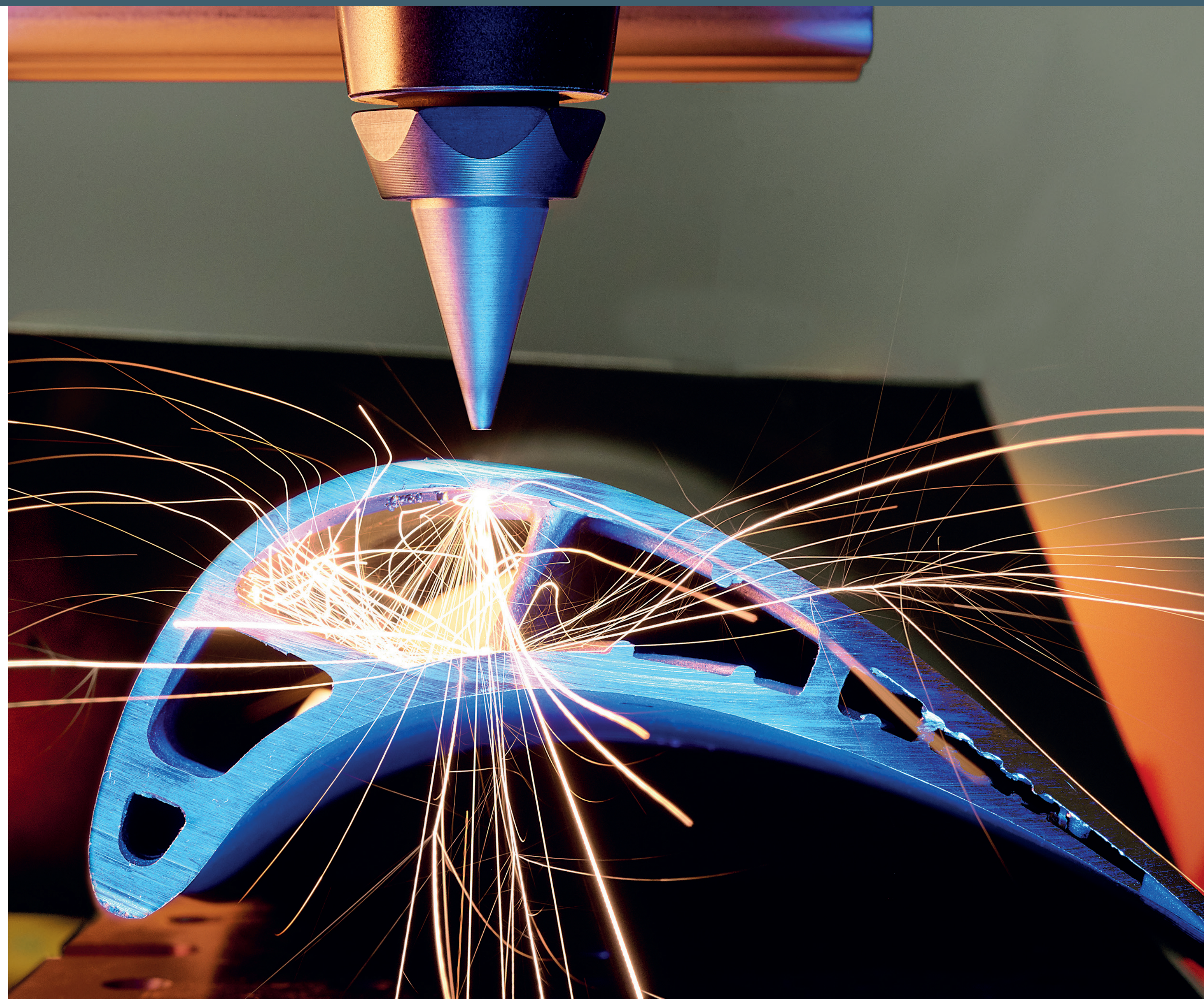
Fraunhofer
ILT

FRAUNHOFER INSTITUTE FOR LASER TECHNOLOGY ILT

LASER DRILLING



DQS certified by
DIN EN ISO 9001:2015
Reg. No. 069572 QM15

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.

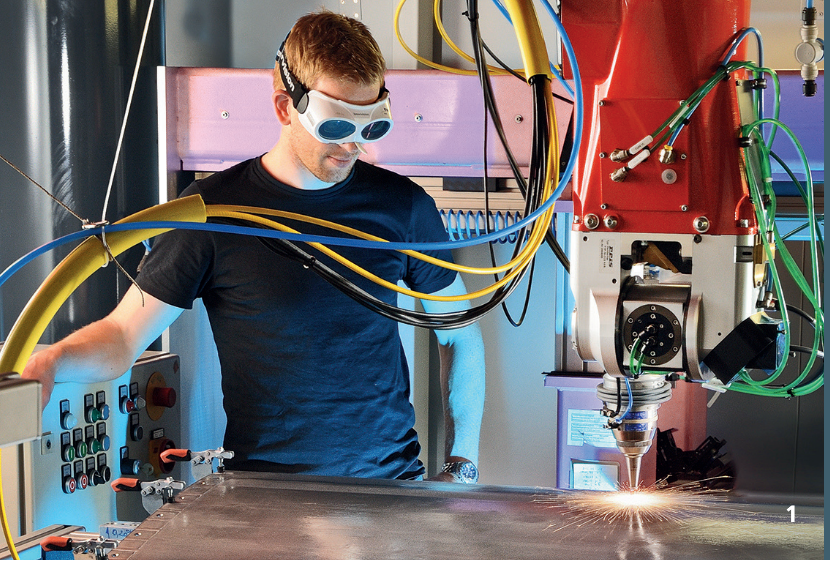
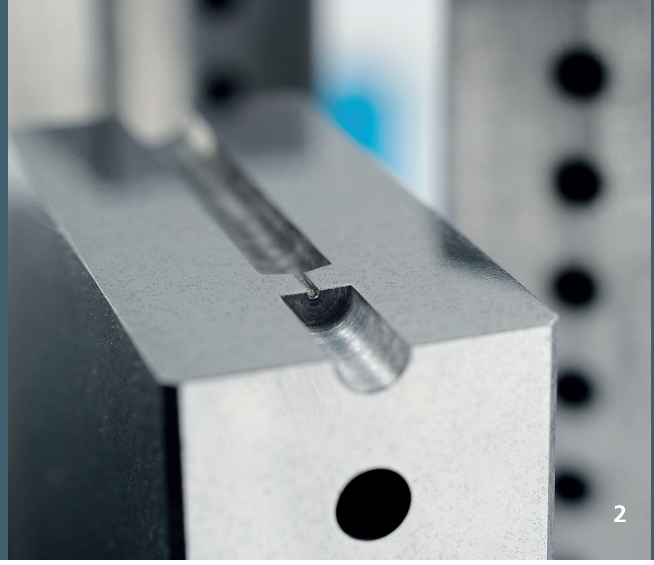
Overall, Fraunhofer ILT is active in the fields of laser plant technology, digitalization, process monitoring and control, simulation and modeling, AI in laser technology and in the entire system technology. We offer feasibility studies, process qualification and laser integration in customized manufacturing 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.

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

Subject to alterations in specifications and other technical information. 11/2021.


LASER DRILLING

Laser radiation can be used to produce holes with diameters ranging from less than one micrometer to several millimeters and large drilling depths. The Fraunhofer Institute for Laser Technology ILT develops various drilling processes from the basics to advanced systems in industrial plants. Laser drilling can be utilized to manufacture vent holes, air-cooling holes, contact drilling holes, filter holes or holes in injection nozzles.

The Process

Holes with diameters ranging from approx. one micrometer to several millimeters can be drilled into the workpiece using single-pulse drilling, percussion drilling, trepanning or helical drilling, depending on the thickness of the component and the required quality (precision) and productivity (drilling duration). The following table shows how individual drilling techniques differ in terms of diameter, drilling depth and duration.

	Diameter	Depth	Duration
Single pulse drilling	40–700 µm	< 2 mm	< 1 ms
Percussion drilling	50–700 µm	< 20 mm	0.1–20 s
	1–50 µm	< 1 mm	< 1 ms
Trepanning	0.3–10 mm	< 10 mm	1–20 s
Helical drilling	10–200 µm	< 2 mm	> 10 s

Single pulse drilling can be done on-the-fly, achieving up to 300 holes per second with a diameter of, for example, 60 µm in 1 mm sheet thickness. Percussion drilling uses a series of pulses at the same position to achieve deeper holes. Depending on the laser beam source used, different hole diameters and drilling depths can be achieved. For drill diameters larger than about 300 µm, trepanning is used, in which the bore is cut out via a relative movement between the workpiece and the laser beam. Helical drilling can be employed, on the other hand, to drill holes that require high geometrical precision and metallurgical quality.

Laser drilling is an alternative to processes such as electron beam drilling, spark erosion, electrochemical drilling and ultrasonic drilling. The laser is preferred, however, when hole diameters of approx. 1 to 500 µm at large aspect ratios (> 1:20) need to be drilled under difficult conditions, such as at a large inclination angle to the workpiece surface or in extremely hard materials (e.g. nickel-based alloys). A challenge here is to minimize both melt layers as well as surface contamination.

Cover: USP drilling of a turbine blade.

1 Laser perforation of a wing demonstrator.

2 Helical drilling of nozzles for CO_2 air conditioning systems.

Physical Process Fundamentals

Laser drilling processes can be divided into melt-dominated and vaporization-dominated processes. In melt dominated drilling processes – with pulse durations in the range of microseconds to milliseconds – the material largely melts and only a small part is vaporized. The resulting vapor pressure expels the molten material from the hole. This drilling method is very productive, but the melt remaining on the bore walls reduces the precision of the bore and can cause cracks in the material. In a vaporization-dominated process – with pulse durations of less than 10 ps – the material is almost completely vaporized, and the heat input into the workpiece is minimal. With an appropriate system technology, cylindrical and conical bores can thus be produced at high precision and a high aspect ratio without generating material defects.

Possible Applications

Since pulsed laser radiation operates at high intensity, it can be used to drill precisely in almost all materials such as metals, ceramics, semiconductors, plastics as well as multilayer systems (CFRP, CMCs) made of these materials. Applications include the production of cooling air holes in turbine components such as blades or combustion chambers, holes for fuel filters or injection nozzles as well as vent holes in injection molds for toolmaking.

Plant and Systems Engineering

In addition to advancing the process engineering, Fraunhofer ILT is developing the equipment required to industrially implement these drilling processes. This includes developing special helical drilling optics with rapid deflection of the laser radiation as well as integrating drilling processes into automated production facilities.

Equipment

Fraunhofer ILT has a large number of modern laser systems for drilling with laser radiation. These include:

- Long pulse lasers (pulse durations µs–ms) such as IPG single-mode and multimode fiber lasers up to 20 kW peak pulse power
- Short pulse lasers (pulse duration ns-µs) such as Edgewave double pulse laser with 2 x 40 W average power, pulse duration 2–10 ns at 50 kHz
- Ultra-short pulse (USP) lasers (pulse durations fs–ps) such as Amphos, Edgewave and Trumpf lasers with up to 400 W average power, pulse duration 900 fs–20 ps
- Optical beam shaping and drilling optics with focusing focal lengths of 70–300 mm, helical drilling optics as well as various scanner systems
- 3-axis and 5-axis machining systems, e. g. from Aerotech
- Sensors, such as cameras, triangulation sensors, OCT for process monitoring and process control
- Analytical equipment such as various light microscopes, SEM, EDX, UV-NIR and FT-IR spectroscopy and others

Contact

Dennis Haasler M. Sc.
Telephone +49 241 8906-8321
dennis.haasler@ilt.fraunhofer.de

Dipl.-Phys. Martin Reininghaus
Telephone +49 241 8906-627
martin.reininghaus@ilt.fraunhofer.de

3 Laser drilled coupling element.

4 Helical drilling optical system of Fraunhofer ILT.

5 Individual drilling in CFRP preform for functional elements.