Fraunhofer ILT

Fraunhofer Institute for Laser Technology ILT

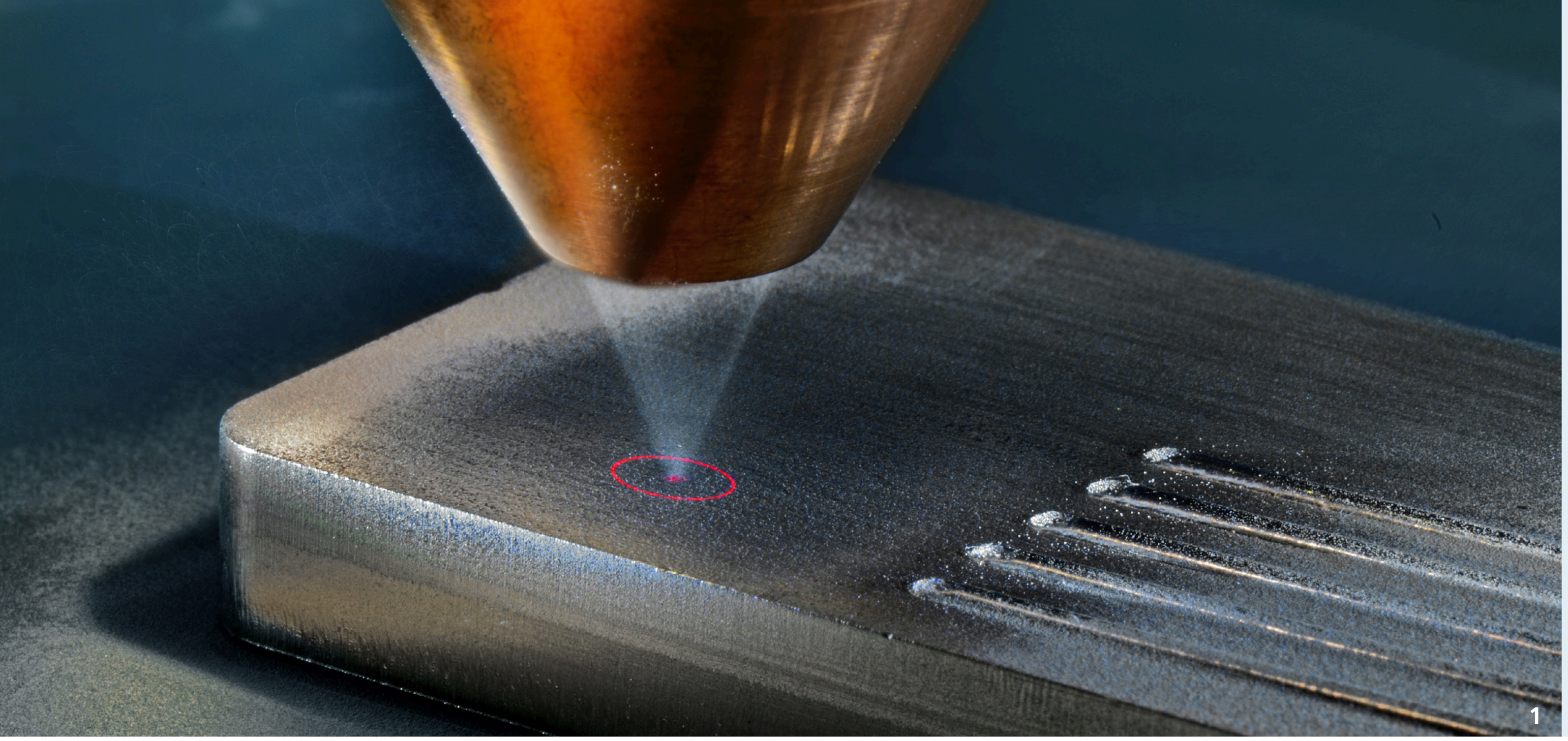
Sensor Systems for Production Measurement Technology

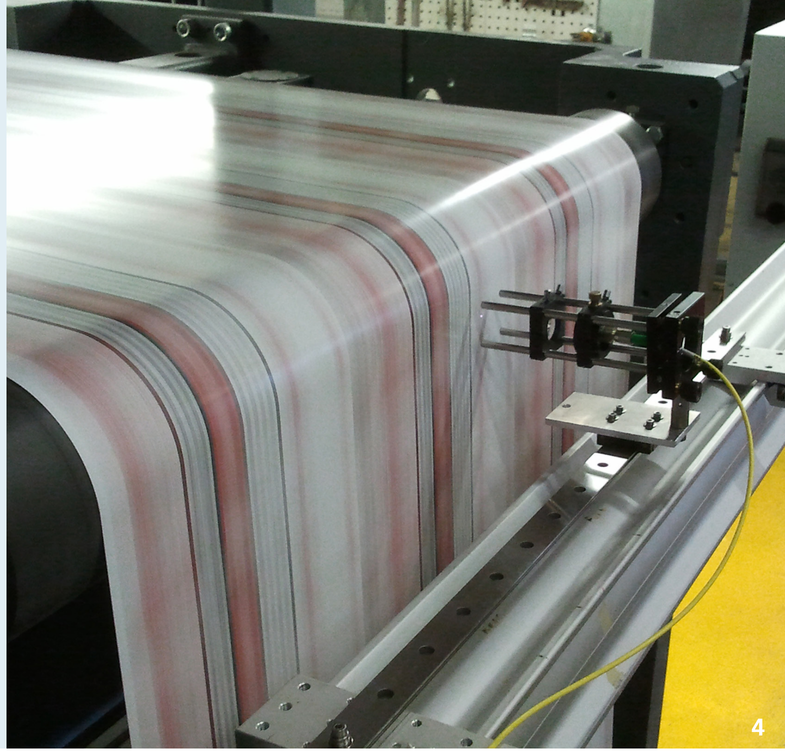
The Fraunhofer Institute for Laser Technology ILT develops laser-based measurement technologies to face challenges in modern manufacturing and inline process control. Together with customers and partners, we implement these technologies in prototypes and small series. One of our R&D focuses is on absolute measuring interferometric distance sensors, which can be used, among other things, to measure geometric properties of components with very high accuracy and throughput. Another focus is on using novel quantum light sources for the generation of entangled photon pairs, with which previously inaccessible spectral ranges can be used in production measurement technology.

Absolute measuring interferometric distance sensors

Distance sensors based on the interferometric measuring principle provide extremely precise measurements at high measuring frequencies. The measuring radiation can be guided via optical fibers or in a free beam, which is why measuring positions that are difficult to access can also be reached. While relative measuring laser interferometers use a single wavelength and have a unique measuring range of around one micrometer, absolute measuring interferometers of Fraunhofer ILT evaluate up to 4,000 individual wavelengths and, thus, achieve unique measuring ranges of 20 millimeters.

Measuring head of the »bd-1« sensor system developed at Fraunhofer ILT.





Sensor Systems for Production Measurement Technology

1. Measuring beam (red) for geometry measurement during Laser Material Deposition.
2. Inline measurement of track heights applied by Laser Material Deposition.

Fraunhofer ILT's absolute measuring interferometric sensors originated from in-house developments in the field of optical coherence tomography (OCT) for medical applications. It mainly focused on developing large measurement ranges with simultaneously very low linearity deviations as well as on continuous data evaluation in real time at measuring frequencies up to 80 kHz. The results of long-term climatic chamber tests prove that the sensors Fraunhofer ILT developed function stably – for example, they are robust against temperature fluctuations ranging from 5°C to 50°C.

In production measurement technology, absolute-measurement interferometric sensors from Fraunhofer ILT have already been validated for 24/7 use, i.e. for measuring single-layer thickness of multilayer plastic films, metal strip thickness in cold rolling mills, and weld penetration depths in laser welding systems.

»bd-x« sensor family

The opto-mechanical integration of the sensors uses compact, robust measuring heads connected to the interferometric evaluation unit via fiber optic cables up to 50 m in length. The measuring radiation is emitted from the measuring head toward the object surface and from there scattered back in the direction of the measuring head. This bidirectional (bd for short) beam guidance requires very little space for the sensor integration in systems and production lines. In laser processing systems, such sensors are advantageous because their measuring radiation can be coaxially superimposed on the processing laser beam and guided via a focusing optical system already present on the process side. This way, distance measurements can be made directly where the processing occurs.

Geometry features such as step heights, hole depths, weld penetration depths, surface topographies and also spatially resolved layer thickness and 3D tomography images can be generated from 1D distance measurements when the measured object is moved or the measuring beam deflected, e. g., with a scanner mirror. The measurement signal quality is not significantly disturbed by measurements on glowing objects (e. g., glass, metal), by laser processing radiation or plasmas (e. g., in laser welding) or by metal powder (e. g., in Laser Material Deposition).

The Fraunhofer ILT's absolute measuring devices can be equipped with independent measuring heads for up to four measuring points. In a time-division multiplexing process, the usable measuring frequency of, for example, 80 kHz (»bd-1«) is divided into two measuring points with 40 kHz each (»bd-2«) or into four measuring points with 20 kHz each (»bd-4«). In addition to the equal splitting of the measuring frequencies, asymmetrical splitting is also possible, such as 90 percent of the measurements at measuring point 1 and 10 percent at measuring point 2. For sensor arrangements requiring several measuring points, this splitting significantly reduces the total costs – by about two thirds.

Available light sources and wavelengths

The measuring wavelength most commonly used by Fraunhofer ILT for absolute measurements is 850 nm since the corresponding radiation can be detected with inexpensive CCD or CMOS sensors. In addition to measuring distance to surfaces, this wavelength can also be used for layer thickness and for tomography measurements on transparent objects such as glasses and plastics.

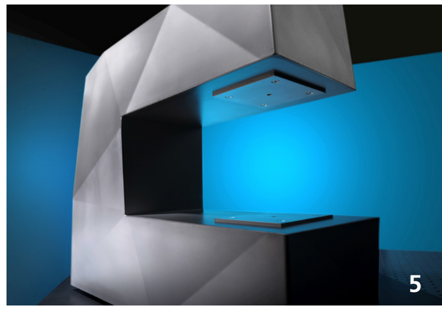
Furthermore, sensors with measuring wavelengths of 1064 nm and 1550 nm have been developed to meet application-specific requirements. For these wavelengths, however, comparatively expensive InGaAs sensors are needed to detect the measuring radiation.

Quantum light sources for the generation of entangled photon pairs are also the subject of research and development at Fraunhofer ILT. Here, photons in the mid-infrared (MIR) are generated to scan objects to be measured, and then transfer their measurement information to entangled photons in the easily detectable visible (VIS) or near-infrared (NIR) wavelength range. This makes the MIR wavelength range from 2 µm to 10 µm accessible to production measurement technology for the first time. Long-wavelength measurement radiation is advantageous, for example, for coating thickness and tomography measurements on objects such as ceramics, colored plastics or foams. These scatter strongly in the VIS and NIR range, but show almost no scattering in the MIR range so that greater optical penetration depths can be achieved.

Real-time data processing

The developments of Fraunhofer ILT are geared to demanding tasks in production metrology which, in addition to fast, robust opto-mechanical arrangements, include above all reliable and uninterrupted data processing. Using measurement frequencies of 80 kHz and PC-based block-by-block processing, this system has latency times of 20 ms and is primarily used for quality assurance. FPGA-based electronics have been developed for controlling fast machining and manufacturing processes in 24/7 use, enabling measurement data processing at 80 kHz and output of a control signal with a latency of only 150 µs.

3. Inspection of form and position tolerances on camshafts.
4. Interferometric embossing depth measurements on cardboard webs.



5. C-frame for two-sided distance measurements to determine metal strip thicknesses.
6. »bd-2« sensor technology and data processing electronics with fiber-optical measuring arm.

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Reg. No. 069572 QM15

Fraunhofer Institute
for Laser Technology ILT
Director
Prof. Constantin Häfner

Steinbachstraße 15
52074 Aachen, Germany
Phone +49 241 8906-0
Fax +49 241 8906-121
info@ilt.fraunhofer.de
www.ilt.fraunhofer.de

Contact

Dr. Stefan Hölters
Phone +49 241 8906-436
stefan.hoelters@ilt.fraunhofer.de

Dr. Achim Lenenbach
Phone +49 241 8906-124
achim.lenenbach@ilt.fraunhofer.de

What we offer

In the field of absolute measuring interferometric sensors, Fraunhofer ILT offers its partners studies, projects for prototype development, small series production and the subsequent transfer of manufacturing documents to licensees. New fields of application for the sensors are being developed within the framework of publicly funded R&D projects.

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.