FRAUNHOFER INSTITUTE FOR LASER TECHNOLOGY ILT

MACHINING TRANSPARENT MATERIALS WITH ULTRASHORT PULSED LASER RADIATION

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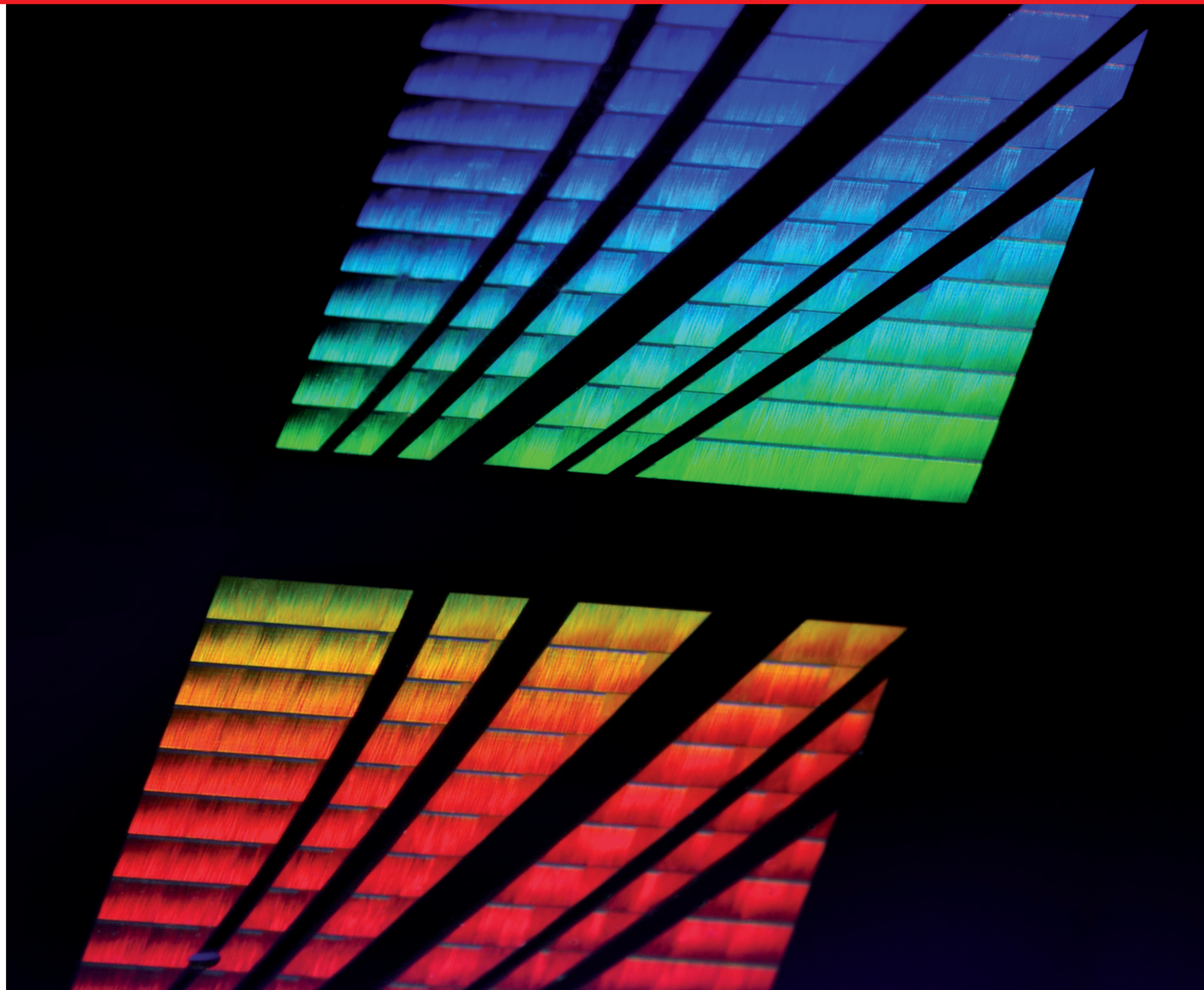
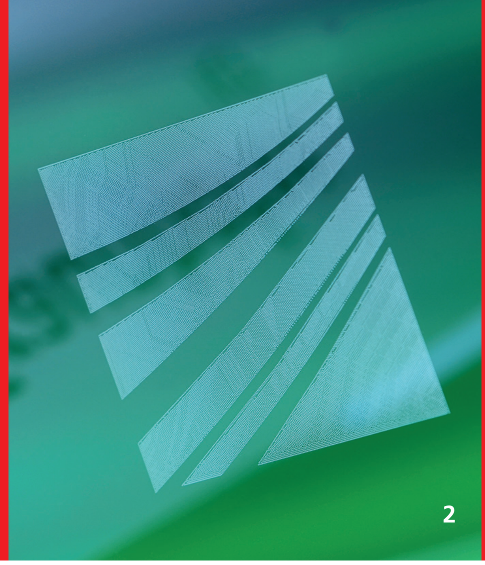
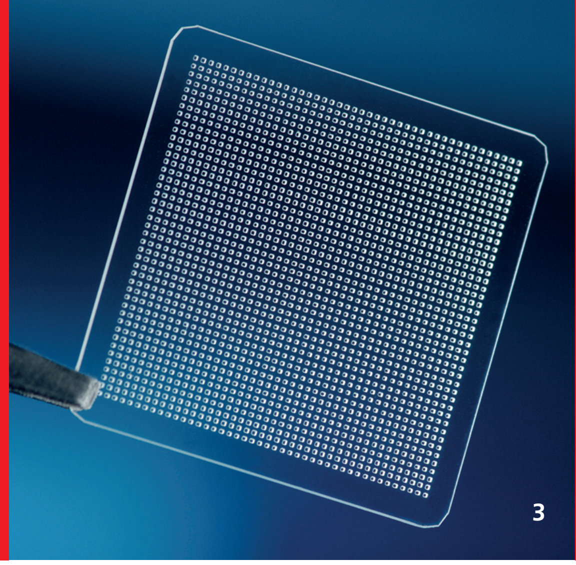
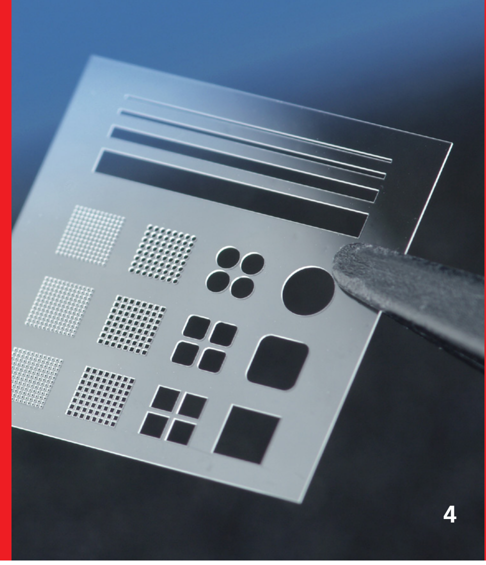
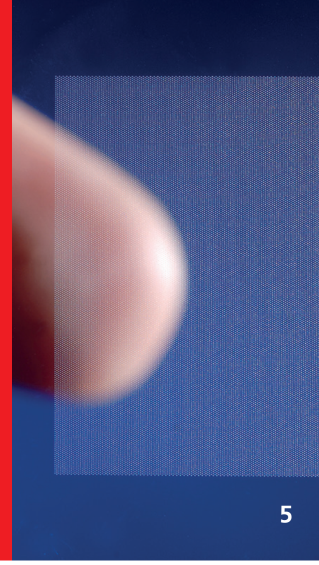
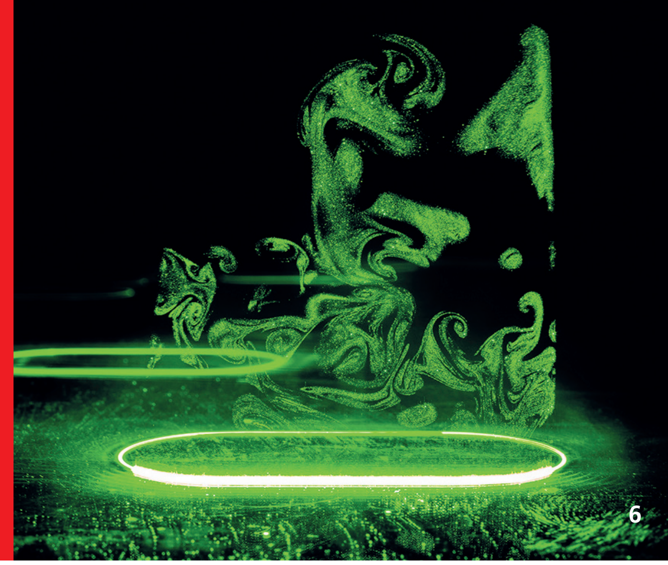
Fraunhofer Institute for Laser Technology ILT

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.



MACHINING TRANSPARENT MATERIALS WITH ULTRASHORT PULSED LASER RADIATION

When ultrashort pulsed laser radiation with a pulse duration in the femto or picosecond range is focused on or in glass or crystals, the surface and in the volume of these materials can be processed with high precision. The Fraunhofer Institute for Laser Technology ILT is developing laser-based processes for the micro- and nanostructuring of transparent materials in collaboration with the Chair for Laser Technology LLT at RWTH Aachen University.

The Process

So that transparent materials can be ablated or modified with laser radiation, the material has to absorb a sufficiently large amount of the energy of the radiation. Due to the large local intensities of focused ultrashort pulsed laser radiation with a pulse duration < 10 ps, non-linear ionization processes can produce a dense material plasma that allows this absorption. The absorbed energy of the laser beam heats the material, either ablating or modifying it as a function of the selected process parameters. Since the necessary large intensities are achieved almost exclusively in the focus volume of the laser radiation, high-precision structures with accuracies < 1 µm can be generated selectively in the volume of transparent materials. One application is to mark in the volume of glass bodies for integrated optics; further fields of application are the separation or marking of glass.

Cover: Colored marking in the volume of glass.

1 Thin glass surface structured by direct laser ablation.

2 Micro-holes in thin glass.

3 Arrangement of micro-holes in thin glass.

Cutting of Glass

Ultrashort pulsed laser radiation can cut glass by successively removing material. When the corresponding focus is used, the upper and lower surfaces of the glass workpiece can be ablated in a targeted and precise manner. The results of processing either the surface or the rear of the glass differ, among other things, with respect to the aspect ratio of the cut edges. By choosing the appropriate process parameters, the users can adjust the quality of the cut edge and the surface roughness carefully according to the respective requirements. Through the use of beam sources with large pulse repetition rates, glass of any thickness from a few 10 µm to several millimeters can be processed with economical process duration. The above-mentioned methods are used, for example, in the processing of glass for entertainment electronics.

Colored Markers in Volume

When ultrashort pulsed laser radiation is focused into the volume of the transparent material, density and refractive indices of the material can be locally altered. In this way, diffraction gratings can be produced; they appear as a structure in the volume and their color changes along with the viewing angle. Such structures can be generated with the »tool light« without damaging the surface and can be used as a tamper-proof safety mark or as an identification number in, for example, logistics. A high-precision microscanner system allows almost any design of the grating, which can also be produced within a few seconds in the glass volume.

Surface Markings and Hole Structures

The combination of different system components, such as a high-precision microscanner, makes it possible to produce almost any desired structures by ablating material. Thus, surface markings or arrangements of angular micro-holes can be produced in flexible glass of up to 100 µm in thickness. The micro-holes can be used as so-called »interposer« structures in the semiconductor electronics industry.

Outlook

In order to precisely adjust the energy deposition in the material for a specific application, Fraunhofer ILT is focusing its current research on modulating the spatial beam shape of the laser radiation. This can occur, for example, by means of diffractive optical elements or so-called »spatial light modulators«, which can be adjusted in a selected manner. Furthermore, Fraunhofer ILT is developing optical systems for the generation of several identical partial beams in order to significantly increase the process speed by parallelizing the machining process.

Plants and Systems

At Fraunhofer ILT, a variety of ultrafast pulsed laser beam sources are available from various manufacturers. This allows us to offer our customers and project partners a broad range of process parameters for different machining processes. In addition, high-precision positioning and scanner systems as well as optical systems are available for rapid processing and beam shaping.

- Average power P = 2 W - 400 W
- Repetition rate f_{Rep} = 1 Hz - 54 MHz
- Pulse duration τ = 80 fs - 20 ps
- Wavelengths λ = 266 nm - 2,400 nm
- Microscanners with positioning accuracy < 500 nm and scanning speed v_{Scan} > 100 mm/s
- Multibeam scanner systems for generating several identical partial beams for parallel processing

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4 Holes with different geometrical shapes in thin glass.

5 Micro-holes in thin glass.

6 Ablation process of glass with ultrashort pulsed laser radiation.