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Measuring residual absorption in highly transparent optical materials using tunable sources: On calibration, spectroscopy and cross-validation

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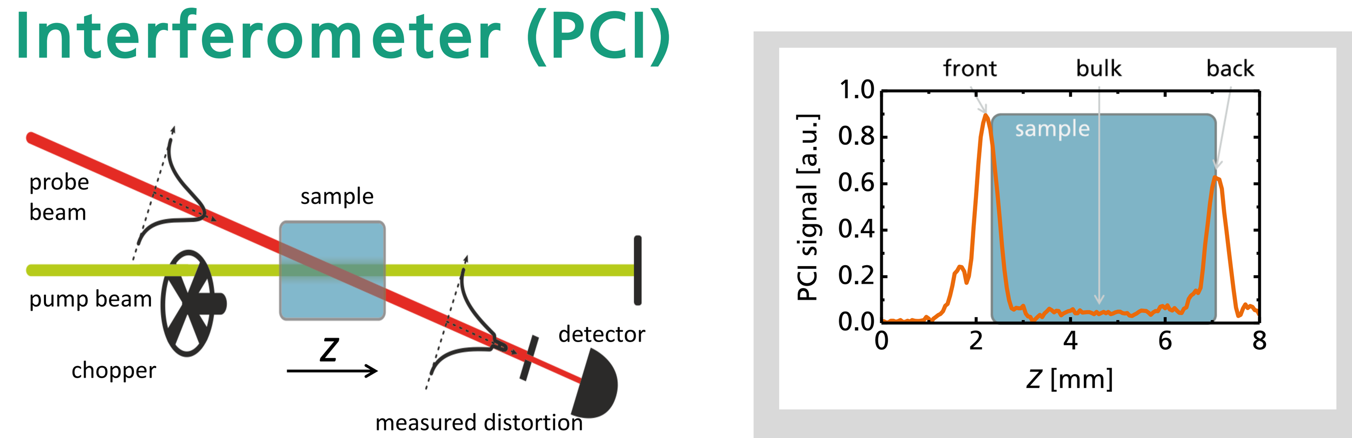
Fraunhofer IPM

IMTEK

Introduction

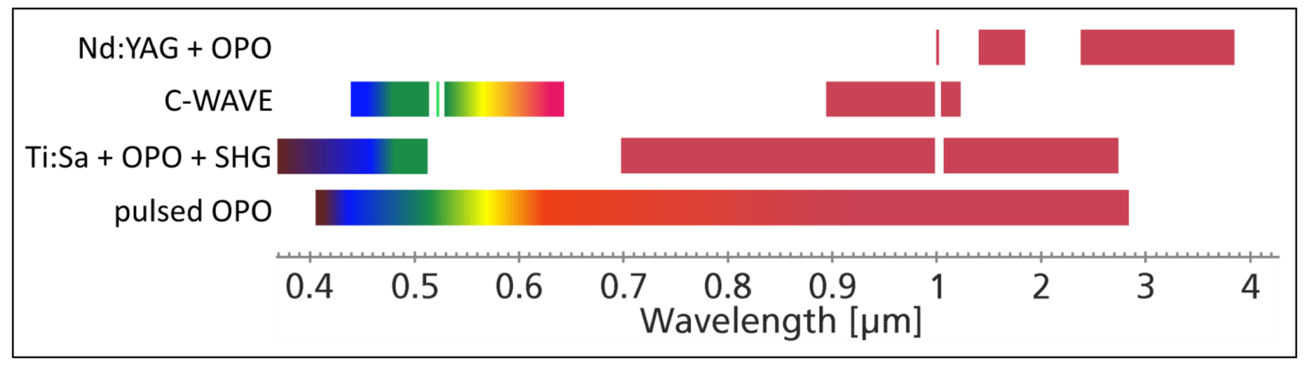
Photothermal Common-path interferometry (PCI) is considered as one of the most sensitive techniques for the measurement of residual absorption in bulk materials and coatings.
At Fraunhofer IPM, the setup is combined with continuous-wave optical parametric oscillators (OPOs) as widely tunable pump sources for measure-ments in the visible, near infrared and middle infrared. This offers new possi-bilities for the calibration of the absolute absorption scale and for the determination of spectral signatures in the material's absorption.
Cross-validation is achieved for bulk data by combinig the PCI results with data from a photoacoustic spectrometer and from loss measurements in whispering-gallery-resonators made from high-purity materials.

Photothermal common-Path Interferometer (PCI)

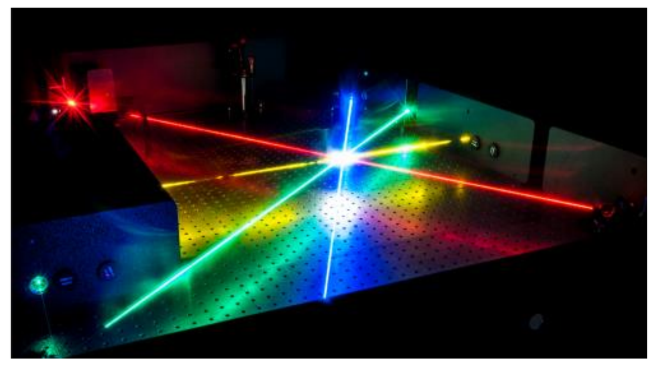


PCI detection scheme and typical Z scan along the sample.

Wavelength coverage

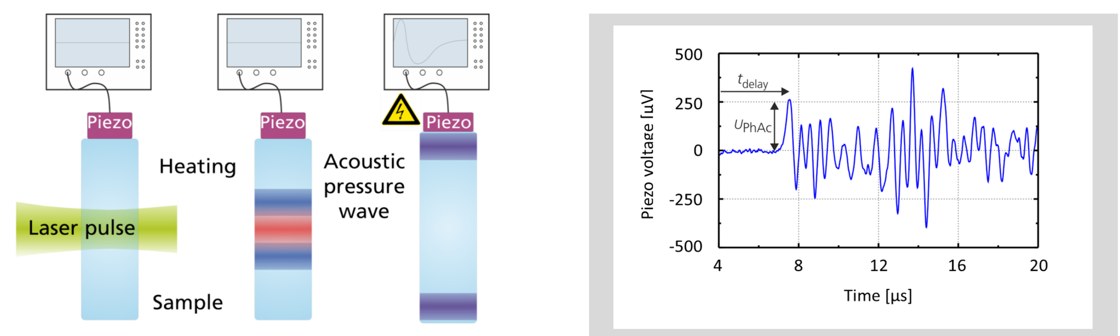


Fraunhofer IPM and IMTEK have a successful track record in the development of cw OPOs. As a result, tunable pump sources are available for PCI and WGRAS in the VIS, NIR and MIR regions. PAS is pumped by ns lasers and OPOs.



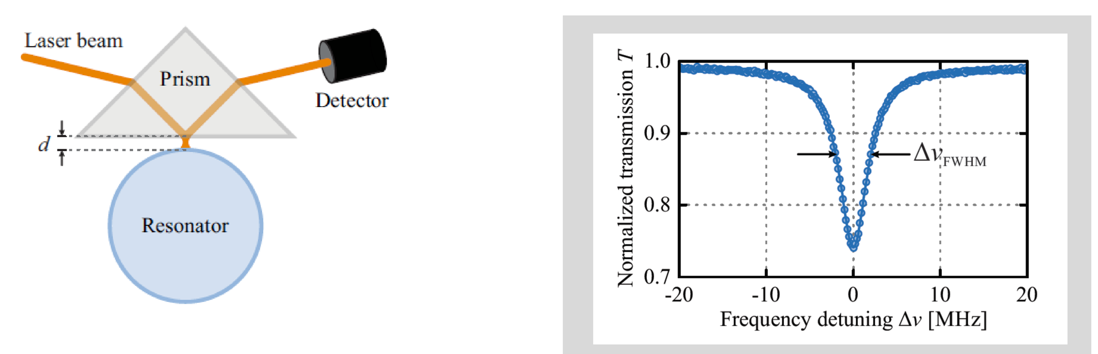
Visible beams of 4 "C-WAVE" OPOs intersecting on the optical table

Photoacoustic Spectrometer (PAS)



Photoacoustic detection scheme and typical PA signal

Whispering-Gallery-Resonator-based Absorption Spectrometer (WGRAS)



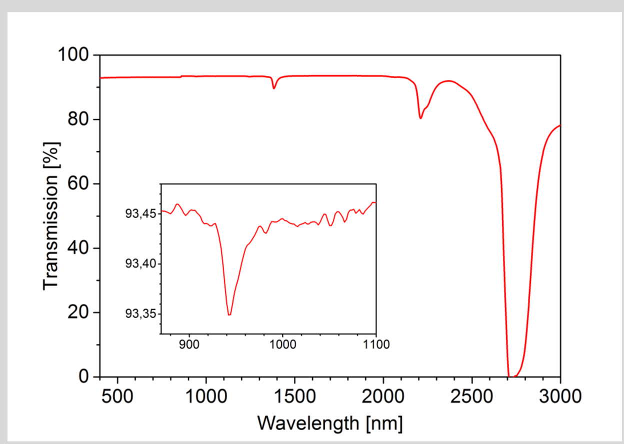
Experimental WGRAS setup and resonance curve

Calibration

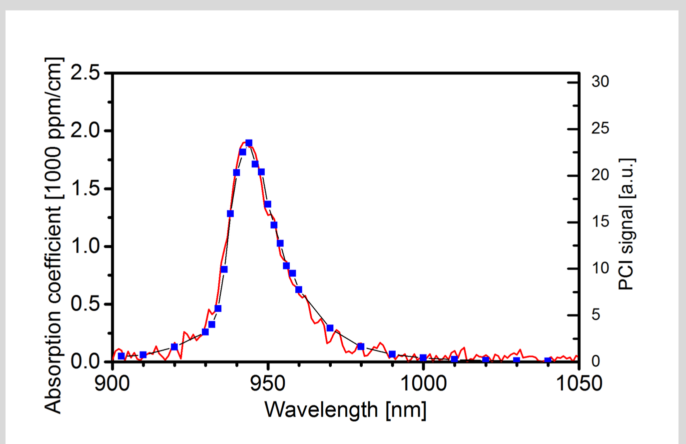
Calibration is a key issue for all absorption techniques relying on secondary thermal effects. The tuneability of the pump sources allows one to probe characteristic absorption features in the samples which are strong enough to be assessed with standard transmission spectrometers (FTIR or spectrophotometer). This is used to adjust the absolute absorption scale of PCI and PAS. WGRAS does not require any absorption calibration.

Fused silica : OH absorption band at 946 nm

Transmission data



PCI vs. Transmission data



Absorption spectroscopy of HR coatings

(Cooperation with Optics Balzers, Jena)

At the edge of the HR band, the interference in the coating stack leads of the multiple reflections leads to resonances with an increased absorption signal.

Data:

(a) transmission curve of the HR mirror

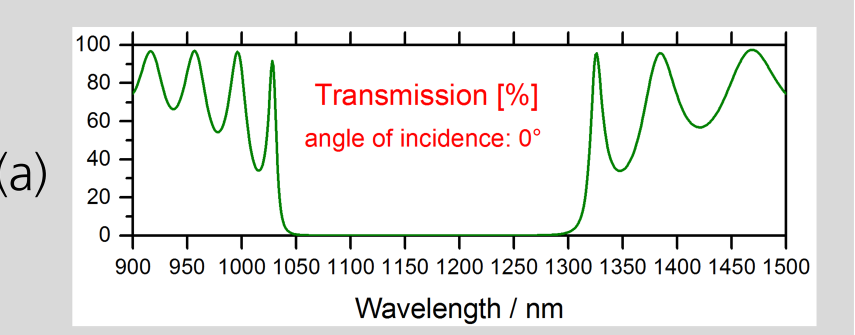
(b) Measured and simulated absorption spectrum of the coating. The grey area indicates the uncertainties, partially dominated by the cross-talk from bulk absorption. Simulations are performed assuming fixed k-values across the spectrum.

(c) Bulk absorption of the fused silica substrate. The strong OH peak at 946 nm masks the second side peak in the coating spectrum.

Samples:

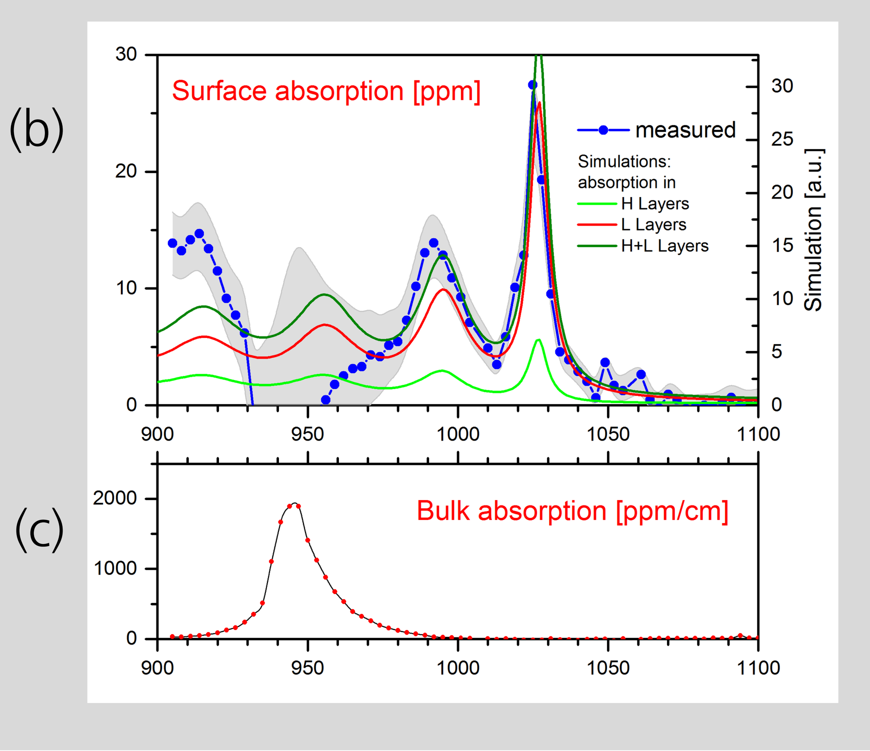
HR(45°, NIR) >99%; Ta_2O_5/SiO_2 coating on fused silica
Technique: plasma-assisted reactive magnetron sputtering (PARMS)

(a)

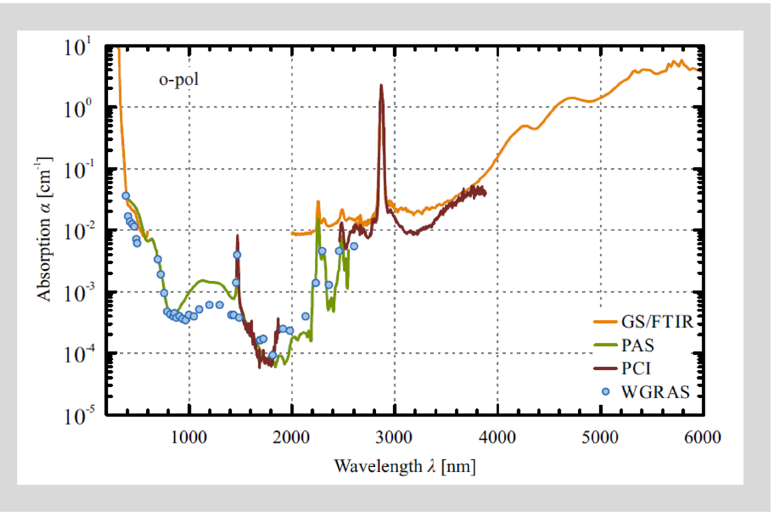


(b)

(c)



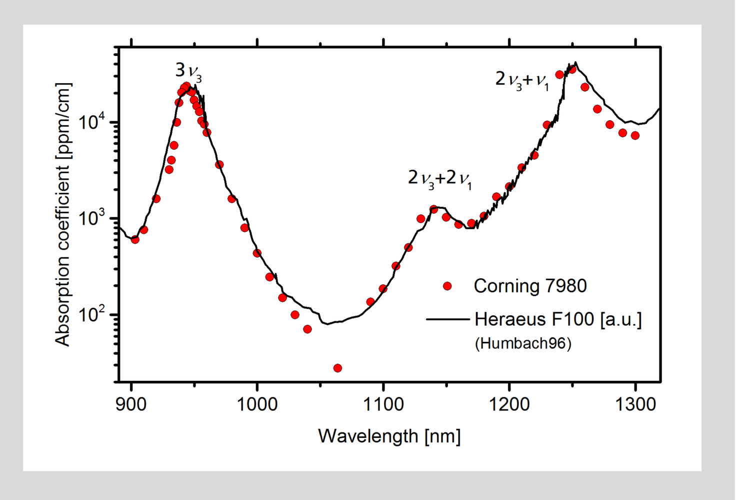
Cross-validation: $LiNbO_3$ spectrum



A $LiNbO_3$ wafer was analyzed with PCI and PAS. After that, a whispering-gallery-resonator was fabricated and tested *[Leidinger15]*.

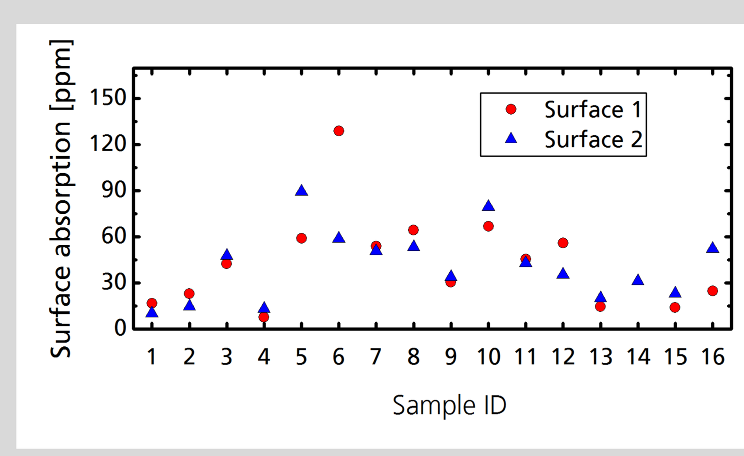
- Grating(GS)/FTIR
- PAS
- PCI
- WGRAS

Spectroscopy of fused silica and data for AR coatings



Left:
PCI spectrum of fused silica (Corning 7980) compared to the spectrum of "wet" fused silica (Heraeus F100, *[Humbach96]*).
Light source: C-WAVE (appr. 500 mW)

Right:
Comparison of different AR coating batches on C7980



References

[Leidinger15]: M. Leidinger et al., „Comparative study on three highly sensitive absorption easurement techniques characterizing lithium niobate over its entire transparent spectral range." Optics Express, 23, 21690 (2015)

[Humbach96]: O. Humbach et al., "Analysis of OH absorption bands in synthetic silica", Journal of Non-Crystalline Solids 203, 19 (1996)

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