

Examples of scattering media.

A variety of theoretical models were developed to accurately determine the optical properties of the investigated scattering media. Efficient algorithms were implemented, which can be used in order for numerous applications:

- Material analysis
- Biophotonics
- Content determination of ingredients
- Quality assurance
- Chemometrics
- Food analysis
- Process control, e.g. pharmacy and cosmetics
- Physics-based rendering
- Quality assessment
- Fabrication of dental restorations
- Determination of vital parameters

The ILM has realized a large number of collaborations and projects with established companies in these markets.



A setup of spatial frequency domain imaging for measuring spatially resolved optical properties.

The ZoE provides a wide field of measurement setups for the determination of optical properties and sample topography:

- Coherent back scattering
- Total reflection
- Collimated transmission
- Integrating sphere measurement (VIS, NIR, IR)
- Spatially resolved reflectance
- Spatial frequency domain imaging
- Angular and spectrally resolved scattered light measurements in VIS and NIR (BSDF)
- Absolute FTIR spectroscopy
- Ellipsometer







ZoE

Center for Determination of Optical Properties at the Institute for Laser Technologies in Medicine and Metrology (ILM) at Ulm University



Integrating sphere device for measuring the optical properties of diffuse scattering samples. The underlying measurement concept was developed in cooperation with the ILM.

The center for determination of optical properties (ZoE) is part of the department Quantitative Imaging and Sensors at the ILM. The ILM transfers findings from applied research into practice. To this end, it works, often together with companies, on publicly funded projects and direct R&D contracts.

The main areas of expertise are "Biomedical Optics", "Optics Simulation and Microoptics" and "Optical Metrology and Sensor Technology". These are also widely used in other business fields.

The mission of the institute is application-oriented research and the transfer of the developed technologies into industrial and medical practice. The ILM uses the entire range of public funds available, from regional calls for proposals through to DFG, BMBF, BMWK, private foundations up to EU funding.

On this basis, companies are provided with tailormade and cost-effective offers. A special concern of the ILM is the transfer of technology to SMEs.

The department Quantitative Imaging and Sensors is engaged in model-based simulative and metrological imaging and sensor technology. The aim is the direct acquisition of information employing physics-based models of light propagation in scattering media or objects, i.e. without having to resort to calibration measurements. For this purpose, a large number of different measurement procedures and theoretical methods have been developed during the last decades.

The ILM wants to provide their measurement capabilities and the exchange of experience directly to the costumer and the industry. For this aim, the Federal Ministry of Education and Research (BMBF) supported the foundation of the **ZoE**, which is arguably **the first center for determination of the optical properties of scattering media worldwide**.

Within the ZoE numerous setups are available for measuring the optical properties of scattering media. In the wavelength range from approximately 250 nm to $20 \mu \text{m}$ the four relevant optical properties of the radiative transport theory (absorption coefficient, scattering coefficient, phase function and refractive index) can be precisely determined. Also devices for characterizing flourescence and

GEFÖRDERT VOM



Raman scattering are part of the ZoE. The spectrum is completed by setups to measure topography, angle resolved scattering and roughness.



A camera image (left) compared to a physics-based rendered image of a phantom sample (right). The underlying optical properties of the rendering were measured with the integrating sphere setup in the ZoE.



The Institute for Laser Technologies in Medicine and Metrology at Ulm University is part of the Innovationsallianz Baden-Württemberg. We offer e.g.:

- Laboratory measurements
- Characterization of optical properties
- Simulation and calculation of light propagation in scattering media
- Custom-built scattering phantoms
- 3D-topography measurements
- Photometric consulting and support
- Customized measurement solutions

Ask for an offer!

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