Background-Corrected Determination of Optical Properties in the Far Infrared Range up to 1 mm

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Abstract

The optical properties transmittance and reflectance of materials are defined as the flux of radiation reflected from or transmitted through a sample with respect to the incident flux. Usual measurement approaches for these quantities follow these definitions and determine the quotient of the reflected or transmitted flux with respect to the incident flux. However, in the Mid and Far Infrared Range (MIR and FIR) this approach might easily lead to wrong results because background radiation sources including the sample itself and temperature gradients inside the spectrometer are not correctly considered in this way. The observed deviations are particularly significant when working with cooled detectors. By carefully temperature stabilizing the spectrometer, by measuring at two flux levels of incident radiation and by using an appropriate evaluation scheme the transmittance and reflectance can be determined in the range from 25 µm up to 1000 µm with largely reduced systematic deviations.

Key words: transmittance, reflectance, MIR, FIR.

Offsets in transmittance and reflectance measurements in the FIR

Transmittance and reflectance of materials are defined as the ratio of flux transmitted through or reflected from a sample with respect to the incident flux. In the following we discuss transmittance only but the discussion is valid for reflectance as well.

The transmittance τ is usually measured by a sequential measurement of the incident flux in an unobstructed beampath of the spectrometer and of the transmitted flux with the sample inserted into the beampath and by a subsequent division of the two:

$$\tau = \Phi_{Sample} \frac{\square}{\square} \Phi_{Inc} = \frac{(\tau * \Phi_{Inc})}{\Phi_{Inc}} \tag{1}$$

However, by insertion of the sample in the beampath additional radiation sources are introduced due to radiation emitted by the sample itself and/or induced back reflections [1]. Approximately the flux measured with the inserted sample under consideration of the additional terms is given by:

$$\Phi_{Sample} = \tau * (\Phi_{Inc} + \Phi_A) + \Phi_B \tag{2}$$

It is evident that a subsequent division of this expression by Φ_{Inc} wouldn't lead to τ but rather to a result with a bias. The deviation is increased when working with cooled detectors and can be minimized when spectrometer (with exception of the source), sample and detector have the same temperature. For an illustration transmittance measurements of a PVDF-membrane recorded with a room temperature detector and a cooled detector are compared in Fig. 1a). The deviation of the uncorrected measurements is obvious.

Background corrected measurements

These systematic deviations can be overcome by reducing the temperature gradients inside of the spectrometer and performing measurements at two levels of incident flux. Care has to be taken that the two flux levels are within the linear range of the detection system and that the spectrometer temperature does not change when changing flux levels. The latter could be achieved by applying external sources which is the approach we follow.

For a background corrected determination of the transmittance a sequence of four measurements is recorded. In addition to the two incident flux levels Φ_{Inc1} and Φ_{Inc2} two measurements of the respective transmitted fluxes are recorded:

$$\tilde{\Phi}_1 = \tau * (\Phi_{Inc1} + \Phi_A) + \Phi_B$$

and

$$\tilde{\Phi}_2 = \tau * (\Phi_{Inc2} + \Phi_A) + \Phi_B \qquad (3)$$

By inserting all four recordings in a quotient of differences:

$$\frac{\tilde{\Phi}_1 - \tilde{\Phi}_2}{\tilde{\Phi}_{Inc1} - \tilde{\Phi}_{Inc2}} =$$

$$= \frac{\tau * (\Phi_{Inc1} + \Phi_A) + \Phi_B - [\tau * (\Phi_{Inc2} + \Phi_A)}{\Phi_{Inc1} - \Phi_{Inc2}}$$

$$= \tau \qquad (4)$$

the background fluxes Φ_A and Φ_B cancel and the offset corrected transmittance τ can be determined.
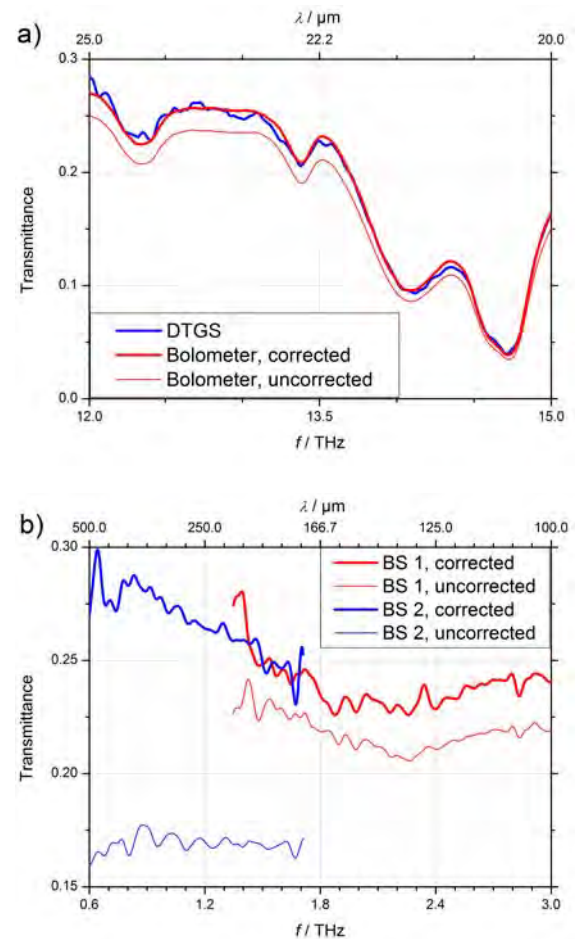

Fig. 1: Transmittance measurements of a PVDF-membrane at a Fourier transform spectrometer. a)Measurements with a room temperature pyroelectric DTGS detector (blue) and a liquid helium cooled bolometer (thin red). A background corrected measurement of the cooled detector (thick red) fits much better to the measurement with the room temperature detector. b) Measurements in the FIR, recorded with a liquid helium cooled bolometer and different beamsplitters (BS 1, BS 2). The background corrected signals show good consistency.

The successful application of this measurement and evaluation scheme is illustrated in Fig. 1 and 2. In Fig. 1a) the background corrected measurement with the cooled detector fits nicely with the result obtained with the room temperature detector. In Fig. 1b) and 2 it is illustrated how often observed offsets due to spectrometer configuration changes can be eliminated by the here applied measurement scheme.

References

[1] J. Birch, F. Clarke, *Analytica Chimica Acta*, 380, 369-378 (1999)
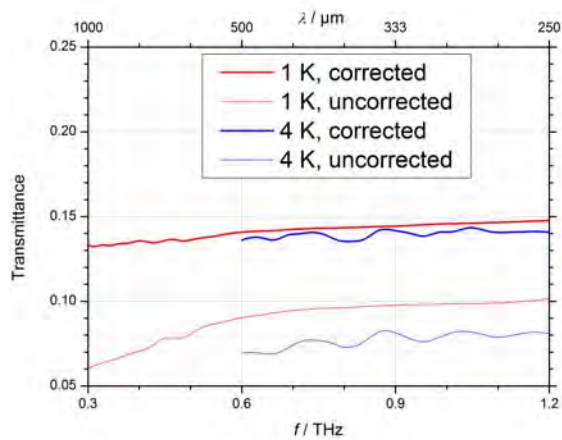

Fig. 2: Transmittance measurements of a metalized SiN *membrane in the FIR, recorded with two liquid helium cooled bolometer operating at different temperatures* (1 K, 4 K). *The corrected signals show a very small deviation in the overlapping region.*