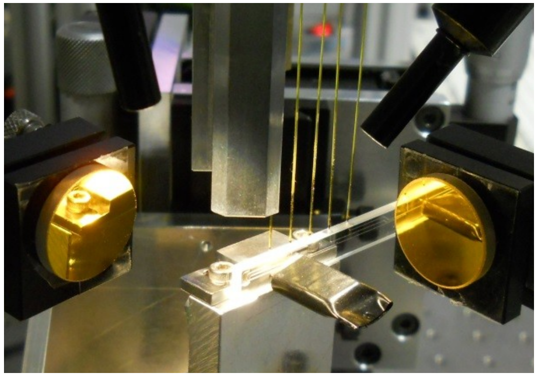




laser fused fiber cap
(or other micro optics)

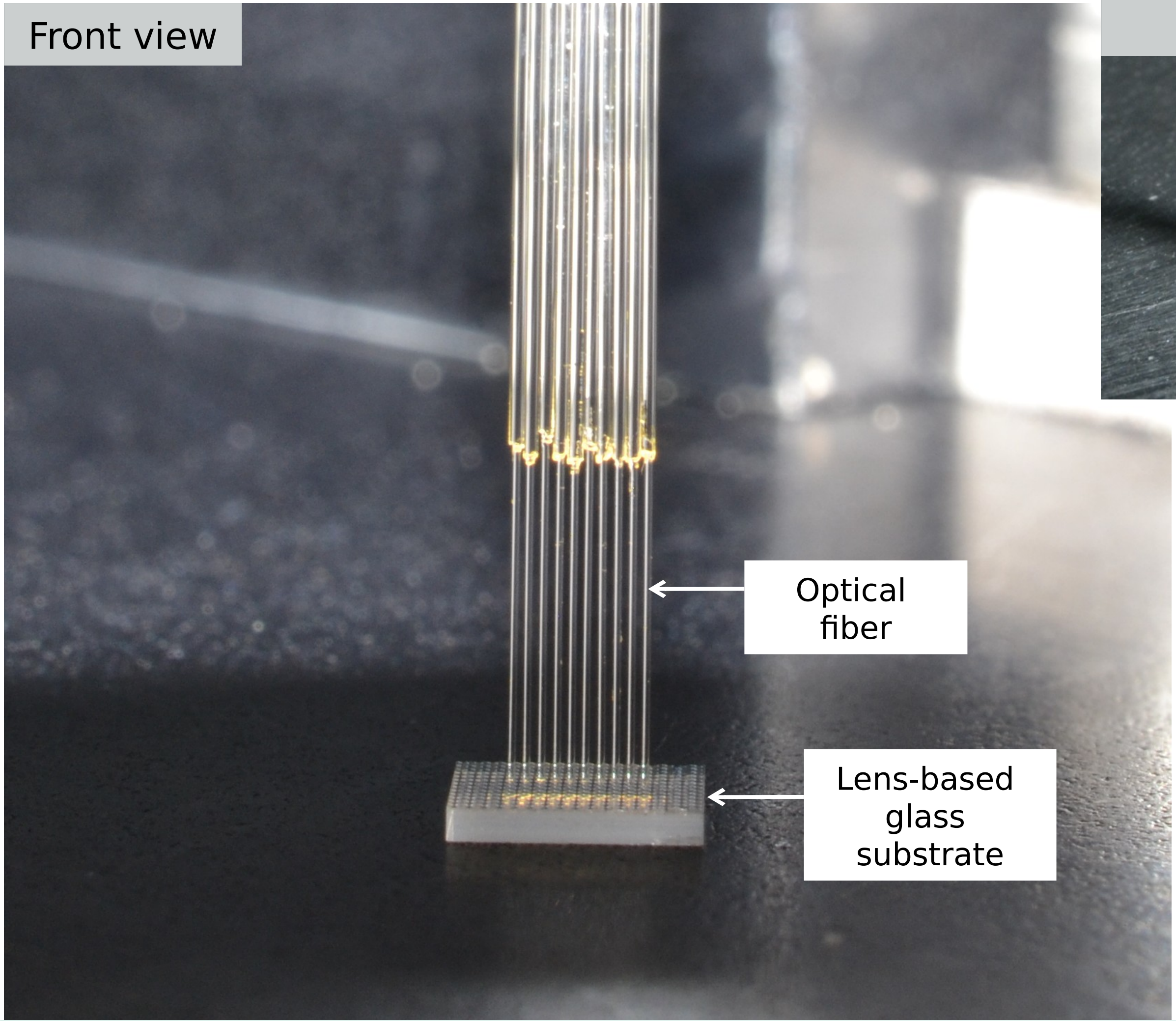


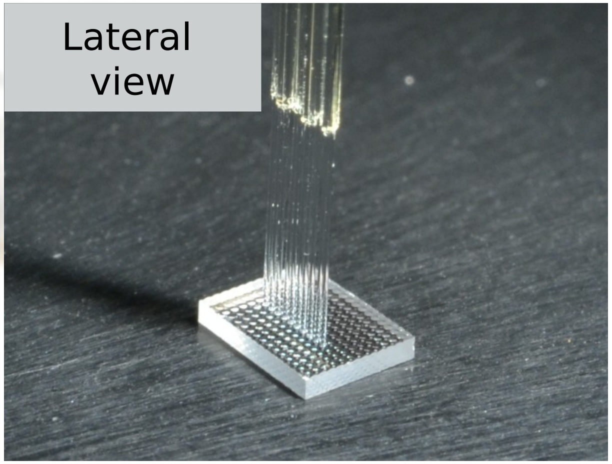
sequential laser process
position accuracy < 5µm



laser fusing of capillaries to chip
here: 5mm pitch (< 2mm possible)

Laser-welding process: 10x1 fiber matrix

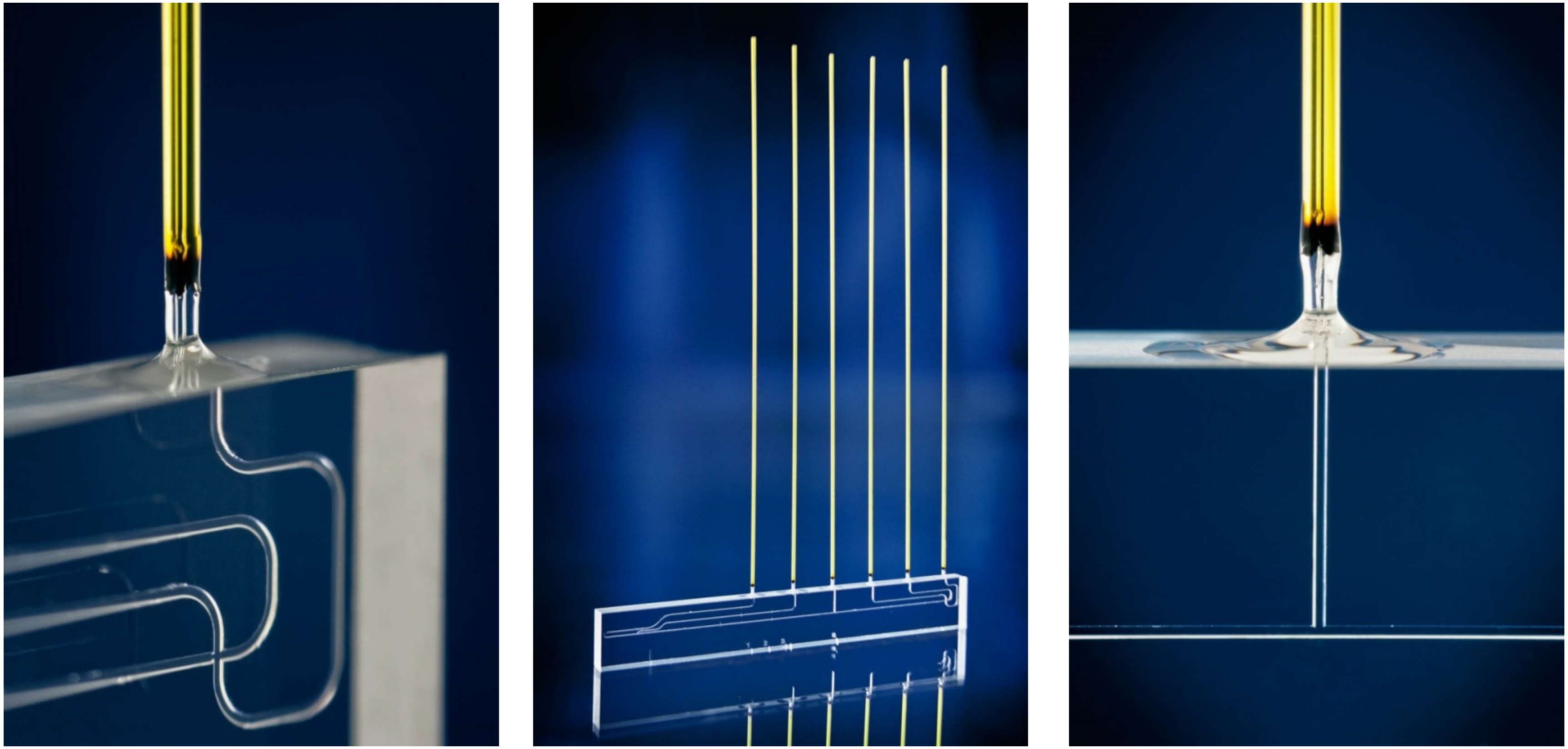




- Pitch: 250µm
- Stable and robust connection
- Fast process

- Fibers welded to the flat side
- Substrate provided by Compass-EOS

Multiple capillary interconnects to bio-fluidic chip



- highly precise + repeatable
- no epoxy in optical/fluidic paths
- induced stress seems acceptable
- withstands thermal cycling (-55..+125°C)
- additionally: capillary bending (R ± 0.05 mm)
- $p_{max} > 150$ bar

Miniature Spectral Tissue Sensing Device

Chip packaging incl. optical interconnnects

InSPECT goal:

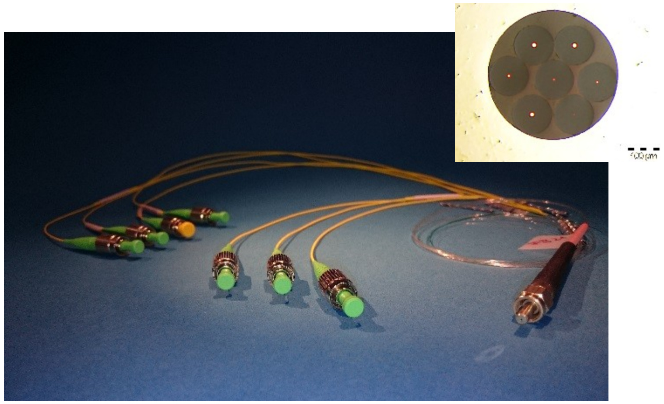
- Broad-band VIS-NIR spectrometer based on an interconnected PIC chip: low-cost, compactness and high spectral resolution

Work at IZM:

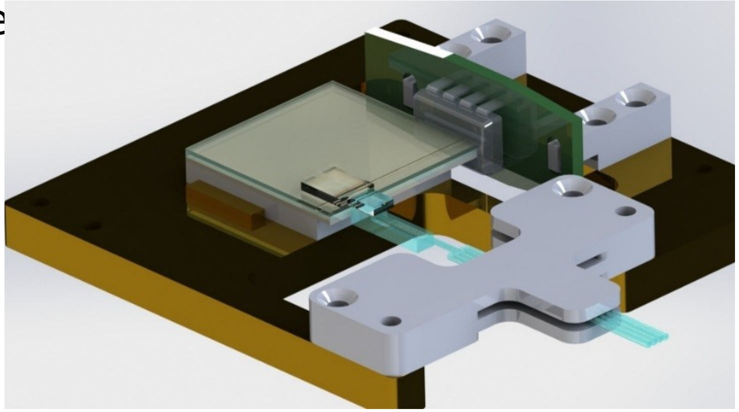
- Defining a broadband MM-to-SM converter
- Design and fabrication of a robust chip package
- Assembly strategy in cooperation with partne

Result:

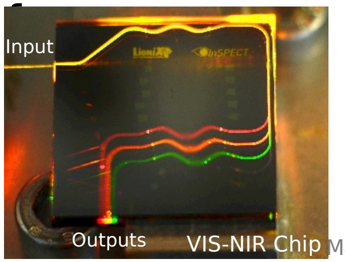
- Packaging strategies for photonic chips operating at visible wavelengths
- New field: Imaging diagnosis f



1x7 Fiber bundle for optical interconnecting



Package concept of a VIS-NIR photonic chip



Marx, J. Herter, N. Arndt-Staufenbiel, V. Zamora-Gomez, H. Schröder

PhotPack – A new approach for 3D Photonic Module Packaging invented

Assembly of optical systems with highest accuracy and stability

Panel Glass Holders and Base Plates

- glass parts quickly designed and laser- cut on IZM panel glass green + CO_2 laser
- various optical and electrical-optical components may be held and fine-aligned

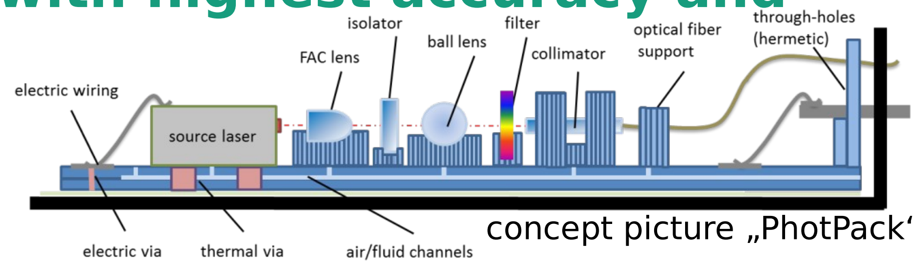
Directy lasered RF leads

- sputtered thin films can be designed and structured for > 40 GHz frequencies
- stable bonding to pads on glass shown

Cooling through glass vias

- through-glass-vias (TGV) can be metal filled for thermal conduction

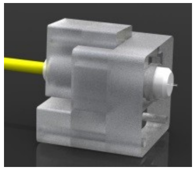
Patent pending

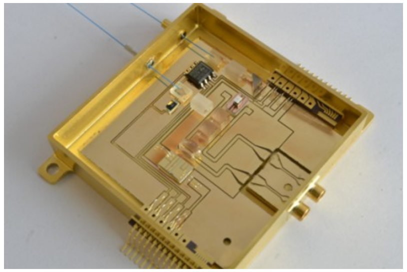


concept picture „PhotPack“

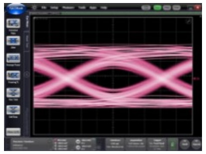
diverse laser-cut glass parts

alignable optical fiber holder

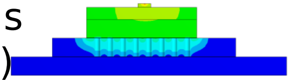




metallized glass assembly plat-form for telecom receivers (100G-scalable)



thermal vias (simulated)



28 Gbps data (measured)

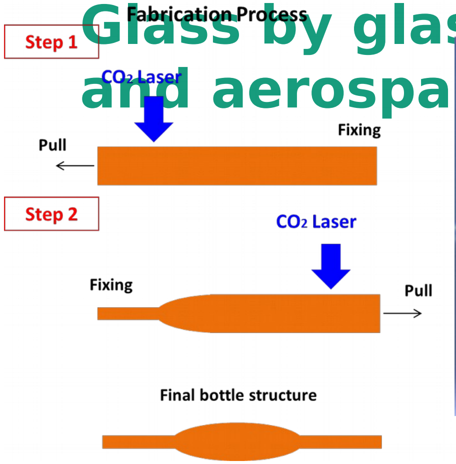
- G. Böttger, N. Arndt-Staufenbiel, S. Marx, M. Queisser, C. Tschoban, C. Ehrhardt, T. Nowak, M. van Dijk, H. Schröder

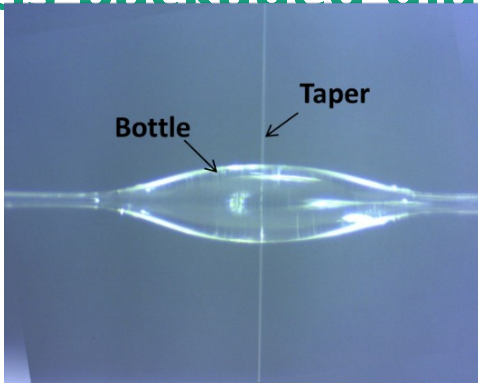
Technische Universität Berlin
Forschungsschwerpunkt
Technologien der
Mikroperipherik

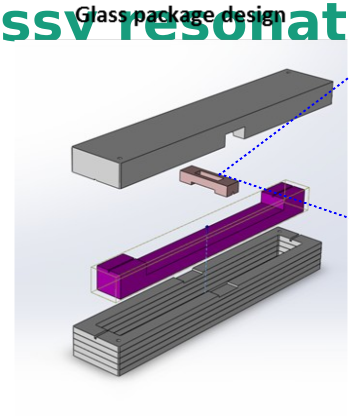
Fraunhofer
IZM

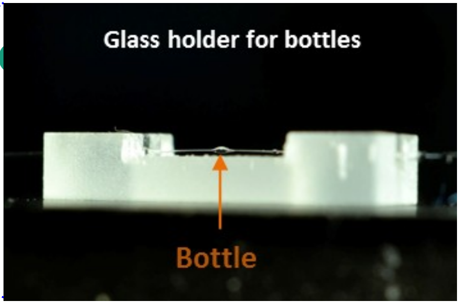
InMIRO – High-Q Optical Bottle Microresonators

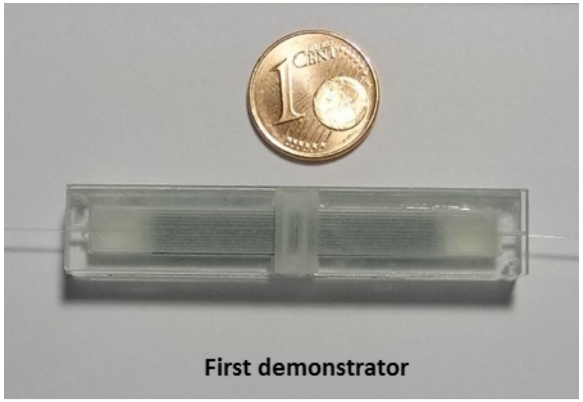
Glass by glass packaged glassy resonators f
and aerospa


Fabrication Process


Optical characterization


Glass package design




First demonstrator

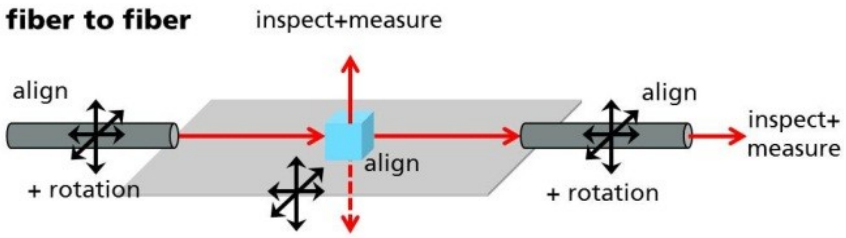
- A CO₂ laser and pull station (IZM design) to manufacture bottle-shaped glass fibers
- Laser-assisted structuring to fabricate a compact stacked glass package for optical resonators
- Application: Miniaturized optical bio- & gas sensor systems, and gyroscopes

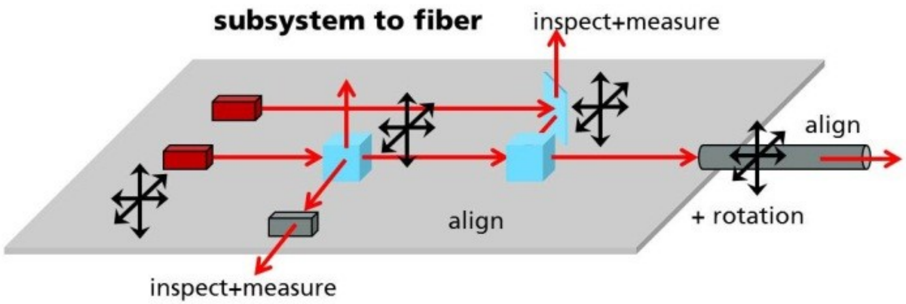

Transmission spectrum of the packaged resonator-taper module

Jonas Herter, Vanessa Zamora, Henning Schröder

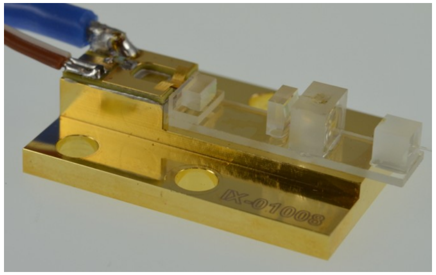
All-glass actively aligned assemblies

- active alignment of all-glass platforms
- efficient single mode coupling reachable



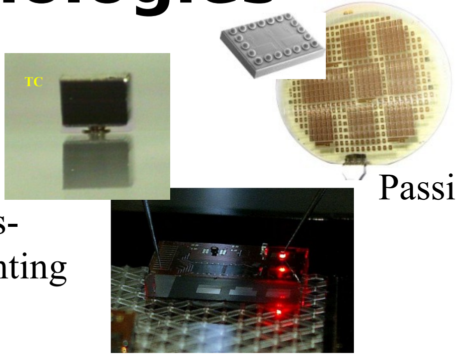


- placing accuracy better than 200 nm, 2 arcsec
- assembling with 6+ DOF



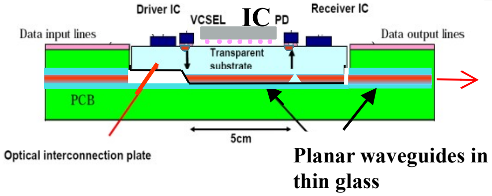
ficonTEC

Summary: Glass based photonic packaging – Technologies and Applications

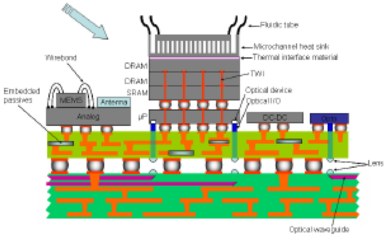


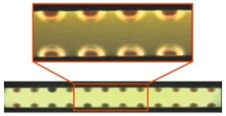
LEDPack,
Chip-on-glass-
Encoder, Lighting

Integrated
Passive Devices



Interposer for PCB integrated
e/o Tx/Rx, SiPhx





EOCB and Sensors

Optical waveguides made for optical interconnects in thin glass substrates

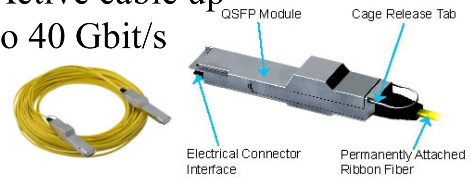
HF Design and thin film wiring on glass, TGV, glass deposition, cutting, bonding

Micro-lens integration, 3D stacking, bonding,

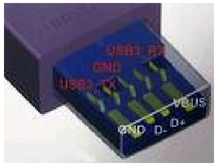
Assembly using active alignment and fiber coupling

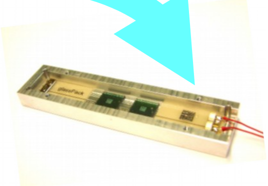
Fluidic integration

Active cable up
to 40 Gbit/s

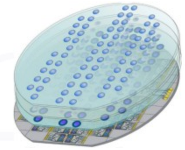


SuperSpeed USB 3.0
up to 25 Gbit/s





Microsensors
Fuel cell
Harsh and Hazardous Environments



Camera Chips

Take home

- **Motivation** for glass in photonic packaging
  - glass is green material with excellent mechanical, optical and electrical properties
- Photonic **system integration technologies**
  - packaging concept based on using thin glass as substrate material
  - Suitable for interposer, module, and large panel photonic packaging
  - EOCB, Tx/Rx, OBT, Sensors with integrated optical waveguides, stacking/lamination, assembly and connectors
- **Interconnection technologies at Fraunhofer IZM**
  - Optical waveguide integration by ion exchange
  - Lens array integration
  - Optical fiber direct fusing
  - Fluidic interconnects
  - Assembly using active alignment and glass made building blocks
  - Through glass vias and thin film processing for electrical wireing