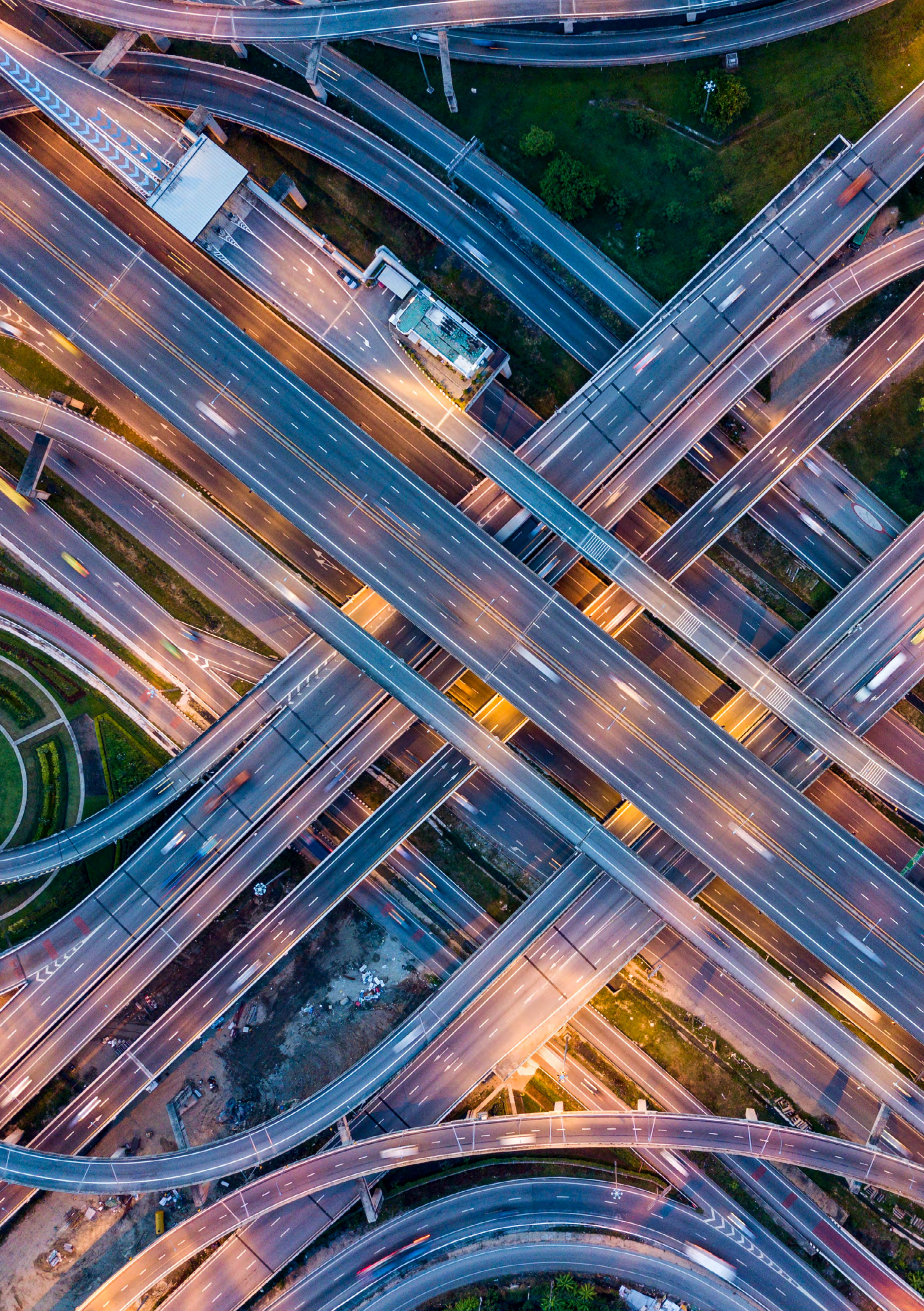
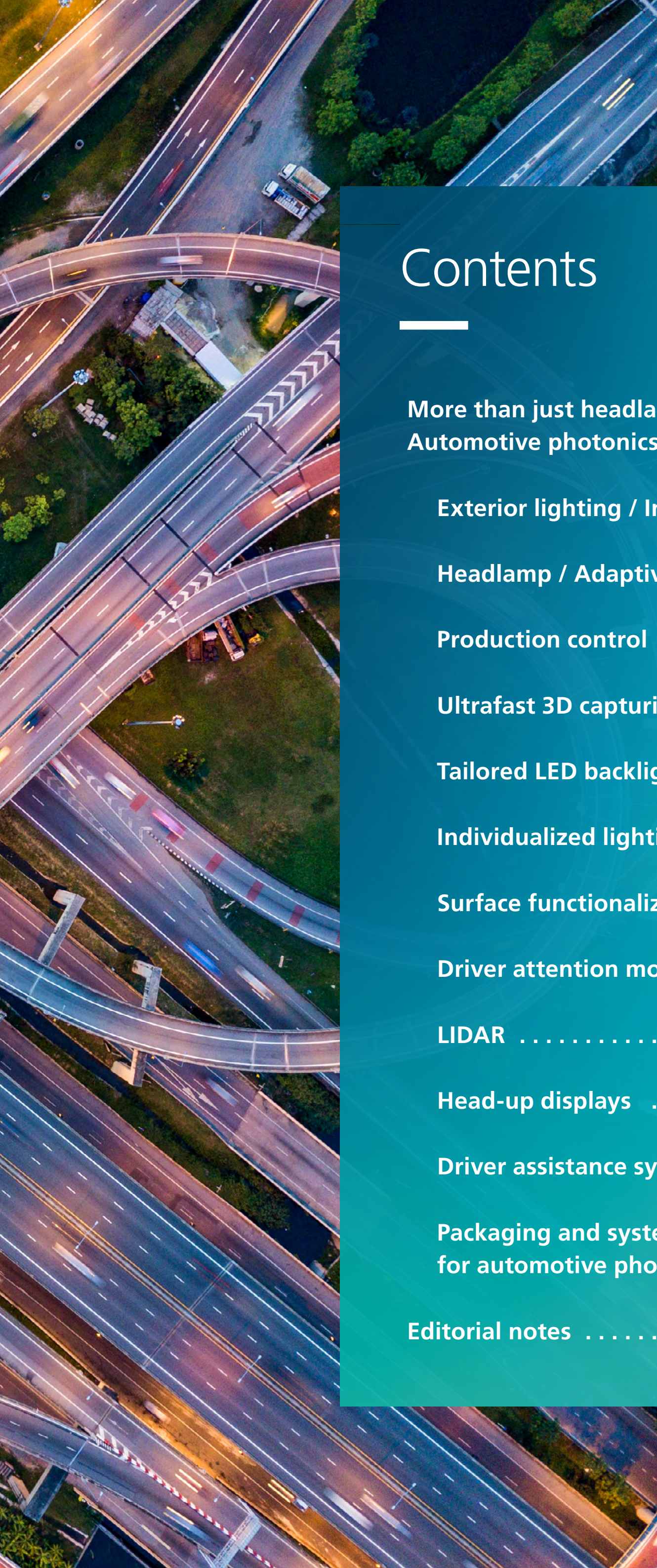
Fraunhofer
IOF

Fraunhofer Institute for Applied Optics and Precision Engineering IOF

Automotive photonics

Optical Components and Systems





Contents

More than just headlamps: Automotive photonics

New opportunities for the automotive market

Photonics has undergone a revolution in the automotive industry in recent years, transitioning from mere lighting functions to providing cutting-edge technology for imaging, sensing, smart displaying, and media communication networks.

Consequently, photonics has taken on new dimensions far beyond lighting in cars as well as in automotive manufacturing and quality control. It is not surprising that the automotive industry is showing an increased interest in innovative, photonics-based technologies. Myriad growth opportunities spur the lighting market to expand by about 5 percent p.a. An even greater boost is expected for the automotive photonics market.

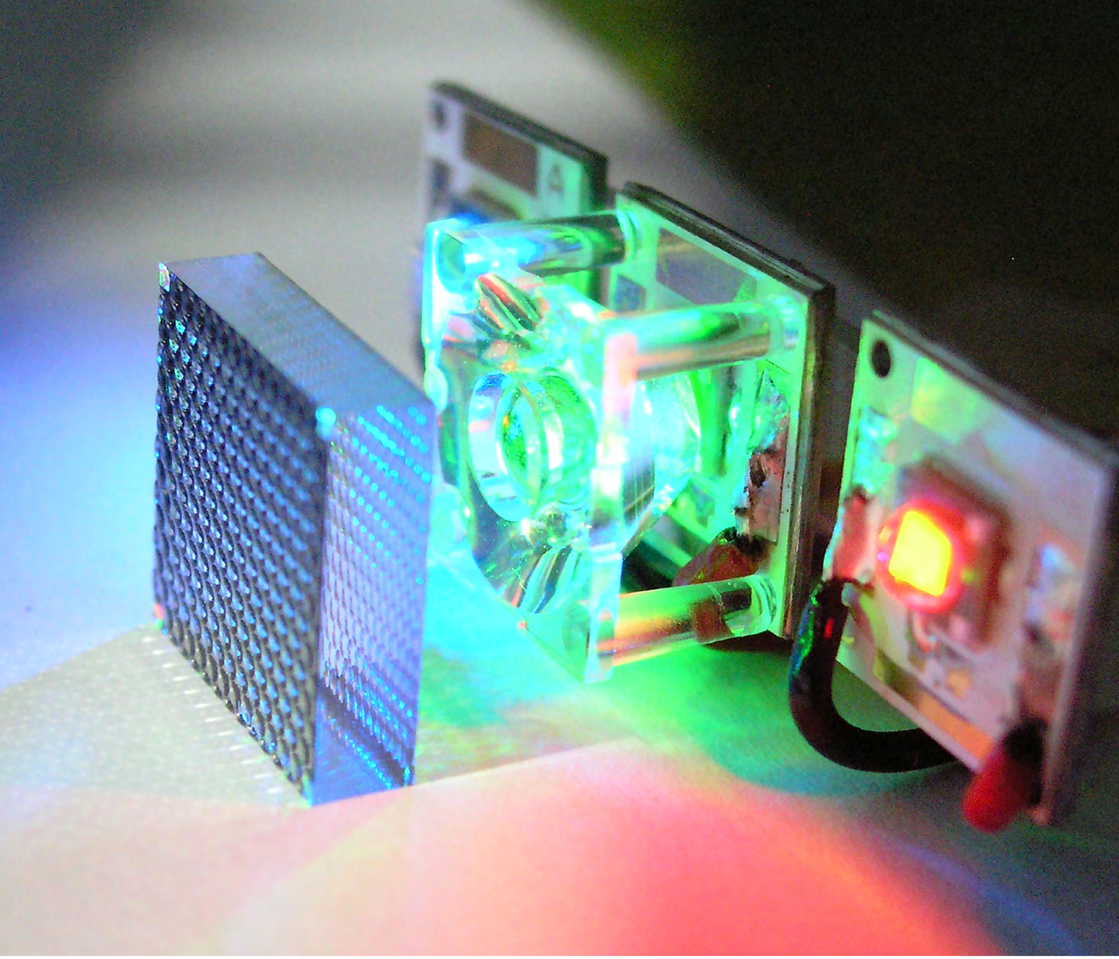
Cover: BMW 7 series with array projector developed by Fraunhofer IOF.

Background: BMW Welcome Light Carpet.

We are ready to launch new innovations to realize your ideas

Fraunhofer IOF transfers research into applicable solutions, offering the complete photonics process chain from system design and simulation, realization of custom-specific solutions to system integration. Thus, we provide our customers with the next generation of innovation in the entire field of photonic applications in cars, automotive technology, and production.

Our customers can benefit from our many years of experience in the field of automotive photonics. The demonstration of our realized solutions will give you an idea for future projects, which we will adjust to meet your individual needs.



Exterior lighting / Indicators

When it comes to avoiding accidents, communicating with other road users while driving is critical. However, this has posed an ongoing challenge for science. Projecting information on the street beside the vehicle is one solution to the problem. This requires bright, cost-effective, and miniaturized projectors for a small number of image contents.

Miniaturized projection systems

Fraunhofer IOF has developed a miniaturized micro-optical array-projection-technology enabling projection onto tilted and curved screens with brightness up to 3000 lux. Continuous innovation has led to displays which are even visible in full daylight. These systems serve as warning indicators for cyclists or as animated graphics to open and close the trunk by waving the foot under the rear bumper.

Projecting logos via signature lighting is a sophisticated feature for brand identification. This technology can be integrated into existing lighting systems e.g., in backlights.

Expertise in the automotive field

Automobile manufacturers have already integrated this feature into their high-end vehicles, such as the Welcome Light Carpet in current BMW models.

Right: BMW 7 series with array projector developed by Fraunhofer IOF.

Left: Experimental setup of an RGB-micro array projector.

Contact
Dr. Peter Schreiber
Phone: +49 3641 807-430
Mail: peter.schreiber@iof.fraunhofer.de

Headlamp / Adaptive lighting system

Adaptive driving beam systems can automatically adjust the driving beam to avoid glaring for oncoming and preceding traffic while maintaining optimal visibility for the driver. Current systems often use moving lamps or even micro displays; both are sensitive and complicated. Innovative micro-optics in combination with LED arrays containing individually addressable LEDs provide alternative energy and cost-saving solutions with a small ecological footprint.

Projection system with controllable segments

Fraunhofer IOF has developed a segmented headlamp based on the technology already used in our array-projection technology (see Exterior lighting / Indicators). 800,000 micro lenses condense and form the light, illuminating the road ahead optimally.

The tilted assembly of the two modules enables immediate switching of horizontal segmentation with 1.5° width. The system fulfils ECE standards with a light intensity of more than 50 kcd. Form and arrangement can be easily adapted to different headlamp layouts. An efficient, miniaturized micro-optical passing beam complements the segmented high beam.

Top: Micro optic headlight for narrow front lights on car.

Left: Segmented, automotive LED driving beam realized as micro-optical, irregular fly´s eye condenser.

Contact
Dr. Peter Schreiber
Phone: +49 3641 807-430
Mail: peter.schreiber@iof.fraunhofer.de

Production control

Many industrial production plants demand 100 percent inspection of the manufactured goods for quality assurance. To guarantee this at high production rates, measurement solutions are vital for an efficient production.

Tailored optical 3D measurement systems

We develop customer-specific, fully automatic, non-contact, optical 3D measuring (inline) inspection systems. These systems can measure areas from only a few square millimeters up to several square meters with rates in the millisecond range.

We use specially developed optical systems and parallelized 3D algorithms based on multi-processor systems. The full-surface measurement can detect and interpret local deformations and defects simultaneously. The 3D measurement accuracy is in the range of 10^{-4} of the measurement field diagonal.

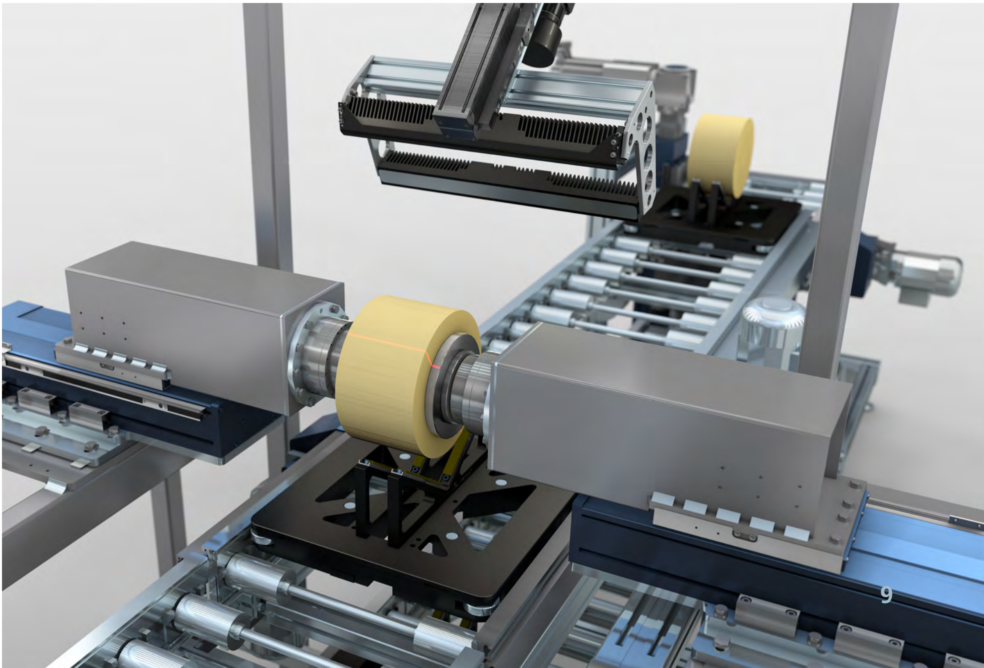
Expertise in the automotive field

We have already integrated systems into the quality control of casted motor blocks, large industrial catalysts, and more. The resulting data is compatible with common CAD systems.

Contact
Dr. Peter Kühmstedt
Phone: +49 3641 807-230
Mail: peter.kuehmstedt@iof.fraunhofer.de

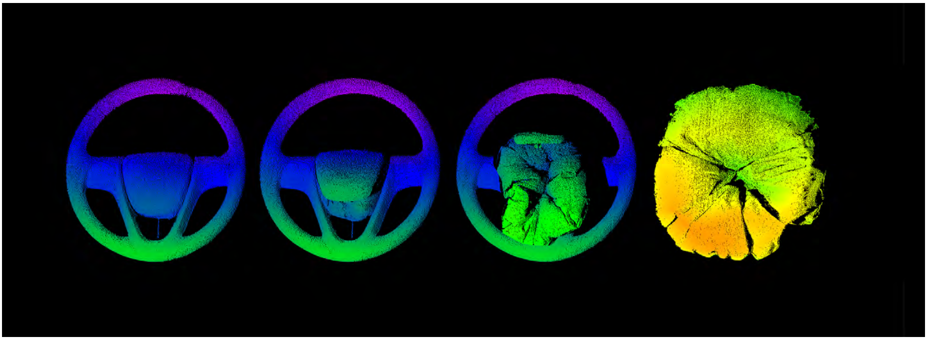
Left: Gesture-controlled 3D sensor platform for autonomous component measurement.

Right: Inline measuring system for quality assurance in production operations with optical 3D and 2D sensor technology.



Ultrafast 3D capturing

Optical 3D measurement technology is a versatile tool that is employed in many areas of industry and research. Especially highly dynamic processes like the inflation of an airbag require high-speed technology to examine and evaluate these moving objects in full 3D.



High resolution at high speed

Researchers at Fraunhofer IOF have developed projection, acquisition, and evaluation technologies with multi-kilohertz frame rates by using high-speed camera systems in conjunction with gobo-projection and parallelized data processing. This enables us to capture and evaluate up to 1,500 3D-frames per second with each frame composed of 1 million 3D-pixels or even 50,000 3D-frames per second with each frame composed of 250,000 3D-pixels.

Expertise in the automotive field

We have already transferred this innovative technology to our customers. One of these systems can capture the crash test of a complete car; another system was optimized to capture a crash test from inside the car – withstanding the strong negative acceleration during the crash.

Top: Demonstration of an airbag deployment: 3D data at four different time points.

Left: High-speed 3D measurement system.

Contact
Dr. Peter Kühmstedt
Phone: +49 3641 807-230
Mail: peter.kuehmstedt@iof.fraunhofer.de

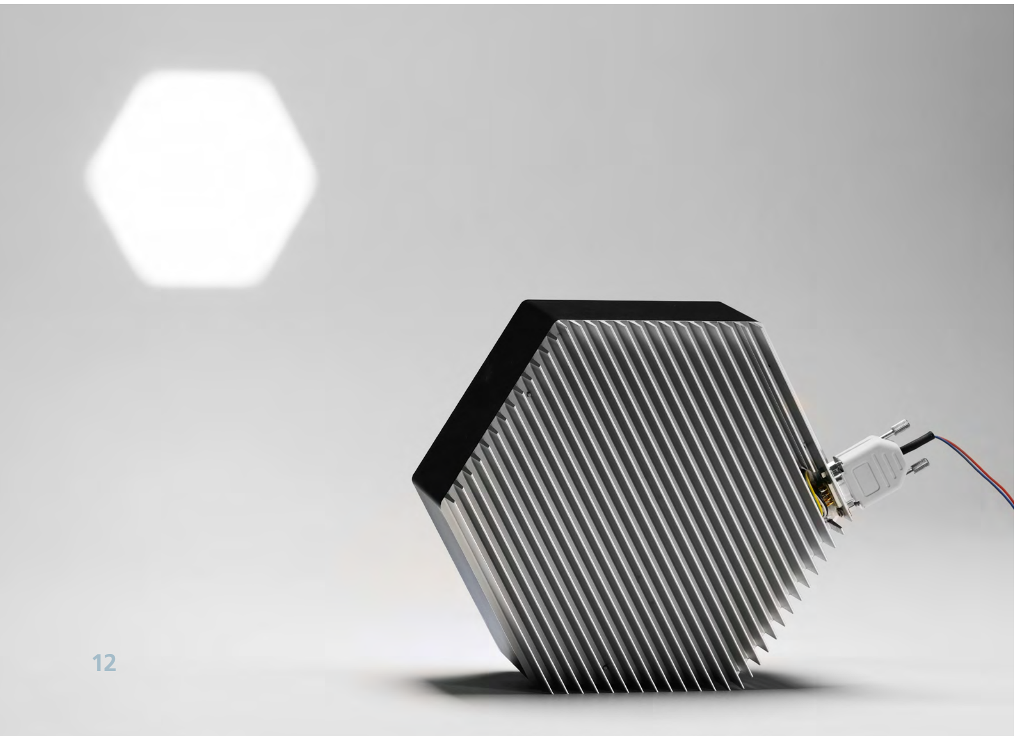
Tailored LED backlights

LED backlights can be optimized concerning their light distribution and arrangement by using tailored light diffusers (TLD). They enable the efficient transformation of incoming light into a desired angular distribution in the far field.

A TLD allows the realization of predefined far field distributions with very high efficiency due to the absence of limiting apertures. The outstanding characteristics of these elements originate from unique optical design methods that also facilitate local variation of the deflection angle.

Recognizable LED backlights through freedom of design

Using this method, the arrangement of the LEDs is free and nearly unlimited. Designing and branding the backlight is easily possible. The outer appearance



(arrangement) can be chosen freely; adapted design ensures almost arbitrary far field distributions. Thus, the backlight can serve e.g. as a brand signature.

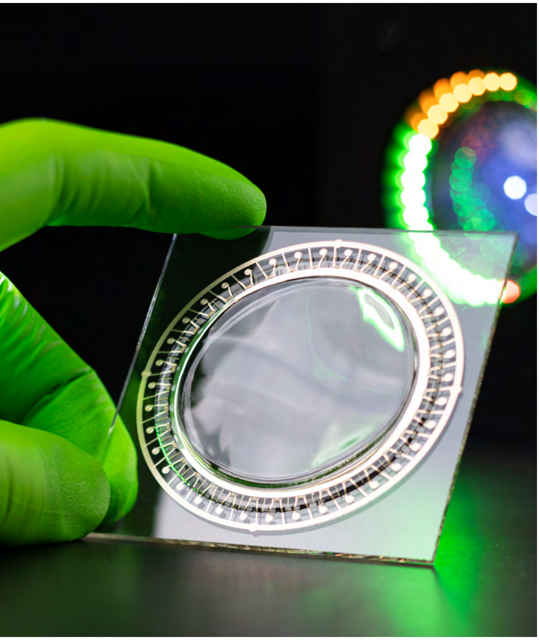
Contact
Dr. Frank Burmeister
Phone: +49 3641 807-274
Mail: frank.burmeister@iof.fraunhofer.de

Left: LED light source and generated spot on one screen.

Right: Star-shape diffusor element.

Individualized lighting

Personalizing one's car is increasingly in demand. The exterior and the technical components as well as individualized interior including illumination have become a means of personal expression.



Freeform illumination optics printed with polymer and equipped with additional functions using complex inkjet processes.

Individualization in mass production

Several Fraunhofer Institutes are currently cooperating in the lighthouse project »Go Beyond 4.0« developing cutting-edge technologies for individualized products and components in mass production.

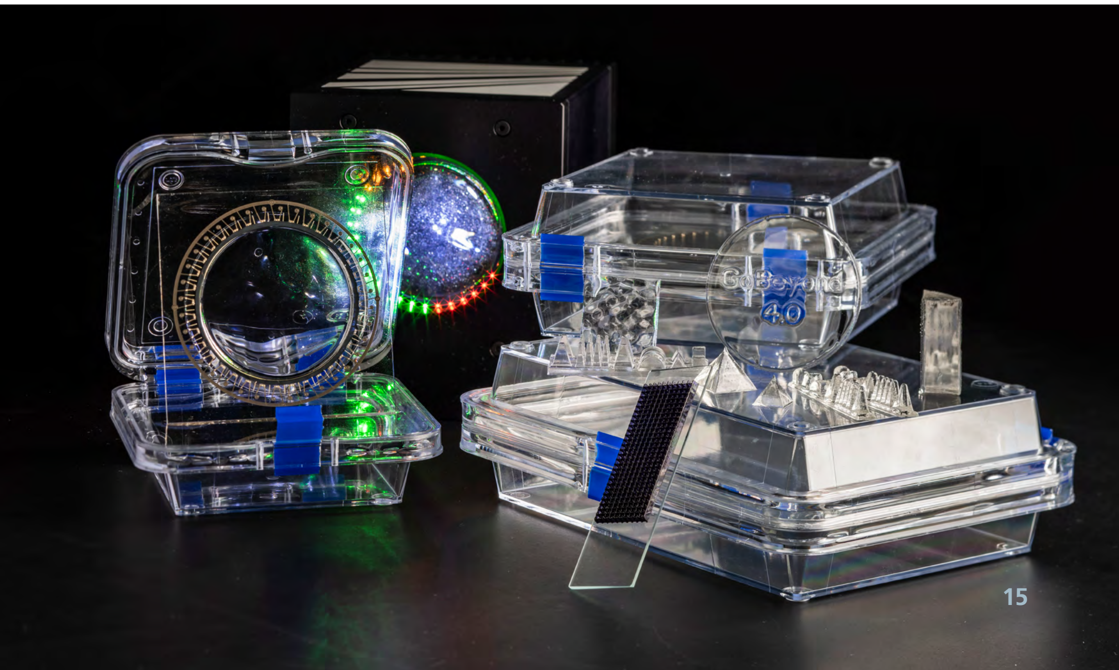
The participating Fraunhofer Institutes have succeeded in manufacturing electrical conductor patterns, sensors, and lighting components, individually created by using digital printing and laser technologies. The result is the individualization of components in mass production environments with new opportunities for design, material savings, and weight reduction.

Smart door with LED illumination optics

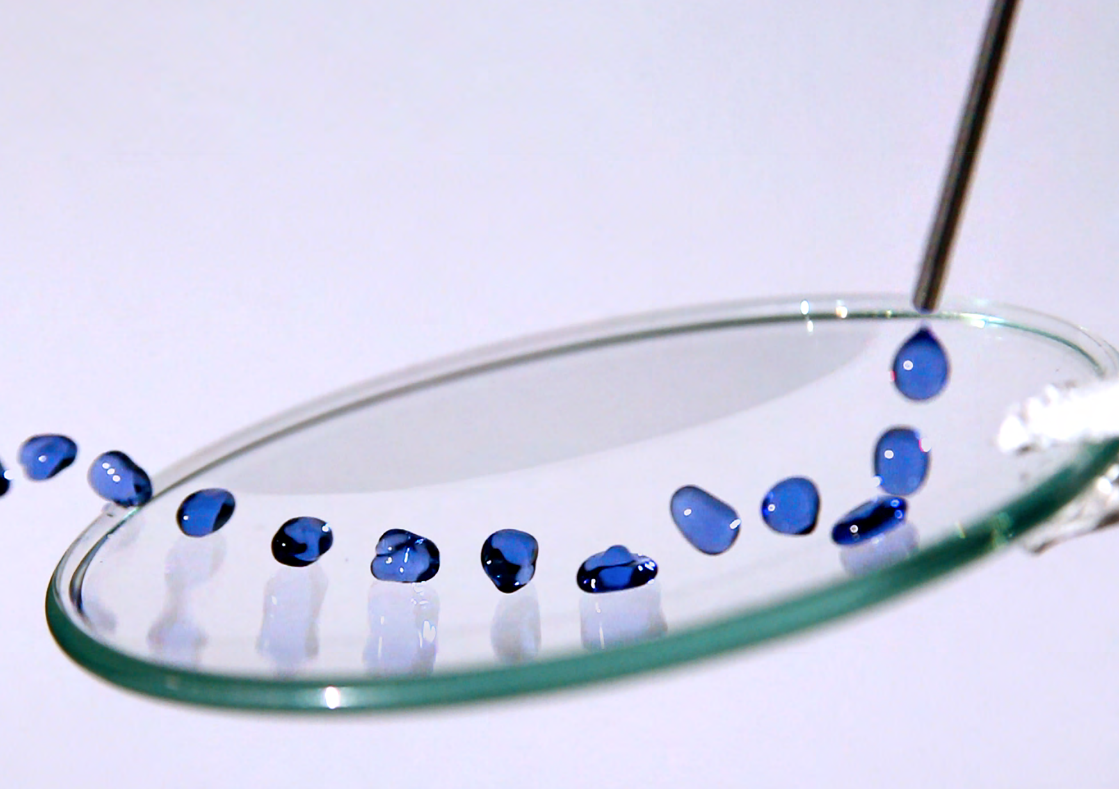
This opens up new avenues to design and realize automotive parts in general, and lighting concepts and arrangements in particular. Within the ongoing project, we have demonstrated a prototype of a smart door with novel illuminated interaction elements for car-to-driver communication and individual LED illumination optics with integrated functionality.

We were also able to apply conductor tracks directly to body parts using digital printing and laser processes. This makes a complex body part lighter and eliminates the need to manually lay a wiring harness.

Contact
Dr. Erik Beckert
Phone: +49 3641 807-338
Mail: erik.beckert@iof.fraunhofer.de



Printed optical elements.



Surface functionalization

Functional coatings and surfaces are often essential elements, because coatings generate tailored surfaces for various applications. We develop surface functionalization and multi-functional optical coating systems on plastics, glass, ceramics, and metal. These technologies have sucessfully been transferred into production and high-volume manufacturing.

We have extensive expertise and technologies in the design and simulation of optical layer systems, the development of coating processes, and in the characterization of surfaces and layers.

Functional coatings for automotive surfaces

Our spectrum comprises

- scratch resistant antireflective coatings on plastics,
- self-cleaning (hydrophobic) surfaces,
- anti-fogging (hydrophilic) coatings,
- anti-icing coatings,
- low loss surfaces (appearance/light scattering),
- all kinds of antireflective or high reflective optics,
- optical filters,
- transparent and conductive coatings,
- wetting coatings of oil/steel systems,
- and much more...

Contact
Dr. Sven Schröder
Phone: +49 3641 807-232
Mail: sven.schroeder@iof.fraunhofer.de

Left: Hydrophobic surface with self-cleaning effect.

Bottom: Antireflective coating for automotive ligthing systems.

Driver attention monitoring

A driver attention monitoring system continually assesses driver behavior to determine if a driver has become inattentive. If the driver is not completely focused or a dangerous situation is detected, the sophisticated system will alert the driver.

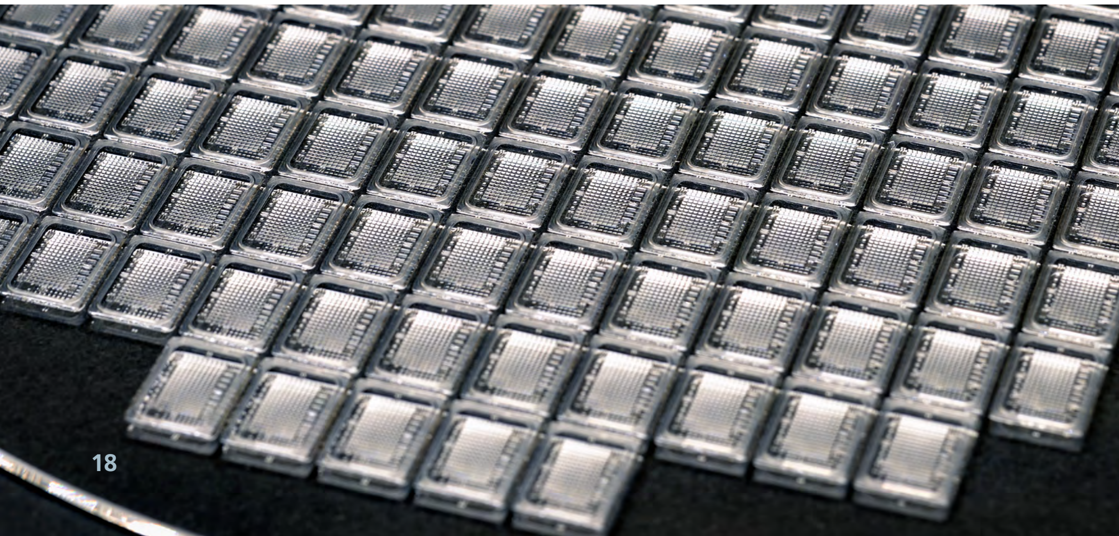
Cameras for indoor surveillance

Fraunhofer IOF develops ultra-thin cameras, which can be easily and almost invisibly integrated in the interior of a car. Driver monitoring and inattentive driving detection can be performed as well as passenger (or child) monitoring.

Functionality in minimal space

The multi-aperture imaging optics concept ensures thinner objectives better suited to integration in ultra-slim modules. The camera module – with an objective – has a total thickness of 2 to 10 mm and offers wide angle capturing with resolutions ranging from CIV to 8 megapixels.

Freeform microlens arrays after cutting.



Miniaturized array camera.

Our optics solutions rely on parallelized processes for the generation of micro-optical components which differ from conventional lens fabrication. Wafers instead of single pieces are handled for process parallelization, enabling high reliability and low-cost high volume production.

Contact
Dr. Robert Brüning
Phone: +49 3641 807-360
Mail: robert.bruening@iof.fraunhofer.de

LIDAR

LIDAR (light detection and ranging) laser systems are already used for applications in active cruise control, collision avoidance, and driving in bad weather. In upcoming applications, LIDAR acts as an eye of self-driving vehicles providing them with a 360-degree view. Thus, for autonomous vehicles LIDAR systems will continuously gain importance.

Requirements for use in the automotive sector

The lasers must fulfil certain automotive requirements like withstanding harsh conditions, drastic temperature changes, vacuum, acceleration, vibration, hard radiation etc.

Ready to hit the road

With our advanced fiber laser-based LIDAR systems equipped for 3D range detection and wind sensing, our prototypes have already met these demands. Due to its high performance, this technology opens up a wide range of new applications. Fiber lasers are long-term stable, energy efficient, and robust.

Left: Qualified short pulse fiber laser for LIDAR applications.

Bottom: Section of the LIDAR fiber laser system in which the fibers are arranged very densely.

Contact
Dr. Thomas Schreiber
Phone: +49 3641 807-352
Mail: thomas.schreiber@iof.fraunhofer.de

Head-up displays

Head-up displays (HUDs) are screens or projectors, which allow additional information to be displayed in the drivers' line of sight so that their eyes can remain on the road. The aim of current developments is to enable HUDs to project information on the entire windscreen and to combine it with augmented reality.

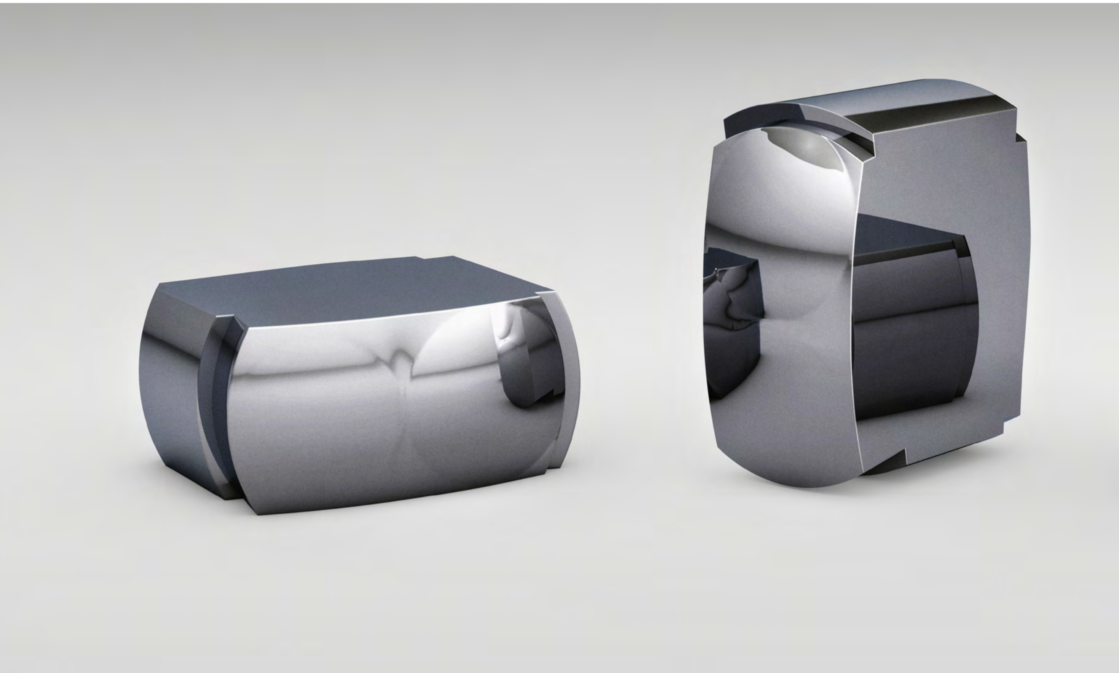
Tailored systems

This requires specially designed and adapted optics. Fraunhofer IOF has strong competence in this field and can design customer or application-specific optical systems and components for HUDs.

This includes, for example, optical design, beam splitters, filters/coatings, DOE (diffractive optical element) combiners, point light sources, stray-/false-light analysis, optimization as well as complete systems. The application of "tailored light diffusers" as intermediate screens with superimposed lenses or deflection functionality contribute to compact (HUD) set-ups with excellent light homogeneity.

Compact optical systems enable driver assistance systems in the automotive sector.

Contact
Dr. Robert Brüning
Phone: +49 3641 807-360
Mail: robert.bruening@iof.fraunhofer.de



Driver assistance systems

Night vision cameras can save lives and are therefore already included in higher-priced cars. Typically, they consist of multiple optical elements, which in turn require large adjustment efforts.

Compact freeforms for night vision cameras

Fraunhofer IOF has the expertise to realize miniaturized and robust monolithical optical elements in the centimeter-range using freeform technologies in order to replace complex combinations of classic lenses and mirrors. We have many years of experience in the demanding manufacture of compact freeforms with

Freeform lens design for night vision optics.

e.g., four optical surfaces on one substrate (FOV 60° x 40°, expanded bandwidth) and in the areas of system design and data flow, freeform optical manufacturing, and system integration covering the entire process chain.

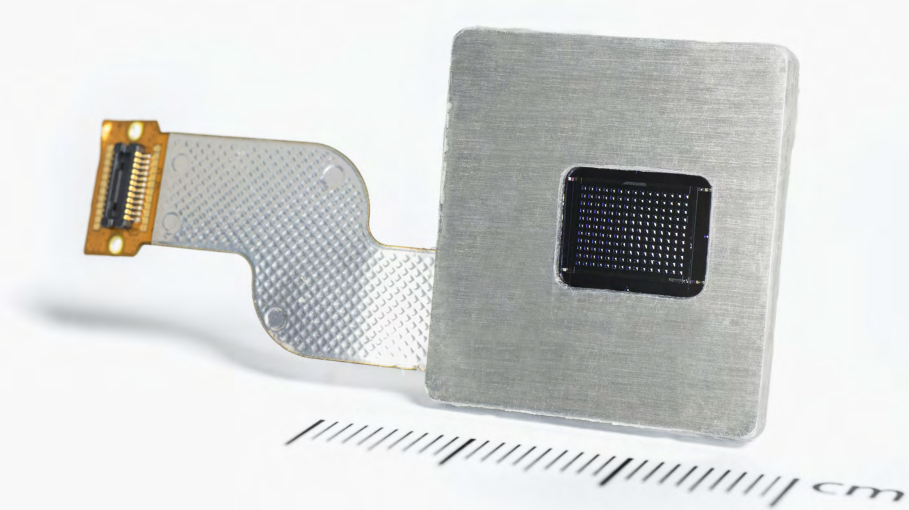
Our ultra-precise methods significantly reduce manufacturing expense and efforts of tooling adjustment.

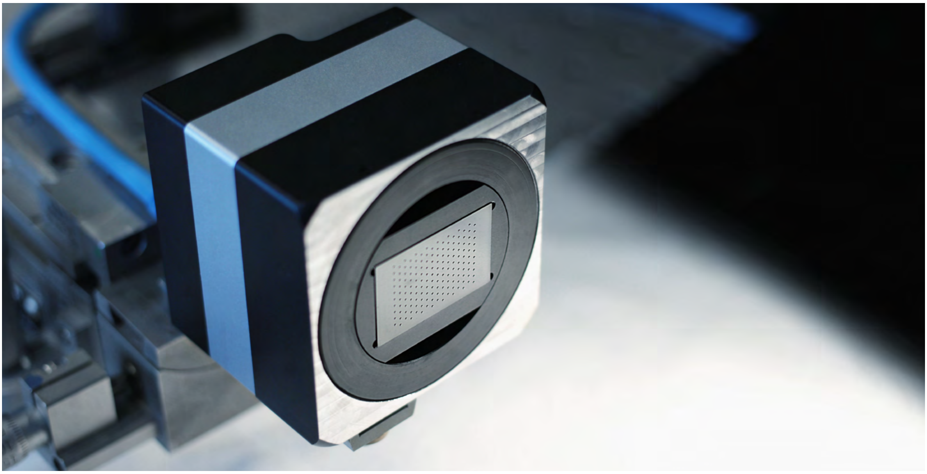
Contact

Dr. Stefan Risse
Phone: +49 3641 807-313
Mail: stefan.risse@iof.fraunhofer.de

Packaging and system integration for automotive photonics

Photonics for the automotive industry requires pioneering approaches for packaging and system integration due to harsh environments, as components and systems must withstand demanding mechanical and thermal loads.





Assembling opto-mechatronical systems

Fraunhofer IOF has expertise in assembling macroscopical and miniaturized, hybrid integrated opto-mechatronical systems.

Our focus lies on alignment strategies and equipment for the micron and even sub-micron alignment of e.g., laser-optical and LED-based systems as well as bonding technologies, such as adhesive bonding and laser-based soldering for the stable fixation of complex alignment states. Design, evaluation, and optimization of assembly processes up to six sigma reproducibility as well as technology transfer for equipment and processes to customer's facilities are part of our core competences.

Aspects of automated assembly for low, mid, and high-volume production can be addressed by the selection of commercial and customized assembly equipment.

Top: An array microscope inside of a commercial camera housing.

Left: Prototype of the assembled wideangle multiaperture camera.

Contact

Dr. Erik Beckert
Phone: +49 3641 807-338
Mail: erik.beckert@iof.fraunhofer.de

Editorial notes

Address

Fraunhofer Institute for Applied Optics
and Precision Engineering IOF
Albert-Einstein-Str. 7, 07745 Jena, Germany
www.iof.fraunhofer.com

Director

Prof. Dr. Andreas Tünnermann
Phone: +49 3641 807 201
Mail: andreas.tuennermann@iof.fraunhofer.de

Contact

Dr. Robert Kammel
Phone: +49 3641 807-394
Mail: robert.kammel@iof.fraunhofer.de

Photo acknowledgements

Cover inside / Page 1: © Adobe Stock / Mongkol Chuewong
All other photos: © Fraunhofer IOF


Fraunhofer
IOF