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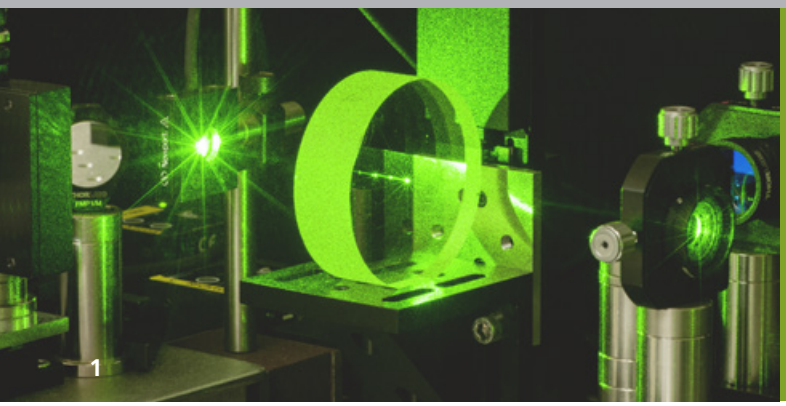
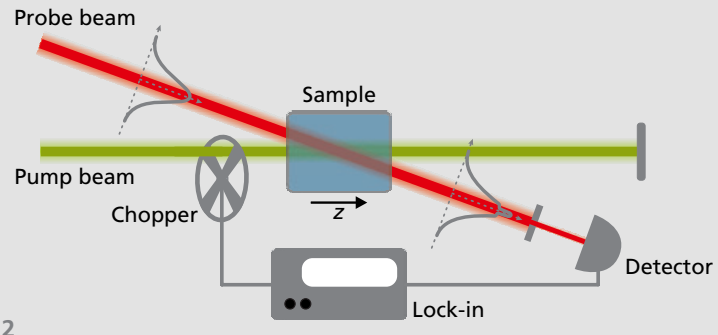
FRAUNHOFER INSTITUTE FOR PHYSICAL MEASUREMENT TECHNIQUES IPM





1 *Optical crystal on the PCI test bench for measuring the residual absorption.*

2 *Schematic setup of a photothermal common-path interferometer. A weak probe beam detects the effects of an intense pump beam passing through a sample.*

ABSORPTION SPECTROSCOPY
OF TRANSPARENT OPTICAL MATERIALS

High powers need high purities: The current development of high-power lasers calls for better quality assessment of optical materials for high-power applications. In bulk materials for lenses and mirrors, in dielectric coatings or nonlinear-optical components, material imperfections or impurities may lead to residual absorption. Under high laser intensities, absorption coefficients of 1000 ppm/cm or below may cause local heating, resulting in component malfunction or even damage.

Several techniques have been developed to detect residual absorption in highly transparent optical materials down to 10 ppm/cm or even less. At such high sensitivity levels, indirect techniques are the only option: They either detect the resulting temperature increase or secondary effects caused by the intense laser illumination, i.e. thermal expansion or refractive index changes.

Photothermal common-path interferometry (PCI)

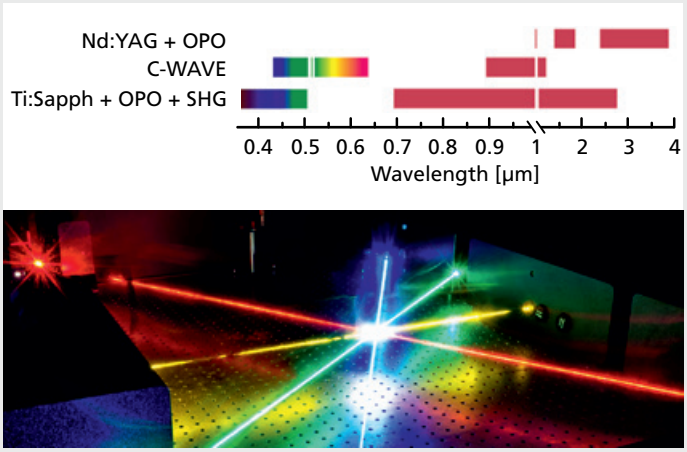
Photothermal common-path interferometry (PCI) is a highly sensitive method, based on a pump-probe-technique: A strong continuous-wave (cw) pump beam is focused into the sample, heating it locally due to light absorption. The resulting local change of the refractive index causes refraction and diffraction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

Fraunhofer Institute for Physical Measurement Techniques IPM
Heidenhofstrasse 8
D-79110 Freiburg, Germany

Contact
Dr Frank Kühnemann
Spectroscopy and Process Analytics
Phone +49 761 8857-457
frank.kuehnemann@ipm.fraunhofer.de

www.ipm.fraunhofer.de/en



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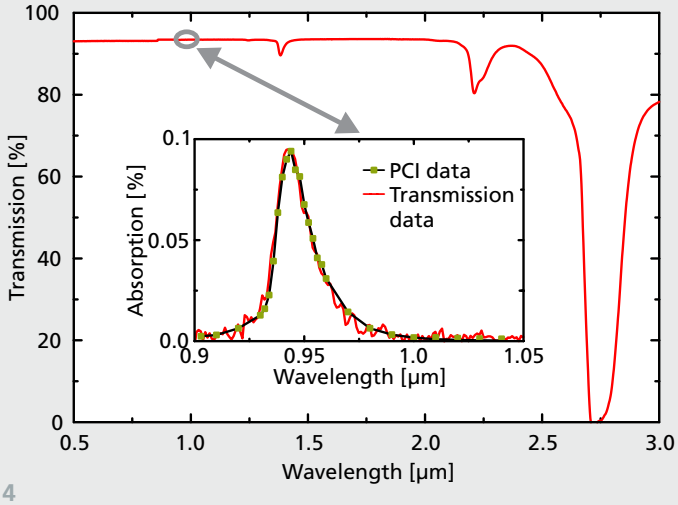

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3 *Top: Wavelength ranges available for PCI measurements which can be covered by widely tunable optical parametric oscillators (OPOs). Bottom: Intersecting beams in the visible range from four OPOs.*

4 *Absorption calibration of a fused silica sample using the weak OH absorption peak at 940 nm. Inset: PCI-measurement vs. absorption values derived from transmission data.*

5 *Measurement of bulk and surface absorption for a fused-silica sample with AR coatings on both surfaces. The sample is translated through the interaction zone of the two laser beams. The PCI signals are then converted in absorption values for bulk and surface using material-specific conversion coefficients.*

Our advantage

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 these 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 high-sensitivity techniques. Hence, calibration is required for absolute measurements. Utilizing the tunability of the OPOs developed at 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.

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. Comparing, for example, PCI results for a sample of lithium niobate ($LiNbO_3$) with data from photoacoustic absorption measurements and total loss data from a $LiNbO_3$ whispering gallery resonator shows good agreement over more than four orders of magnitude.

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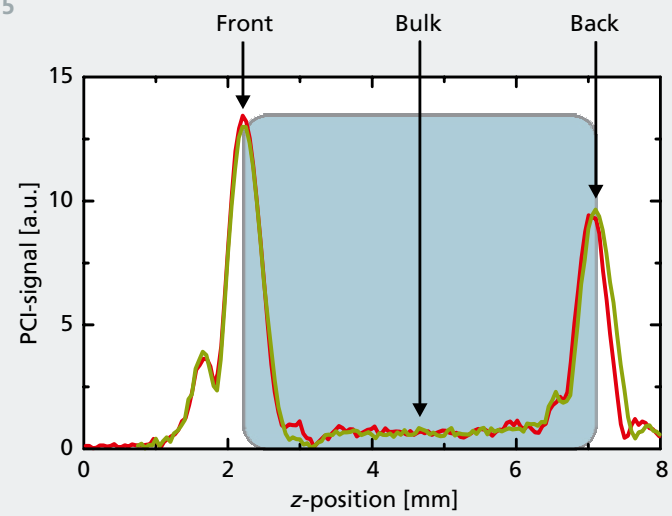

Measured absorption:

Front
13.2±0.5 ppm

Bulk
6±2 ppm/cm

Back
9.5±0.5 ppm

SPECIFICATIONS

- ***Detection limits***
  10^{-5}-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***

OUR PORTFOLIO

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