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FRAUNHOFER INSTITUTE FOR LASER TECHNOLOGY ILT

DESIGN OF FREEFORM OPTICS

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Fraunhofer Institute
for Laser Technology ILT

Director
Prof. Constantin Häfner

Steinbachstraße 15
52074 Aachen, Germany
Telephone +49 241 8906-0
Fax +49 241 8906-121

info@ilt.fraunhofer.de
www.ilt.fraunhofer.de

Fraunhofer Institute for Laser Technology ILT

The Fraunhofer Institute for Laser Technology ILT is one of the most important development and contract research institutes in laser development and application worldwide. Its activities encompass a wide range of areas such as developing new laser beam sources and components, laser-based metrology, testing technology and industrial laser processes. This includes laser cutting, ablation, drilling, welding and soldering as well as surface treatment, micro processing and additive manufacturing. Furthermore, Fraunhofer ILT develops photonic components and beam sources for quantum technology.

Overall, Fraunhofer ILT is active in the fields of laser plant technology, digitalization, process monitoring and control, simulation and modeling, AI in laser technology and in the entire system technology. We offer feasibility studies, process qualification and laser integration in customized manufacturing lines. The institute focuses on research and development for industrial and societal challenges in the areas of health, safety, communication, production, mobility, energy and environment. Fraunhofer ILT is integrated into the Fraunhofer-Gesellschaft.

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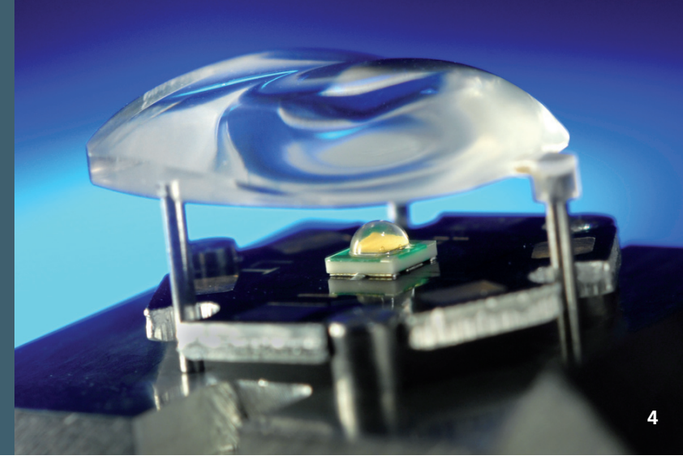

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DESIGN OF FREEFORM OPTICS

At the Fraunhofer Institute for Laser Technology ILT, our experts develop freeform optics tailored to our research and industrial customers' non-imaging applications. Collaborating with local manufacturers, we turn your ideas into reality – providing everything from virtual prototypes with production-ready design to characterization of the finished optical systems.

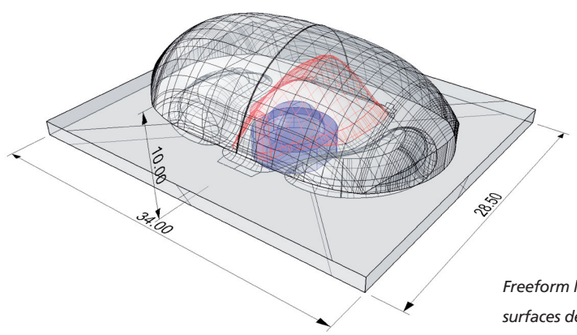
Design Algorithms for Freeform Optics

The term freeform optics refers to refracting and reflecting surfaces that can be clearly distinguished from spherical and aspherical geometries. One of many application areas for freeform optics is the lighting sector, where they are used to lower the energy consumption – and with it the operational cost – of various lighting scenarios. And in addition to raising efficiency, freeform optics increase flexibility in lighting design.

The design of freeform optical surfaces no longer has to conceptually follow that of imaging optics, but instead aims to redistribute energy by light refraction and reflection. Generally speaking, the design process is intended to achieve tailored irradiance distributions while at the same time maximizing the usable light output and minimizing the number of optical surfaces.

Fraunhofer ILT develops design algorithms for freeform optical surfaces that meet these requirements. Key characteristics include the algorithms' flexibility when designing two-part freeform optical surfaces, whereby refracting and reflecting surfaces can be combined within a single optical element. By combining two complementary freeform refracting surfaces it is possible to reduce losses caused by Fresnel reflection and, in contrast to freeform optics with only one freeform surface, increase efficiency as closely as possible to its maximum point.

Although in theory freeform tailoring methods can achieve very complex irradiance distributions, this capability is limited to point light sources. As real sources are always extended to a certain degree, it was possible only to approximate them. At Fraunhofer ILT, we have now developed phase-space-based techniques capable of working out freeform optical surfaces with extended sources, thus removing the need for approximation.



Freeform lens with optimized optical surfaces designed for an LED street lamp.

Prototype Development

Our years of experience in the realization of freeform optics and our close working relationships with manufacturers guarantee that the virtual prototypes we produce can be used to manufacture finished optics. We assist our customers in developing pioneering technologies that range from optical simulators to designs for functional optical elements with smooth or microstructured freeform surfaces. We also help them optimize the chosen manufacturing process.

A given optics design is first used to create a virtual prototype that is then put through its paces using simulation software. At Fraunhofer ILT we have access to a wide range of software packages – some commercial, others developed in-house – that can be used to verify photometric parameters and determine the influence of production and assembly tolerances.

Measuring Technology for Lighting Applications

The final service Fraunhofer ILT offers its customers in the area of freeform optics design is the measurement and functional assessment of manufactured optical prototypes. Measurements of light intensity and luminance as well as assessment of the prototypes' light-intensity distributions ensure that the desired functionality can be precisely carried over into series production.

Our Services at a Glance

- Prototype development
  - Virtual prototyping
  - Optical design preparation for manufacturing
- As our design algorithms are developed in-house, they can be expanded and tailored to fit a wide range of applications in the field of high-efficiency freeform LED optics:
  - General, street, and architectural lighting
  - Specially adapted illumination geometries with limited range and placement (e.g. wall washers, designer lighting, light engines)
  - Optimum process lighting
  - Automotive applications (e.g. multifunctional lenses for combined lighting functions)
  - LED fiber coupling
- Measurement technology for lighting applications
  - Measurement of light intensity, luminance and light-intensity distributions
  - Comparison of simulation and experimental results

Contacts

Dr. Rolf Wester
Telephone +49 241 8906-401
rolf.wester@ilt.fraunhofer.de

Dr. Martin Traub
Telephone +49 241 8906-342
martin.traub@ilt.fraunhofer.dede

1 High-efficiency freeform LED optics for street lighting.
2 Stretch of road lit using fewer lights.
3 Compact freeform lens for a fog light.
4 LED with injection-molded freeform optic.