Fraunhofer IPM

Absorption spectroscopy of transparent optical materials

Sensitive measurements of bulk material and optical coatings

Scattering of pump and probe beam during a PCI measurement.

High powers need high purities: The current development of high-power lasers calls for better quality assessment of optical materials for high-power applications. Sensitive photothermal measurement methods help to measure and secure the performance and quality of optical materials and coatings.

Photothermal common-path interferometry (PCI)

Photothermal common-path interferometry (PCI) is a highly sensitive method, based on a pump-probe-technique: A strong continuous-wave (cw) pump beam is focused into the sample, heating it locally due to light absorption. The resulting local change of the refractive index causes refraction and diffraction effects on the crossing probe beam.

This distortion is proportional to the absorption of the sample and can be measured by a lock-in technique. Translating the sample in z-direction through the interaction zone of the laser beams delivers spatially resolved PCI data that provide values for both bulk and surface absorption.

Tunable pump lasers provide new measurement options

Traditionally, high-sensitivity absorption measurements are performed at the fixed wavelengths of high-power lasers, since these are the most relevant ones for the use of such optical components. Fraunhofer IPM goes one step further by combining PCI with in-house developed cw optical parametric oscillators (OPO) as pump lasers. This way, absorption spectra of materials and components can be provided that cover large wavelength ranges.

Calibration

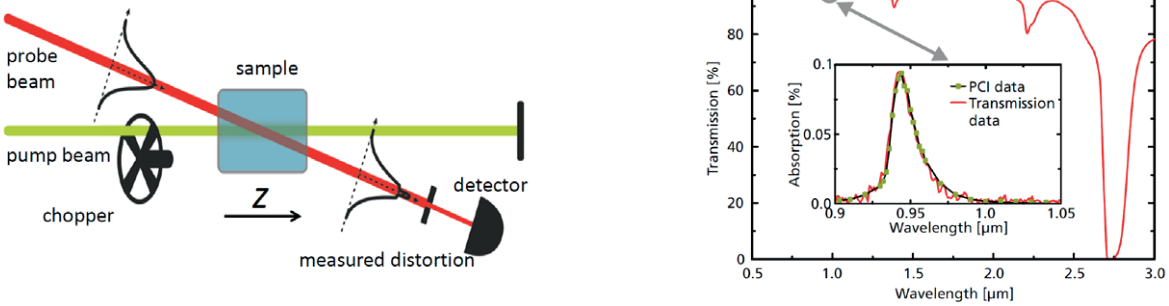
PCI measurements yield only relative absorption data, as it is the case with all

Our portfolio

- Service measurements
- Quality control for supply-chain support
- Delivery of customized measurement systems

Specifications

- Detection limits
  10^{-4}–10^{-6} cm^{-1} for bulk absorption
  10^{-6}–10^{-7} cm^{-1} for coatings (wavelength- and material-dependent)
- Spatial resolution
  50 µm transversal
  700 µm lateral
- Measurement of AR and HR coatings, lenses and mirror blanks

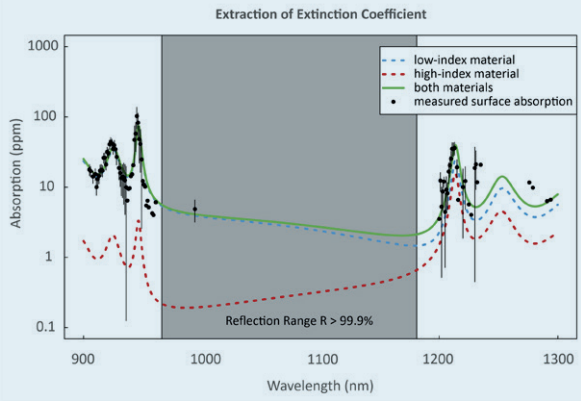


Left: Schematic setup of a photothermal common-path interferometer. A weak probe beam detects the effects of an intense pump beam passing through a sample. Right: Absorption calibration of a fused silica sample using the weak OH absorption peak at 940 nm. VIS-to-MIR transmission spectrum. Inset: PCI data vs. absorption data derived from transmission.

high-sensitivity techniques. Hence, calibration is required for absolute measurements. Utilizing the tunability of the OPOs by Fraunhofer IPM, the absorption features present in the sample, e. g. OH absorption in fused silica, may be recorded with the PCI spectrometer. Comparing these measurements with transmission data provides the required calibration information. This approach avoids the need for doped samples. It results in a higher accuracy of the absorption calibration and facilitates the analysis of new materials.

Application: Absorption measurement of high reflective dielectric coating

The advantage of having this wavelength-dependent information is shown in a measurement of a high reflective (HR) dielectric coating. The absorption contribution of the low-index material and the high index material differ for wavelengths below and above the HR region. By measuring and simulating the surface absorption in these separate wavelength regions, one can determine both contributions separately.



Measurement of the surface absorption of HR coating below and above the HR region. Comparing the measured signal with the simulated contributions of the low-index material and the high-index material, they can be determined separately.

Cross-system validation

In addition to PCI, Fraunhofer IPM has access to two other methods for the sensitive detection of residual absorptions in highly transparent materials. In [1], PCI results for a sample of lithium niobate ($LiNbO_3$) are compared with data from photoacoustic absorption measurements and total loss data from a $LiNbO_3$ whispering gallery resonator. Over more than four orders of magnitude the results from all tree measurements show good agreement, what emphasizes the capability of this measurement technique.

[1] M. Leidinger, S. Fieberg, N. Waasem, F. Kühnemann, K. Buse, and I. Breunig, "Comparative study on three highly sensitive absorption measurement techniques characterizing lithium niobate over its entire transparent spectral range," Opt. Express 23, 21690-21705 (2015).

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