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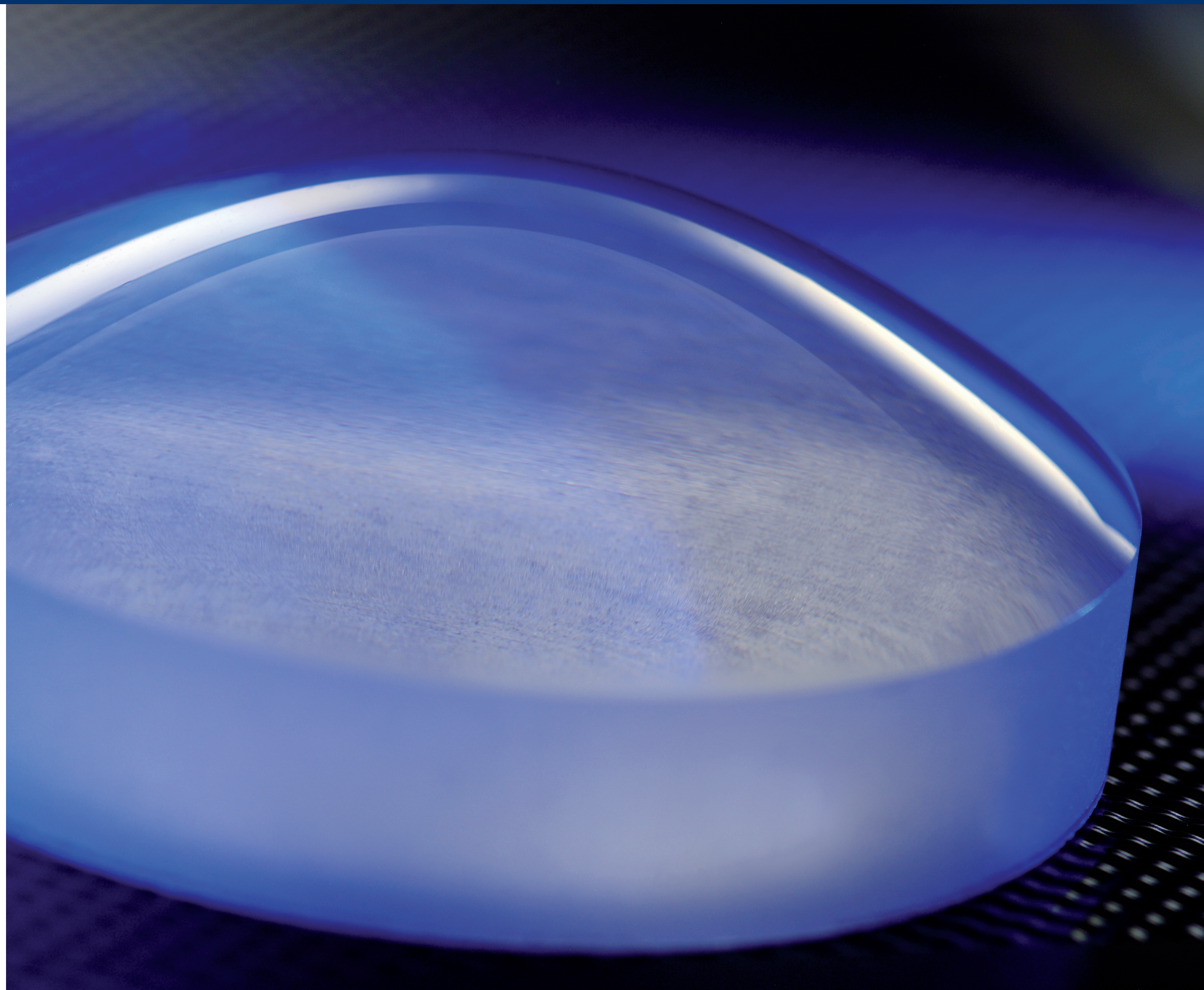
LASER POLISHING OF GLASS AND PLASTICS



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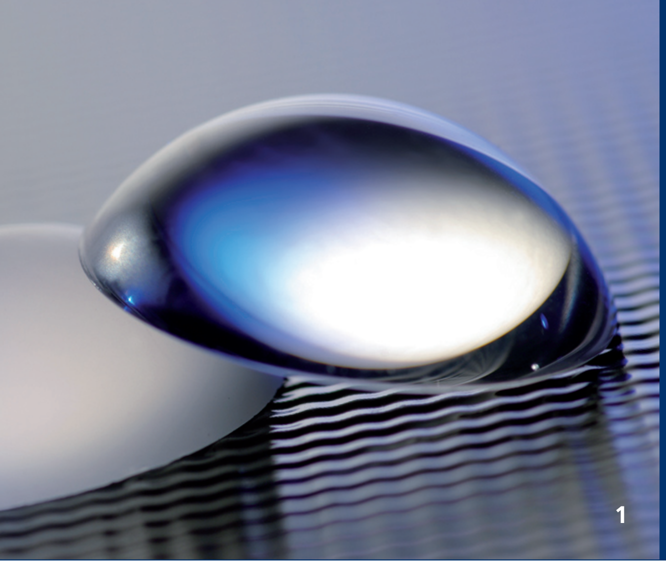
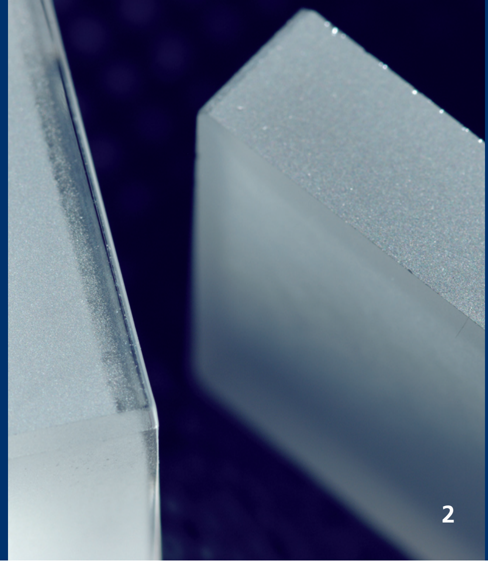
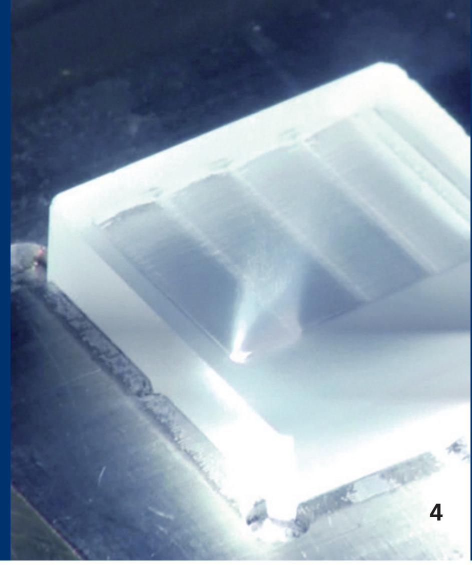
Fraunhofer Institute for Laser Technology ILT

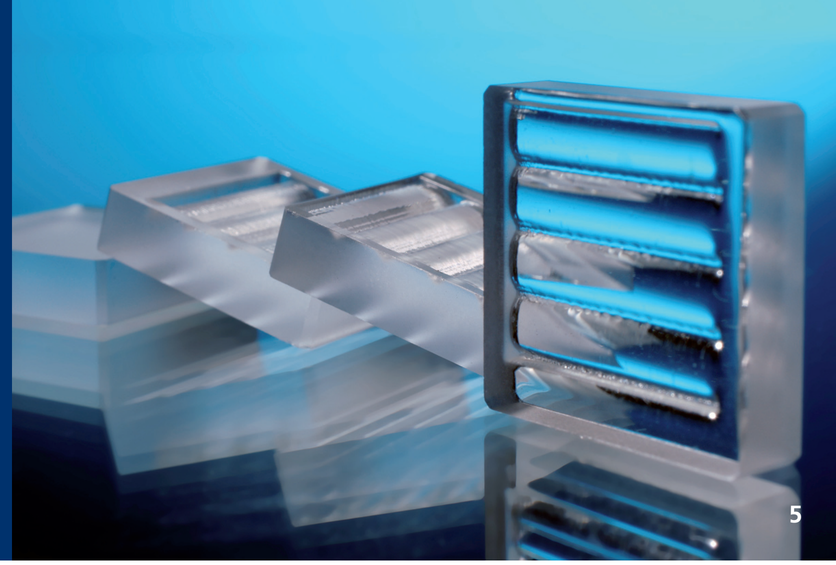
The Fraunhofer Institute for Laser Technology ILT is one of the most important development and contract research institutes in laser development and application worldwide. Its activities encompass a wide range of areas such as developing new laser beam sources and components, laser-based metrology, testing 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.









LASER POLISHING OF GLASS AND PLASTICS

Aspherical optics and freeform surfaces are being used increasingly in the lighting sector as well as for imaging optics. As a result, the demand for adaptable and quick polishing processes for optics with non-spherical surfaces is growing. For this application, the laser polishing process developed at the Fraunhofer Institute for Laser Technology ILT provides a flexible and economical alternative to conventional polishing methods.

The Process

Polishing glass and plastic materials with CO_2 laser radiation is based on the absorption of the radiation in a thin border layer of the work piece such that temperatures just below the evaporation temperature are attained on the surface. As a result, the viscosity of the material is reduced so that the roughness flows and the surface is smoothened due to surface tension. In comparison to conventional polishing methods, the innovation of laser polishing lies in a fundamentally different active principle: surface smoothing through remelting rather than material removal. This way, laser polishing achieves, among other things, a favorable smaller micro roughness.

By choosing the corresponding process parameters, such as preheating temperature, feed speed and intensity distribution, a user can flexibly adapt laser polishing to nearly any surface form. Due to the high process speeds of up to 1 cm²/s for quartz glass and up to several 10 cm²/s for plastics, laser polishing is faster than conventional polishing processes by up to two magnitudes.

Process Characteristics and Advantages

- High flexibility due to contact-free processing
- Processing various surface geometries, in particular aspheres and freeform surfaces, with only one tool
- High process speed independent of surface geometry
- Smaller micro roughness than attainable with conventional polishing processes
- Selective polishing due to local processing
- No incorporation of polishing liquids into the surface
- No polishing waste

Laser Polishing of Glass

The conventional polishing process for glass materials uses disc or point tools and a polishing liquid, which is applied to the work piece. In this process, large amounts of waste arise. By means of laser polishing, glass surfaces can be polished without creating waste, independent of the surface form and with the same tool. In addition, the processing time of laser polishing is smaller by a factor of up to 100 times. It can attain a surface roughness of quartz glass down to Rms < 5 nm (1 x 1 mm² measuring field) and micro roughness down to Rms < 0.4 nm (50 x 70 µm² measuring field).

Applications for laser polishing of glass surfaces are, among others, lighting optics, for which the values currently achieved are sufficient. By increasing the form accuracy and reducing the waviness, the Fraunhofer ILT aims to make the process suitable to polish imaging optics which need to fulfill higher demands. The process can be applied to nearly all kinds of glass, whereas higher process speeds are reached for low-melting glasses.

Laser Polishing of Plastics

Since thermoplastics such as polycarbonate can be formed when heat is applied, laser polishing is also suitable for this kind of plastic. On account of the smaller temperatures required, the process speeds for laser polishing of plastic are – at several 10 cm²/s – significantly faster than those for glass. The overall surface roughness attainable is already sufficient for lighting optics (Rms < 25 nm, 1 x 1 mm² measuring field), whereas the micro roughness, at Rms < 1 nm (50 x 70 µm² measuring field), exhibits comparable values to those achieved using conventional polishing methods. The process development aims at reducing the resulting surface roughness even further such that the process will be suitable for imaging optics as well. A possible application is for polycarbonate eyeglass lenses.

Internal Polishing of Drill Holes

Laser polishing can process non-accessible areas such as the inner walls of drill holes, a great advantage in specific applications. By means of a deflector unit, the laser radiation is directed onto the wall inside the drill hole. The processing times do not change and the process can attain a micro roughness on the inner walls of drill holes in quartz glass of Rms < 5 nm at an initial roughness of approx. Rms ≈ 500 nm (measured length = 5 mm).

Deburring and Form Generating Melting

Laser polishing can also be used to remove burrs and to round off edges on glass as well as on plastics. For example, burrs that occur between the molds on injection molded parts can be removed using this process. This can significantly improve the visual appearance of products. In addition, when glass edges are rounded off, the stability of the entire component increases.

Expanding the Process with Form Generation and Correction

Due to remaining form deviations and waviness, laser polishing cannot currently be used to process imaging optics. One solution to this may be the expansion of the process by a subsequent laser-based step to correct form deviations. In this processing step, material is ablated locally in very small amounts at the desired location, which thereby reduces waviness. In addition, laser radiation can also be applied to generate the surface form itself – this process step can be placed upstream of the laser polishing. The resulting laser based process chain for manufacturing optics, existing of these three steps, is currently under development at the ILT and shall be used to manufacture freeform optics, since the production times for this kind of optics can be reduced dramatically.

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1 Laser-polished sphere out of glass.
2 Rounded edge (left).
3 Fused silica before and after laser polishing.

4 Generating the surface form.
5 Process chain for laser based optics manufacturing.