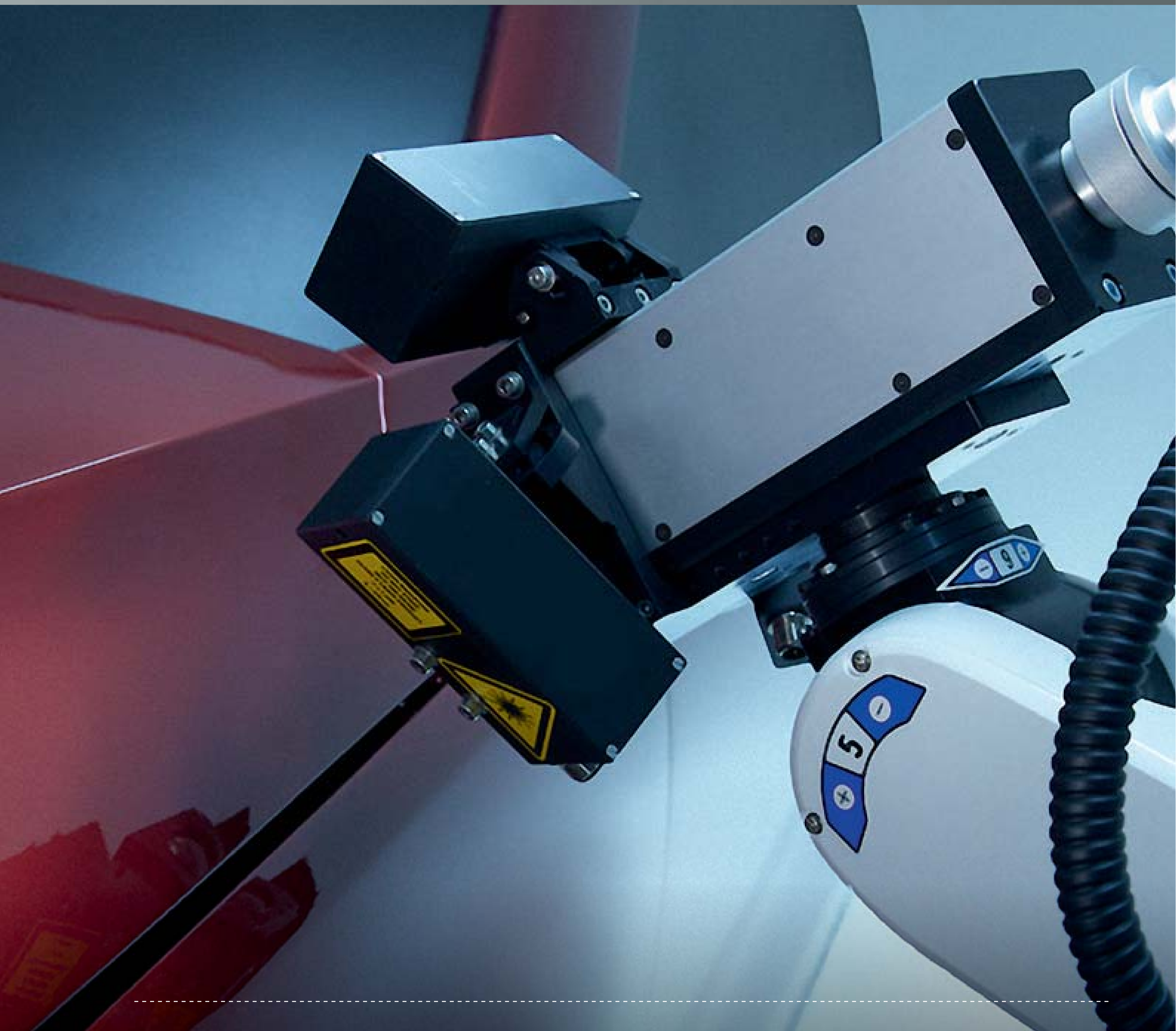
CENTER MATERIALS CHARACTERIZATION AND TESTING



Terahertz radiation measuring systems offer a non-contact and non-destructive method for measuring the coating thickness of multi-layered paint structure on vehicle surfaces. Sensors control the vertical orientation of the robot-mounted measuring head to guarantee the best signal quality. The terahertz waves used for the measurements carry so little power that, in effect, they are harmless to user's health and can be operated without any protective measures. The measurement and evaluation time is about one second per measurement.

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In January 2017, the Center for Materials Characterization and Testing became the ninth department of Fraunhofer ITWM at the Fraunhofer-Zentrum in Kaiserslautern, although it was established several years ago as part of Fraunhofer IPM. The work of the Center focuses on the non-destructive and non-contact testing of materials using electro-magnetic waves. The department is a leading international center for the characterization of multi-layer systems, for example, the materials found in the automobile and aviation industries. We use the terahertz range of the electro-magnetic spectrum because most of the materials tested are transparent in this range. Other application areas include testing glass and natural fiber reinforced composites for internal defects and monitoring the wall thickness in the production of plastic pipes and tubing. The Center provides the complete range of consulting services from the optimal measurement methods to special plant constructions for use on the production lines. Sophisticated algorithms evaluate the recorded measurement data and supply clear decision criteria as to whether the tested component meets the quality standards or is rather to be classified as defective. The close cooperation with the Image Processing department and the Competence Center for High Performance Computing enables rapid implementation of challenging solutions.

MAIN TOPICS

- Non-destructive and non-contact thickness measurements on micrometer to centimeter scale
- Defect detection in composite materials
- Wall thickness determination in plastic pipe production
- Terahertz spectroscopy for material identification
- Design and development of special equipment

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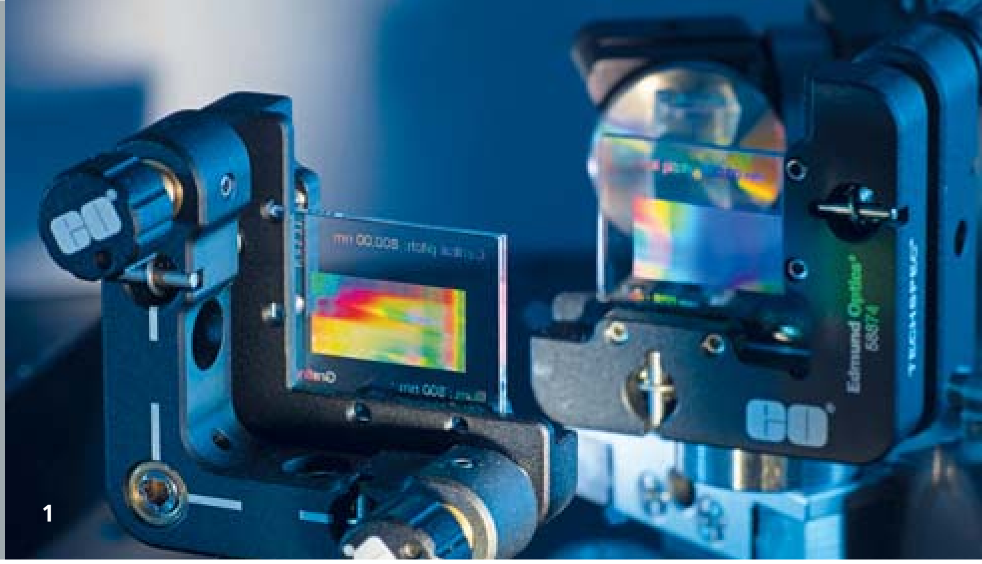

OPTICAL TERAHERTZ MEASURING SYSTEMS

1 *Setup for compensating the dispersion of optical fibers used to transmit ultrashort laser pulses*

The group primarily designs and builds turnkey, terahertz time domain systems for the generation, detection, and analysis of broadband terahertz radiation. The applications range from robot-mounted coating thickness measuring systems and high spatial resolution spectroscopy, to metering systems for ultrafast electronics that combine extremely fast electro-optical converters and ultrafast optics. The group recently added a new branch to work on optical coherence tomography (OCT), which expands the range of layer thickness measurement to below 10 µm.

Terahertz technology is becoming established as the non-contact method for determining thickness, for example, in car paint finishing systems. In contrast to other non-destructive analysis methods, terahertz waves (that are in the range between infrared and microwave) can be used to obtain precise analyses of even the most complex multilayer systems. The reason behind this is that terahertz waves are reflected at every individual boundary at which the refractive index changes. Based on the different propagation times of the reflected partial waves, the layer thicknesses in multilayer systems can be very accurately determined – non-contact/non-destructive – and, this nearly independent of the substrata. The only method currently available to achieve this is the terahertz technology.

The measuring systems based on time domain spectroscopy are useful in the industry relevant range of single and multilayer systems from 10 – 500 µm. Fraunhofer ITWM has already successfully demonstrated this range in cooperation with several industry partners in the automotive industry. One very promising application of the technology is in measuring soft, structured layers, for example, the skins of PVC plastics used for car interiors. The evaluation of the detected terahertz signals is based on a complex evaluation algorithm, which is implemented on a commercially available graphic card and able to reliably determine the thickness distributions of a 4-layer system in less than one second. This determination is performed with an accuracy of up to ±1 µm.

The layer thickness evaluation algorithm is currently being further developed at Fraunhofer ITWM in cooperation with the High Performance Computing department. The aim is to increase robustness and efficiency to allow either an accelerated evaluation or a reduction of the hardware. This effort is in response to inquiries from industry.

ELECTRONIC TERAHERTZ MEASURING SYSTEMS

Another research priority at the Center for Materials Characterization and Testing is electronic terahertz measuring technology. This effort focuses, in particular, on the lower terahertz spectral region between 0.1 THz and 1 THz. In this sub-region of the spectrum, a good penetration depth of measuring signals in dielectrics like ceramics, textiles, plastics, or fiberglass reinforced composites, enables not only accurate determination of thickness in multilayer systems having a total thickness of up to a few decimeters (adjacent to the thickness measuring systems based on optical terahertz technology), but also lends itself very well to imaging in terahertz testing.

Complementary to ultrasound or x-ray testing, terahertz technology enables the visual inspection of dielectrics for internal defects or characteristic features. The non-contact terahertz testing also typically delivers very high-contrast images for soft materials and synthetic composites. Similar to ultrasound methods, tomography-like sectional depth images are produced and, in contrast to x-ray radiation, terahertz waves are not ionizing and do not require any protective measures.

Terahertz imaging systems, which scan the object pixel by pixel by means of a single sensor unit, have already proven their worth in preliminary testing and sample measurements. Meanwhile, the Center for Material Characterization and Testing has continued to significantly expand the portfolio for fast, industrial terahertz wave testing systems: It includes a broad range from hand-held single point sensors and fast scanning systems to in-line capable sensor networks for large area quality control testing.

A particularly interesting application is used for the inspection of the radomes on aircraft, both in the field and in production. Radomes are generally found on the nose of the fuselage and are composed of complex, fiberglass composite structures with functional materials incorporated such as foams or Kevlar. In addition to the structural integrity of the dome, it is also necessary to ensure trouble free operation of the radar system. Terahertz imaging allows these aspects to be addressed during production, enabling early detection of manufacturing defects as well as identifying optimization potential. When deployed in the field, terahertz imaging can be used to check for proper functionality as it makes it possible to detect damage that may not be visible from the outside, for example, due to impact.

1 *New concepts like the MIMO technique are evaluated for faster and more cost-efficient imaging solutions; here a MIMO radar system with 12 transmitters and 12 receivers, which are operating from 75 to 110 GHz.*