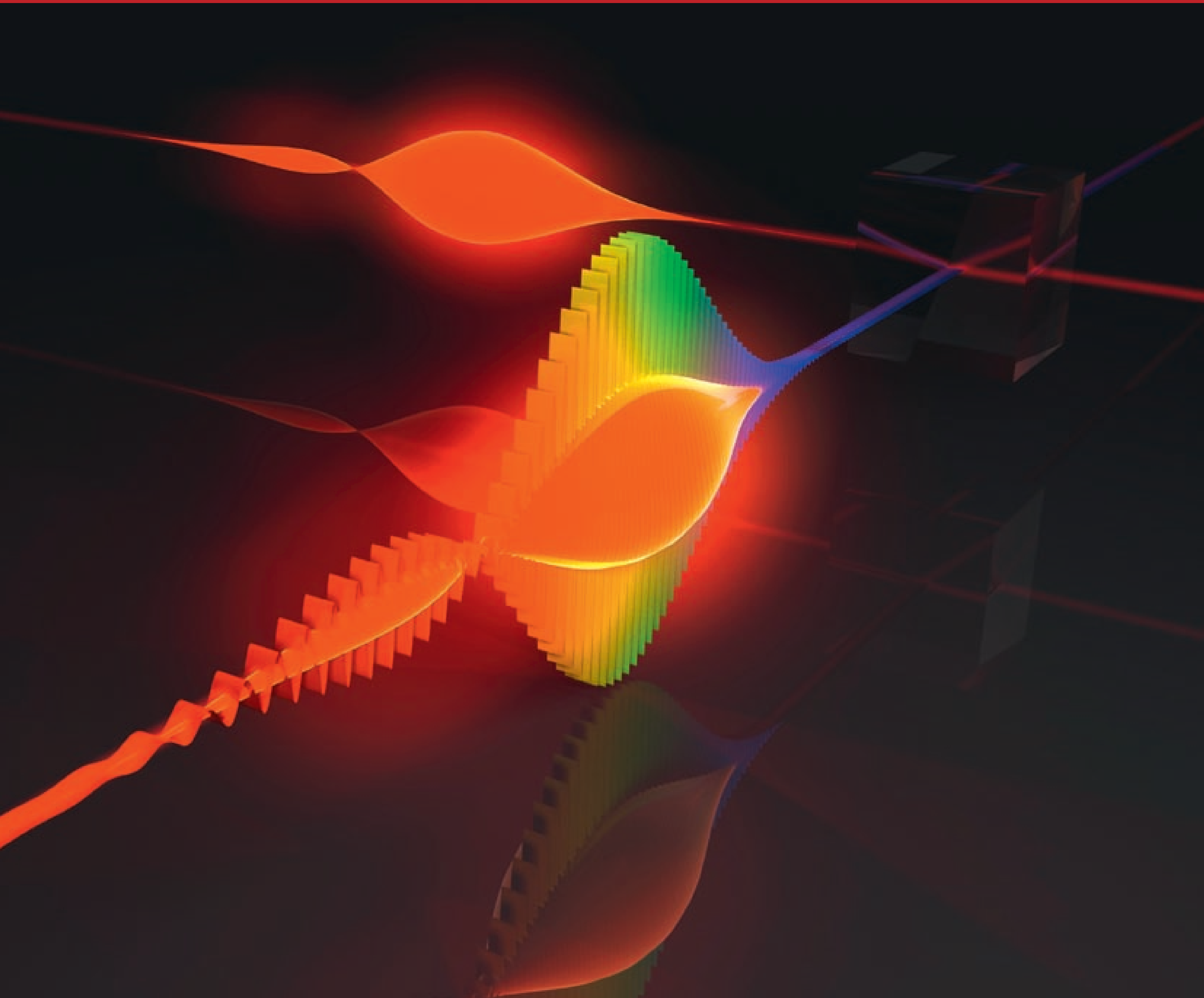
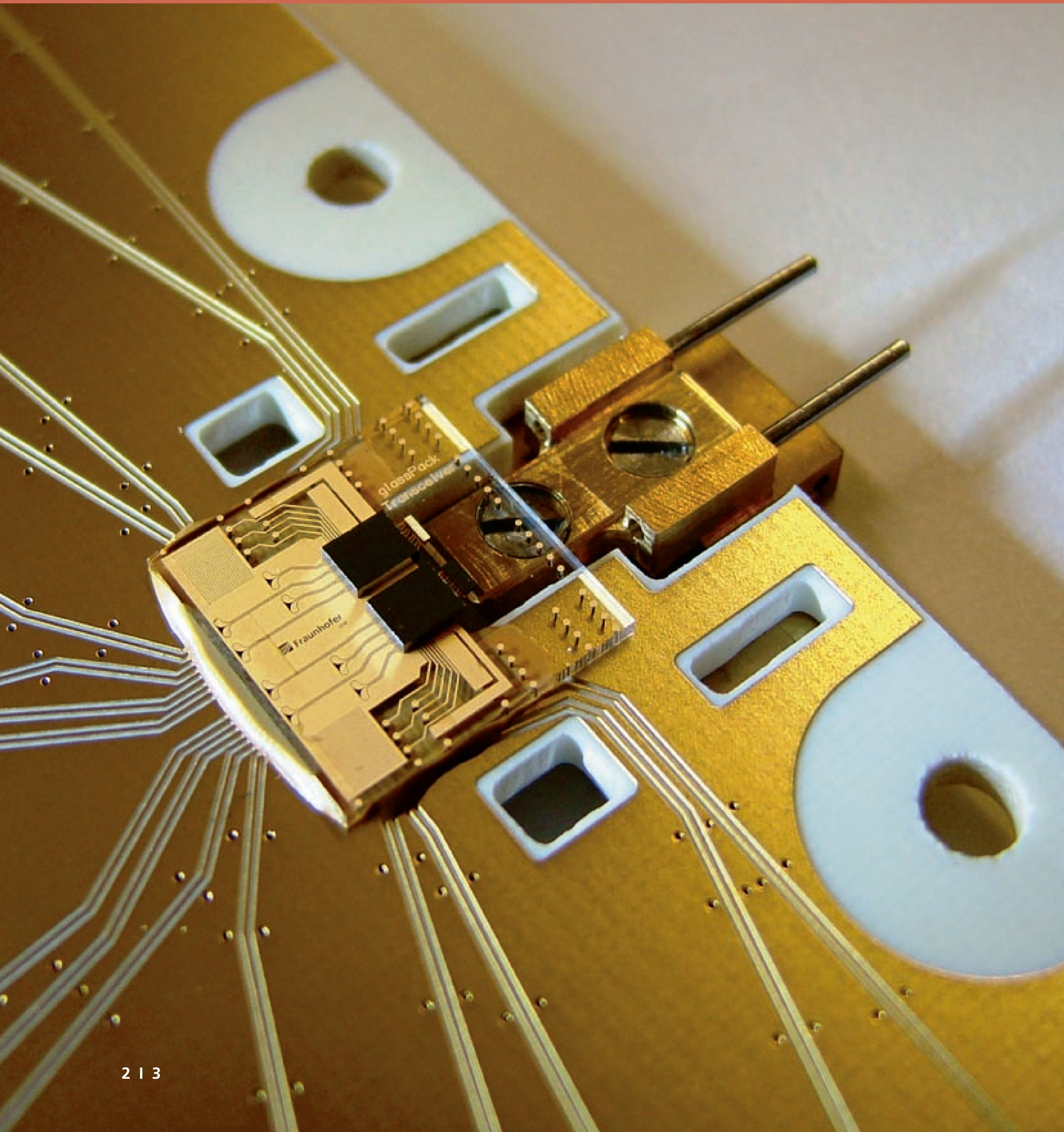
Fraunhofer
IZM

FRAUNHOFER INSTITUTE FOR RELIABILITY AND MICROINTEGRATION IZM

PHOTONIC SYSTEMS



PHOTONICS – COMMUNICATION, LIGHTING AND OPTICAL SENSORS



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Photonic technology is the use of photons to meet human needs and today extends into every sphere of daily life. Since its first archaic use as artificial light in the form of fire, it has now come to assume a key role in modern, efficient lighting, ultra-fast data transfer and processing and in sensors for the environmental, transportation, industry and medical engineering industries. Modern materials processing is also unthinkable without photonic technology. Increasing functionality, smaller space and high power densities are the main challenges. As a result of this complexity reliability issues become more and more important as every link in the chain has to be uniformly highly reliable. Meeting this challenge cost-efficiently, while at the same time advancing photonic technology, increasing functionality and maximizing resource efficiency, is Fraunhofer IZM's goal.

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

3D INTEGRATION, ASSEMBLY AND OPTICAL INTERCONNECTION

Prior to assembling optoelectronic and optical components, an optical simulation of the systems is generally the first step to determine the optimal layers and tolerances. This information is used to operate modern pick-and-place equipment. During assembly with such equipment active alignment is used to place laser diodes, optics and fibers with < 100 nm accuracy for x/y/z and only few arc seconds around the three axes, equating to level of precision two times greater than that of electronic components. Targets vary according to the application, however high bandwidth with low crosstalk, high energy efficiency and good EMC are key parameters.

To achieve the best possible results Fraunhofer IZM uses the following technologies:

- Adhesive bonding of microoptics using UV/IR-radiation systems with defined/minimal shrinkage
- Automatic active alignment at < 0.5 µm tolerance
- Fiber optical tapers and non-adhesive, direct joining of glass fibers to micro-optics

COVER

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

LEFT

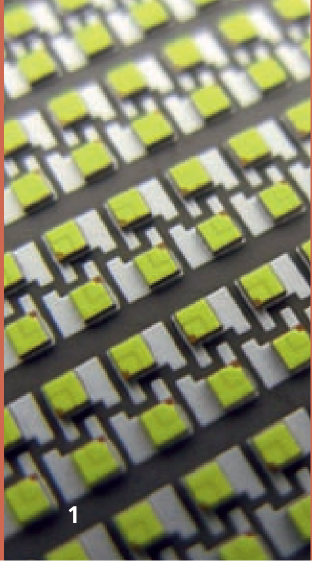
GlassPack: Electro-optical transceiver with bidirectional 4 × 10 Gbit/s

1

ADOSE: Multifunctional optical sensors for automotive applications

2

3D wafer level packaging of a micro camera



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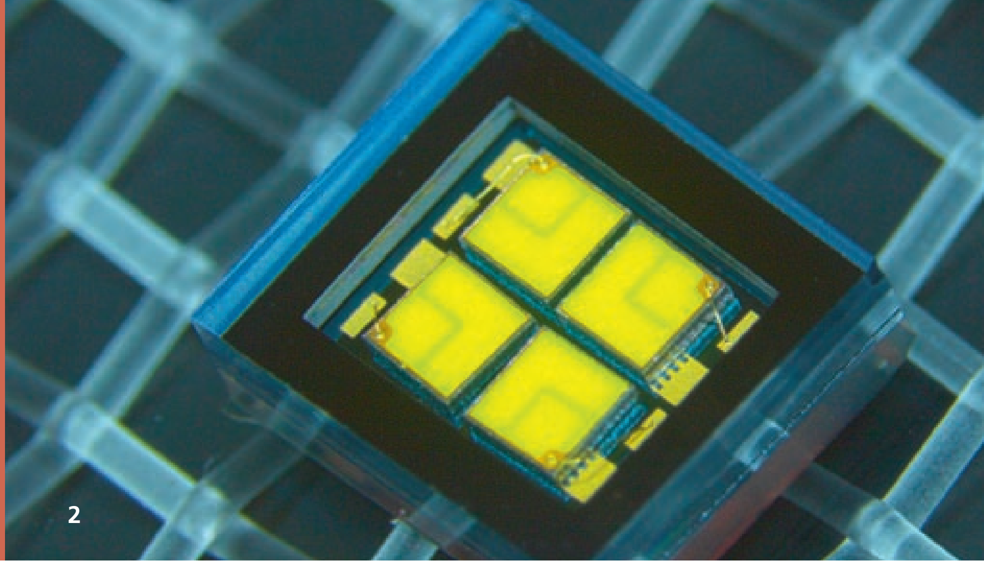

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SOLID STATE LIGHTING

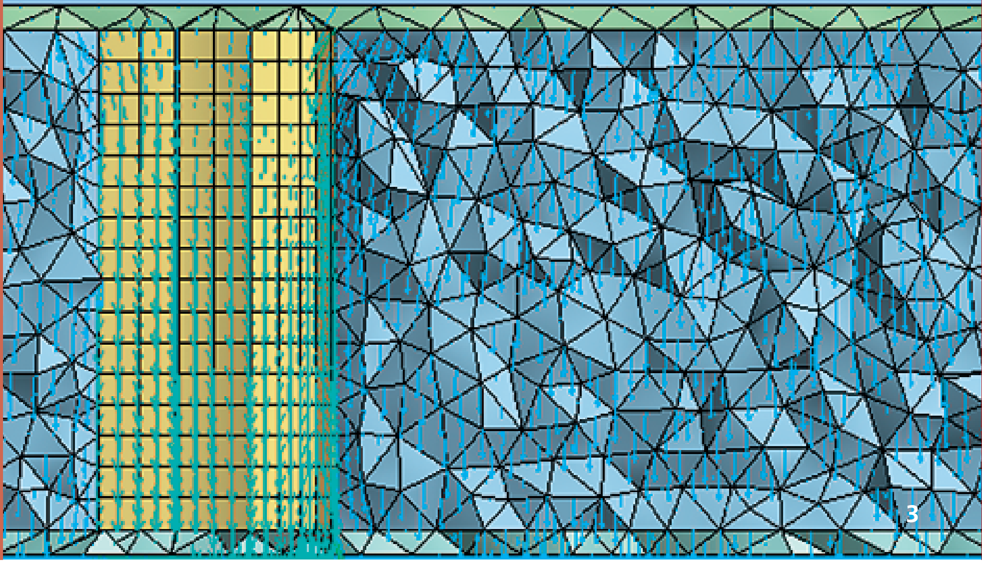
COMPREHENSIVE SUPPORT FROM LOW COST TO HIGH END

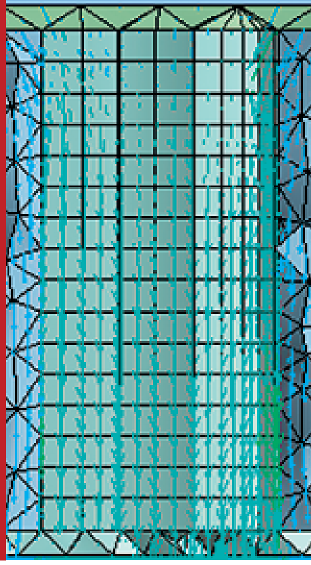
LEDs already make up a notably high proportion of the general lighting market. Moreover, it is continuing to expand into other areas of lighting, from interior to outdoor lighting , vehicle components, materials processing, through to medical applications and analytical equipment. The efficiency of today's solutions is already close to that of fluorescent tubes and can be expected to double in the future. Apart from the natural evolution of efficiency over time, technology advancements like the integration of sensors, bidirectional communication and integrated color adjustment can revolutionize the field.

These challenges and the corresponding solutions are key research areas at Fraunhofer IZM. New interconnection techniques help to keep the operating temperature of LEDs low and thereby improving power efficiency. Multi-die bonding of very small chips is also used to provide more flexible thermal dissipation designs in a cheap manufacturing process. In the area of integrated functionality we develop both, high-end solutions using 3D silicon packaging and high volume lamination and interconnection processes on board-level.

Consequently, Fraunhofer IZM has the right services to help its customers develop cost-efficient and reliable products, including:

- Advanced interconnection techniques to improve efficiency and lifetime
- Integrated functionality using 3D silicon and PCB technology
- Improved color homogeneity
- Customized developments like hermetic modules, assembly of substrate-free LEDs, high power density on specialized substrates
- Characterization, failure and reliability analyses
- Thermal and thermomechanical design, simulation and characterization





RELIABILITY AND THERMAL MANAGEMENT

Thermal management is a key challenge in most of today's photonic systems, because power loss density increases with increasing functionality or extreme temperature stability is a cornerstone requirement especially for data communication. Efficient heat dissipation is consequently an essential factor in optimizing reliability and lifetime. The heat generated in the chip is dissipated through several substrates, thermal interface materials, and heat spreaders before being dissipated to 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 already be laid out for maximum efficiency during the design phase, which improves reliability and lifetime significantly. Typically the used materials have different thermal expansion coefficients.

Fraunhofer IZM also offers comprehensive reliability analyses addressing the thermomechanical stresses generated during assembly and operation. Analyses are not only based on literal data, but on individual measured values, taken from the used materials. Finally the simulation is correlated with the results of accelerated aging tests.

Understanding of the underlying failure mechanism then allows us to not just define the reliability, but also to develop recommendations for our clients based on very specific, defined improvement targets. As an overview, we provide:

- 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

RELIABLE THERMAL DISSIPATION AND LONGTERM-STABILITY AT SUB-µ SCALE

1

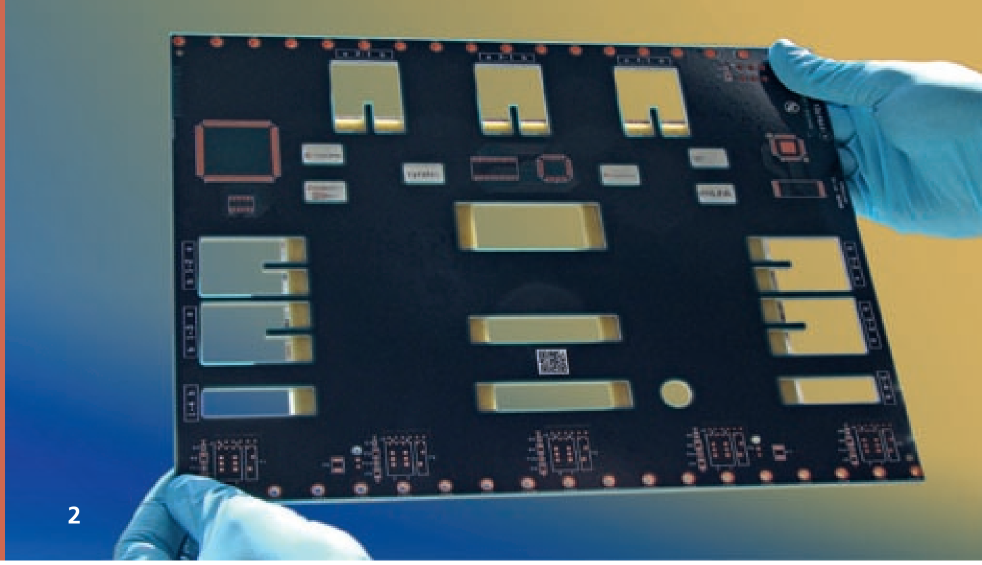
1,200 W high power LED module with sinter technology

2

Hermetic package for solid state lighting and sensors

3

Thermal flow simulation of submounts and through silicon vias



ELECTRO-OPTICAL INTEGRATION ON SUBSTRATES

INTEGRATION OF OPTICAL AND ELECTRICAL SIGNALS FOR MAXIMUM COMMERCIAL POTENTIAL

Establishing photonic packaging for an existing product often requires a complete redesign. But the new architectures (3D integration), materials (glass and silicon photonics) and underlying mechanisms (plasmonics) also open up new design possibilities. Suitable application areas include above all tele- and data communications, as well as sensors, lighting and projection technologies. The surface area necessary for the application is a key determinant of which technology is selected.

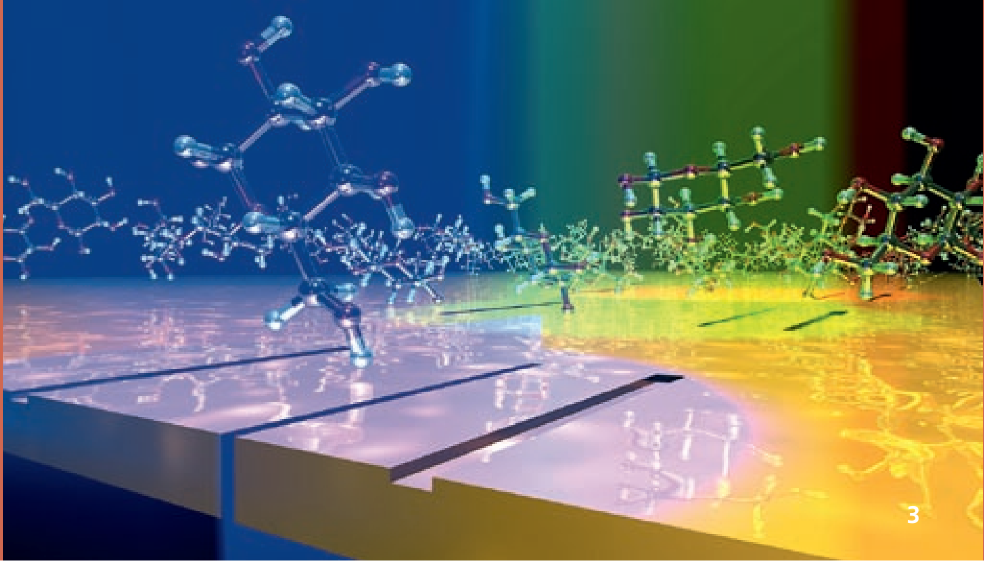
For this reason, Fraunhofer IZM takes a three-pronged approach on PCB-level:

- Thin-glass substrates with integrated multimodal gradient index optical waveguides
- Polymer-based substrates with integrated optical step-index waveguides
- Embedded technology and lamination with standard PCB materials

Designers of optical system platforms have to integrate optical components of steadily increasing performance into continually shrinking build spaces. Moreover factors like single mode optics, heat dissipation, current density and loss of electrical signals must be taken into account.

Optical integration of signal paths at module level is possible here by:

- Structured silicon substrates/micro-optical benches with precision routing for component alignment by etching and ultra-precision milling
- Silicon-on-insulator (SOI)-based photonic components and platforms
- Thin glass-based substrates with multi-mode and single-mode gradient index optical waveguides
- Tailored interfaces for optical glass-fiber coupling



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FUTURE PHOTONIC SYSTEMS

Enhanced photonic systems is an approach to designing and building photonic systems in sophisticated ways. Plasmonics, whose potential does justice to its futuristic sounding name, is at the center of these new developments. Although plasmonic effects have been used for centuries to manipulate light, only today's understanding of the underlying physics allows us to harness these for specific goals. For example, it has led to the development of extremely sensitive sensors and allowed the acceleration of even fast glass-fiber technologies by several orders of magnitude.

Optical sensor technology is also entering a new era. Cost-efficient, reliable systems will be available for industries as diverse as agriculture, ambient and assisted living and safety and security. However, ongoing advancement of the technology is already charting new horizons. For example, ultra-sensitive optical sensor systems currently under development are likely to pave the way for improved medical diagnosis and treatment tools that will transform medical engineering and, in the long run, play a key role in meeting the challenge of providing adequate medical care to an aging population.

An additional research area in future photonic systems is the design of new pure optical components. Here optical memory and active optical components like combiners, filters, resonators and splitters are assembled, for which SOI approaches are used.

To ensure that the transition from conventional technologies to tomorrow's photonic systems is as smooth as possible in terms of both speed and technology, we are also establishing processes for designing RF cables, antennae and microwave routing on an ongoing basis and designing interfaces between existing and the new photonic systems.

The challenge for Fraunhofer IZM is integrating these disparate technological approaches with conventional technologies into one product. Here, we are focusing on the following areas:

- 3D photonic and plasmonic components and systems
- Silicon photonics
- Microwave and millimeter-wave photonics
- Multiphysics packaging

PHOTONICS FOR RELIABLE MEDICAL ENGINEERING SOLUTIONS AND IMPROVED QUALITY OF LIFE

1

Cross section of glass waveguide panel with thickness of 500µm and waveguide array pitch of 250 µm

2

Glass waveguide panel laminated in printed circuit board

3

Biochip, using plasmonic interferometers to measure the concentration of glucose molecules in solution

YOUR PARTNER – FRAUNHOFER IZM

SUMMARY OF SERVICES AT FRAUNHOFER IZM

COMPREHENSIVE DEVELOPMENT SUPPORT FOR ALL PROJECTS, NO MATTER THEIR SIZE OR COST

Fraunhofer IZM develops packaging technologies for boards, modules and systems to meet the current and future challenges of photonic technology. We adapt established and new microelectronic techniques – such as wafer level packaging (WLP), PCB integration and surface mounting technologies – with available equipment to optoelectronics and other related, application-specific systems. Our approach places high value on reliability and maximizing the potential for cost-effective automation.

We offer many different services in this area of expertise, including:

- Manufacturing and assembly of optical components
- Electro-optical circuit boards
- Packaging of electro-optical components
- Integration on wafer-level
- Enhanced photonic and plasmonic systems
- Simulation, design and quantification (thermal, mechanical, optical and RF)
- Qualification, failure and reliability analyses

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