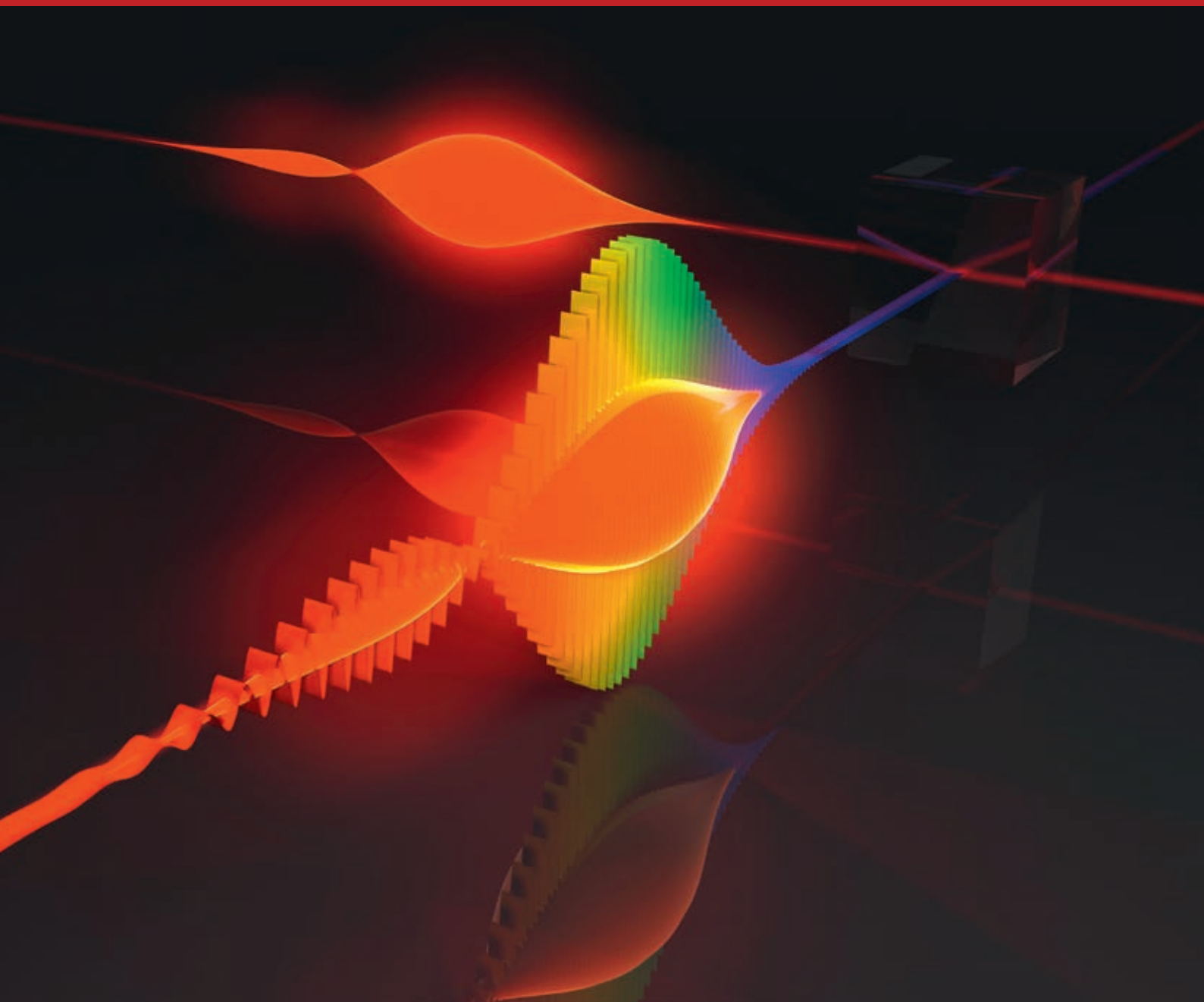
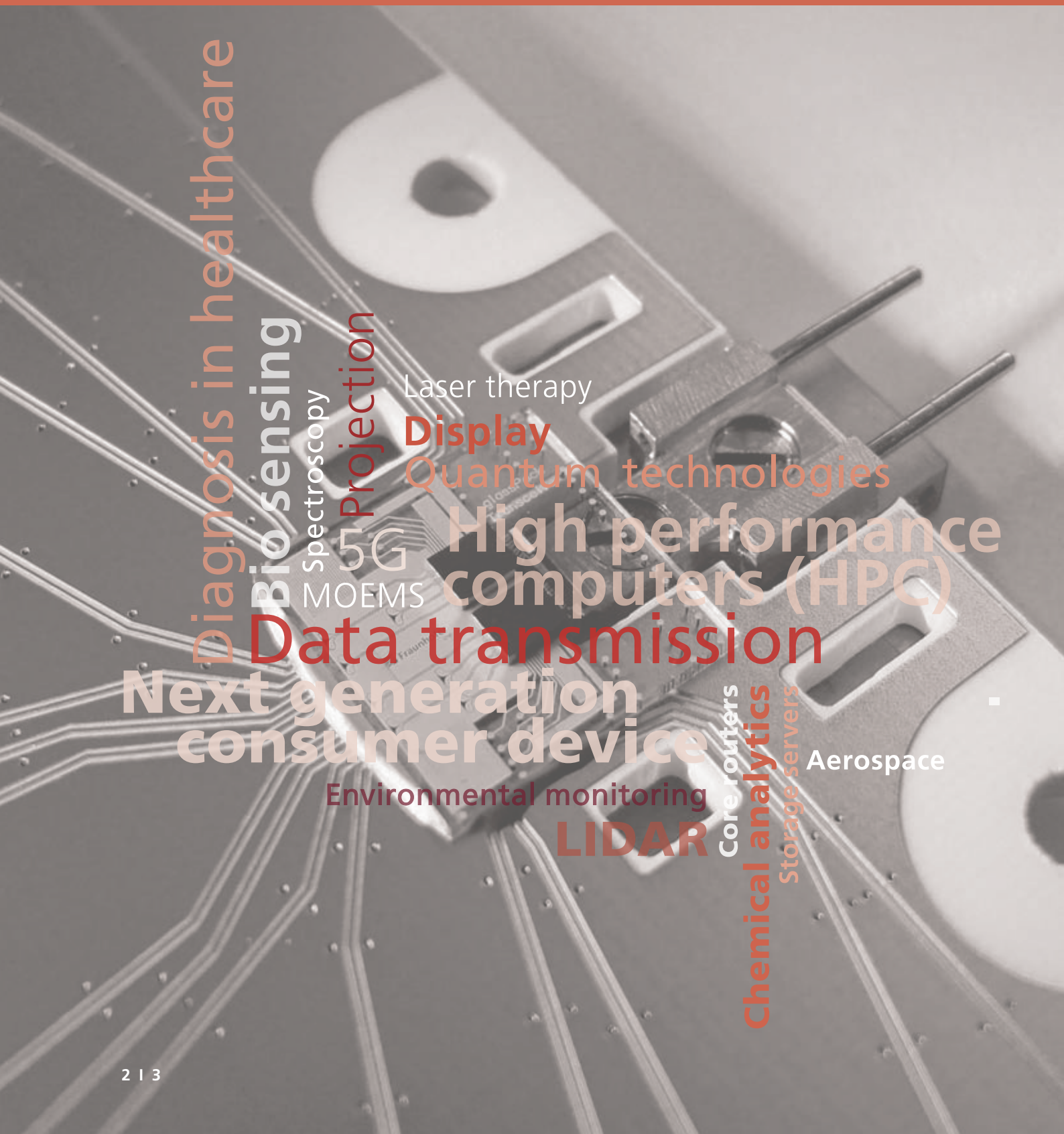
Fraunhofer
IZM

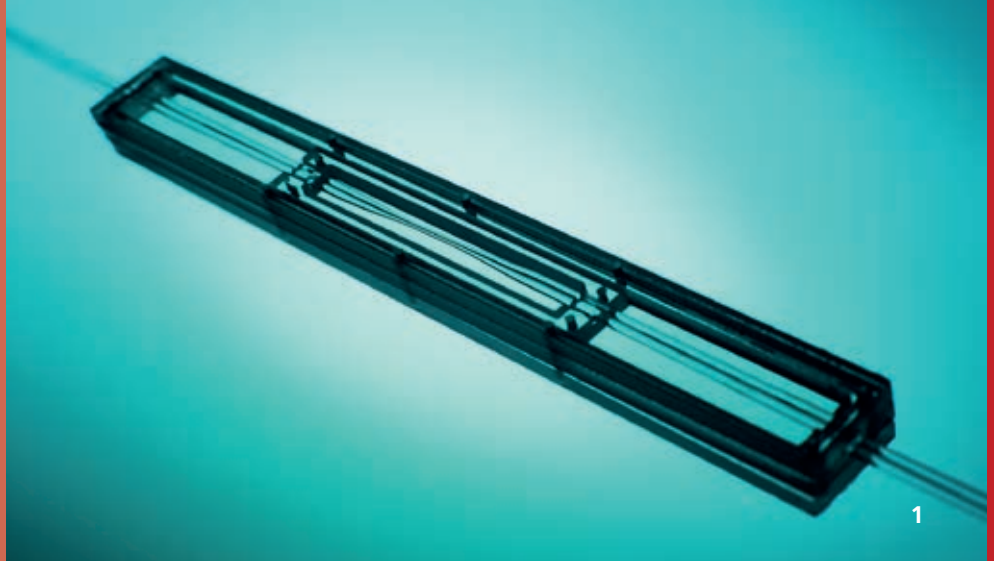
FRAUNHOFER INSTITUTE FOR RELIABILITY AND MICROINTEGRATION IZM

PHOTONIC SYSTEMS



PHOTONICS – COMMUNICATION, LIGHTING AND OPTICAL SENSORS





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2

We provide photonic system integration based on free space, fiber, and waveguide optical interconnects. Our services cover the entire range from design for packaging and prototyping to process development and transfer.

At Fraunhofer IZM, a wide variety of fiber optical components have been developed in response to growing demand in communication, sensing, healthcare, and other semiconductor laser applications. Fraunhofer IZM has all the capabilities needed to perform the passive and active alignment of light sources and microoptical elements for optimal coupling. Final assemblies can be constructed with established or purpose-built bonding and fusing processes – ready for transfer into industrial practice.

ONE-STOP DEVELOPMENT OF MINIATURIZED FULL-SCALE PHOTONIC SYSTEMS FROM THE DESIGN STAGE TO PROTOTYPE

OPTICAL INTERCONNECTION DESIGN, SIMULATION, AND ASSEMBLY

Optical fibers with different geometries and spectral ranges from UV to MIR can be designed and processed to create fiber components such as radial-firing fibers, fused couplers, lensed fibers, bundles, fiber caps, fiber-formed optical microresonators, bent fibers, connections for fiber-to-chip and fiber-to-GRIN lens coupling and many more. These components can be packaged with 2.5D glass stacking technology for full panel formats. Own processes allow optical wave guide integration into substrates.

CO_2 laser assisted systems offer a contactless method for processing optical fibers that applies heat in a specific area of the glass material. This allows the production of reliable fiber caps and direct connections between fibers (capillaries) and glass optical (microfluidic) chips. Single fibers or arrays of optical fibers can similarly be attached to glass elements, such as GRIN lens and substrates with integrated optics, to benefit from a crucial advantage: glue-less optical interfaces.

Fraunhofer IZM uses and develops advanced technologies to satisfy your optical interconnect demands, including:

- Design and simulation for photonic packaging including reliability
- High precision component alignment to reach highest coupling efficiency
- Application tailored fixing by gluing, welding, and soldering
- Single mode and multimode waveguide integration in thin glass sheets and polymer
- Optical characterization on material, component and system level

COVER

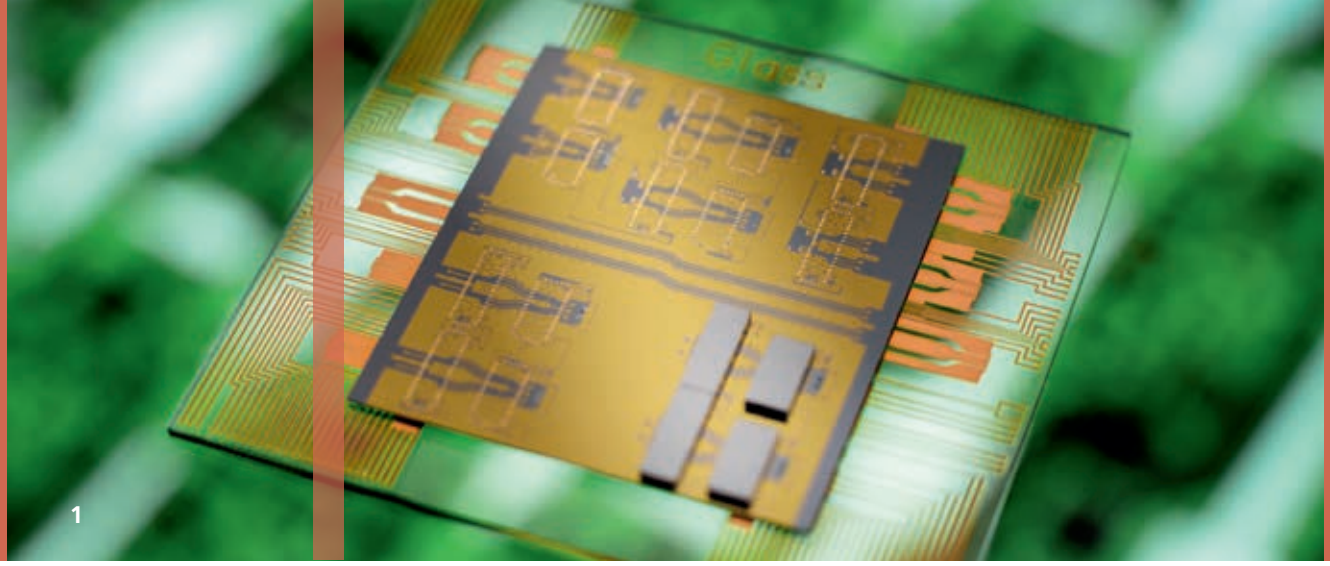
Optimal detection of a single photon by a precisely matched laser pulse

1

High reliability glass packaged 1x2 large-core fiber coupler

2

Packaging of customer spectrometer PIC based on SiN



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WAFER LEVEL PACKAGING

COMPREHENSIVE SUPPORT FROM LOW COST TO HIGH END

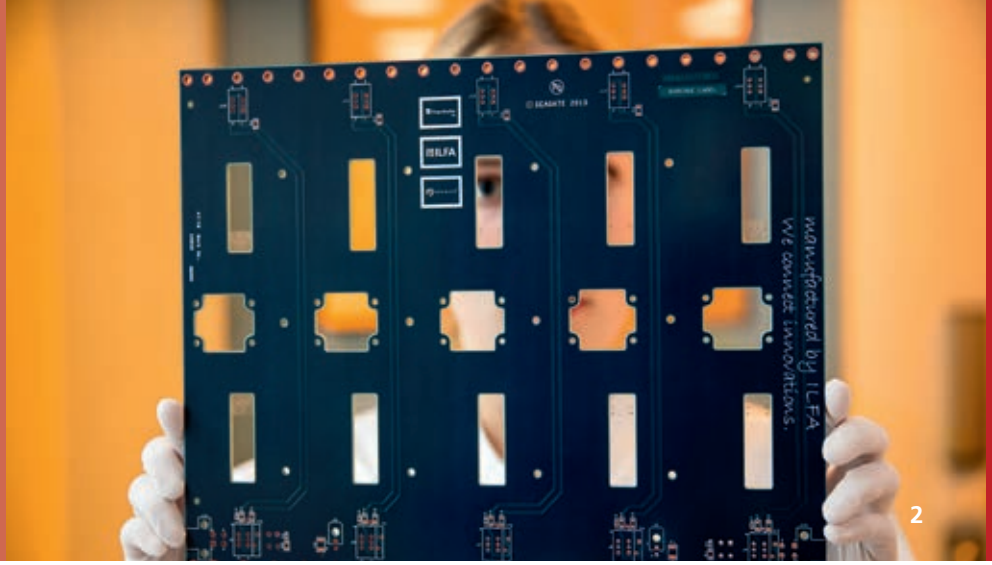
Most electro-optical components are based on compound semiconductors like GaAs, InP, or GaN. For flip chip applications, Fraunhofer IZM employs wafer-level bumping with gold-tin, gold, or nanoporous gold solders for use in fluxless assembly. With this technology, silicon-based drivers, TIA, or control circuits can be bumped and flip chip-bonded very close to active electro-optical devices.

Photonics ICs are possible with silicon or silicon nitride waveguides, using optical interfaces like optical mirrors or gratings and edge coupling features. These innovative ICs represent a platform for wafer level packaging, like 3D integration using TSV, RF-compatible multilayer signal routing, micro-bumps, and mechanical features formed in MEMS processes.

For passive optical coupling, precision flip chip assembly can be achieved at submicron-level accuracy by using thermode bonders with half-micron precision on substrates of up to 300 mm in diameter. Mass production becomes a viable option with solder-assisted self-alignment with and without mechanical stops. The technology also allows 3D chip stacking and hermetical sealing; capping wafers or chips can be attached and sealed vacuum tight even for bolometer or inertial MEMS applications compatible with applied getter depositions.

Fraunhofer IZM employs leading-edge technology for the cost-efficient development of reliable high-performance products, including:

- 3D integration using through-silicon vias, RF-compatible redistribution layers, and micro-bumping
- Permanent and temporary wafer bonding/debonding, hermetical sealing, and wafer thinning
- High-precision micro-assemblies, solder-assisted self-alignment
- 3D stacking chip-to-chip and chip-to-wafer or massive parallel assemblies



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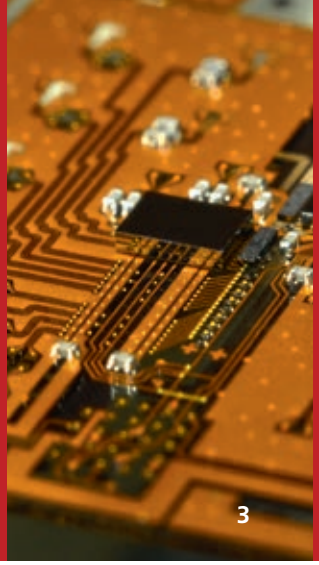


3

MODULE AND BOARD LEVEL INTEGRATION

Extensive automation allows the cost-efficient and fast assembly of even complex optical modules with fiber filters, prisms, and mirrors in photonic platforms. Our assembly equipment allows flexible applications from prototype to batch production, in communication, medical sensing, space, quantum technologies, Lidar.

Our established Electronics Manufacturing Services (EMS) portfolio has been expanded to include innovative optical component capabilities. A versatile range of interconnection processes, materials, and components is at your disposal to turn your product vision into a real-world success. All joining and interconnection processes can be tested for the conditions typical in industrial operations. Additional test cycles for more rugged environments can be implemented, including destructive tests with later analysis.

OUR PHOTONIC COMPETENCES ARE YOUR ADVANTAGE FOR INNOVATION AND TIME-TO-MARKET

Photonics in healthcare and bio sensing promise breakthrough solutions for detecting and measuring a wide range of biotargets, overcoming the current drawbacks of unwieldy and expensive diagnostic methods. Photonic packaging strategies play a key role in enabling optimum miniaturization and functionality. The competences and experience of Fraunhofer IZM continue to advance the state of the art, fiber-interconnected PIC spectrometer package and optical micro resonators. Innovative integration technologies have also been explored to bond opto-fluidic chips made from the same or different materials at room temperature, using laser-patterned double-sided adhesive tapes.

Our PCB activities are focused on embedded glass-based EOCBs with integrated, gradient-index, single or multi-mode waveguides, which exhibit very low propagation loss. A pre-processed glass panel with planar-integrated optical waveguides is embedded into PCBs with proven industrial processes.

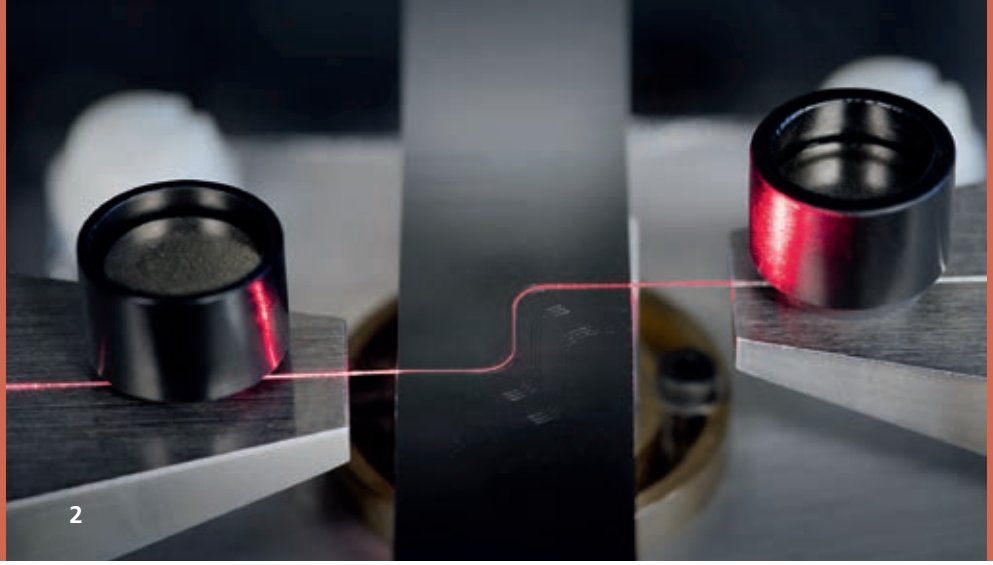
Fraunhofer IZM employs cutting-edge technologies for photonic system integration on all packaging levels as:

- Assembly using automated passive and active alignment of optoelectronic and micro-optic components
- Fiber and ribbon etching, lensing, fusing and assembly to PIC and laser components
- Optical wire bonding and out-of-plane coupling
- PCB integration of optical waveguide layers made of thin glass and polymer, connectors
- Hybrid assemblies for multifunctional chips (electric/optic/fluidic) and appropriate module integration

1
Photonic 3D interposer with electronic and optical add-ons assembled on a glass substrate

2
Electrical-Optical Circuit Board (EOCB) with thin glass integrated optical waveguides for Datacenter

3
On-board optical transceiver realized on transparent glass



PHOTONIC SYSTEM DESIGN AND QUALIFICATION

FROM DESIGN AND SIMULATION TO CHARCTERIZATION – THE WHOLE VALUE CHAIN

Serious development in photonics begins with a good design and simulation and should be followed by the qualification of the prototype. Fraunhofer IZM can rely on outstanding capabilities for integrating elecronic components, and has adapted and optimized these to master the challenges of integrated photonics for the future.

EVALUATION AND DESIGN:

Photonic components and subsystems

- Building blocks for photonic integrated circuits (PICs) and subsystems for PON, access and metro networks, inter- and intra-DC interconnects, 5G, IoT, LiDAR and sensors
- PDK development for monolithic and heterogeneous integrated platforms (SoI, SiN, polymer, glass and InP)
- Plasmonics: CMOS-compatible building blocks

Electromagnetic simulations for photonics

- Microwave, RF and wireless design taking into consideration signal integrity
- Design of conventional and electro-optical PCBs and interposer

Co-design for photonic and electrical integration and subassemblies

- 3D integration and packaging
- Photonic co-package (system in package, system-on-chip)
- Photonic chiplet

QUALIFICATION:

On chip

- DC characterization (L-I-V curves, optical spectrum, temperature behavior)
- Small-signal measurements (S-parameter, RF adjustment, resonance behavior)
- Large-signal measurements (eye charts, Q-factor, extinction, bit pattern effects, bit failure rate measurement up to 50 GBd and for different modulation formats, optical transmission experiments)

Photonic interconnect systems

- Transmission measurement (rack-to-rack, board-to-board, chip-to-chip transmission, eye/constellation diagrams, bit error-rate)

RELIABILITY AND THERMAL MANAGEMENT

Thermal management is a key challenge in most of today's photonic systems, as power loss density increases with increasing functionality and extreme temperature stability is a cornerstone requirement for data communication in particular. This makes efficient heat dissipation an essential factor for optimizing the reliability and life expectancy of products. The heat generated in chips is dissipated through several substrates, thermal interface materials, and heat spreaders before being dissipated into the environment. Each of these components affects the system's thermal resistance and has to match the demands of the application in question.

Using simulation and experiments, the thermal path can be laid out for maximum efficiency already during the design phase, which improves reliability and lifetime significantly. The chosen materials would typically have different thermal expansion coefficients.

Fraunhofer IZM also offers comprehensive reliability analyses addressing the thermo-mechanical stresses generated during assembly and operation. Analyses are not only based on reference data, but on individual measured values taken from the used materials. Finally, the simulations would be tested against the results of accelerated aging tests.

Our insight into the underlying failure mechanism allows us to not just define the reliability, but also develop recommendations for our clients based on very specific, defined improvement targets. Our services in this area include

- Thermal and thermo-mechanical simulation, optimization, and characterization
- Thermal characterization of thermal interface materials
- Accelerated aging (thermal and operating cycles, temperature and moisture, vibration, temperature shock, UV and daylight ...)
- Electromigration

OPTICAL COUPLING EFFICIENCY AND RELIABILITY ARE GUARANTEED BY APPROPRIATE DESIGN AND MATERIAL SELECTION

1
Electro-optical analysis

2
Polymer optical flex

FRAUNHOFER IZM – YOUR PARTNER FOR PHOTONIC PACKAGING

FEASIBILITY STUDIES
PROTOTYPING
DEVELOPMENT PARTNERSHIP
MANUFACTURING SERVICE
PROCESS TRANSFER

We offer a range of services in photonic packaging, including:

Manufacturing and assembly of optical and microelectronic components

- Passive and active sub-micron alignment of photonic components
- Wafer and panel size processing
- Fiber optical pig tailing, fiber arrays, lensed fiber
- Etching and fusing of fibers and capillaries

Electro-optical circuit boards

- E/o design and waveguide layouting
- Full PCB integration of glass waveguide panels
- Ion exchange for glass embedded single- and multi-mode optical waveguides

Photonic interposer

- Wafer-level integration
- Bumping and flip chip bonding
- Wire bonding

Enhanced photonic and plasmonic systems

- Design and manufacturing of smart photonics integrated circuits (Silicon nitride, polymer)
- Benchmarking of photonic interconnects

Simulation, design and quantification

- Thermal, mechanical, optical and RF
- Zemax, Comsol, Optiwave, OptiBPM
- Single and multi-emitter beam forming and combining
- Optical system design and tolerance analysis
- Simulation of high efficient optical mode coupling interfaces

Qualification, failure and reliability analyses

- Variable ambiance and harsh environment testing
- Beam profile analysis, near/far field analysis
- Refractive index profile, spectral transmission, insertion loss, numerical aperture

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