Asymmetric comb-FTIR for Characterizing Metamaterials

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***Abstract*—A Fourier-transform spectrometer has been developed that can simultaneously determine the *amplitude and the phase* spectrum. It is based on the interference of two coherent frequency-comb beams and *uses no moving part*. As its first application, the complex transmission of free-standing metal wire materials is measured at varying, precise incidence settings.**

I. Introduction And Background

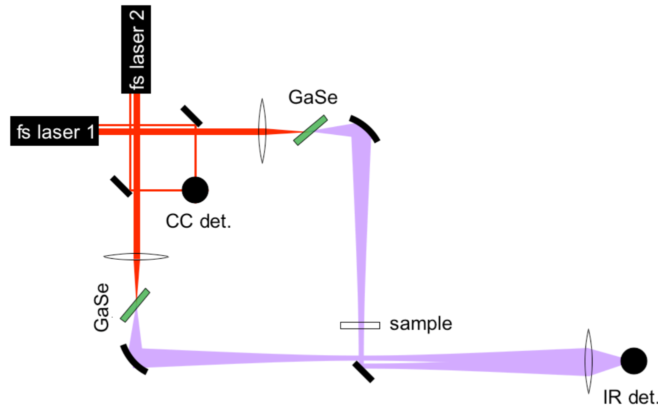
INFRARED spectroscopy heavily relies upon commercial Fourier-Transform Infrared Spectrometers (FTIR) which place the sample in the outgoing beam, after the beam splitter/combiner. This allows to detect the transmittance (or reflectance) of a sample only. To obtain the full optical response a Kramers-Kronig analysis has to be performed.[1] An alternative has been the combination with polarization analysis (ellipsometry) with the advantage of unambigous determination of the complex dielectric function $\varepsilon' + i\varepsilon''$.[2]

A more direct method has been the placement of the sample ino one of the interferometer arms, with the consequence that the simultaneous recording of both amplitude and phase spectra yield the complex dielectric function without assumptions on its properties outside the measured spectral range. This "asymmetric" FTIR instrumentation was pioneered by Ludwig Genzel in the 1970's but has not found its way into a commercial instrument.

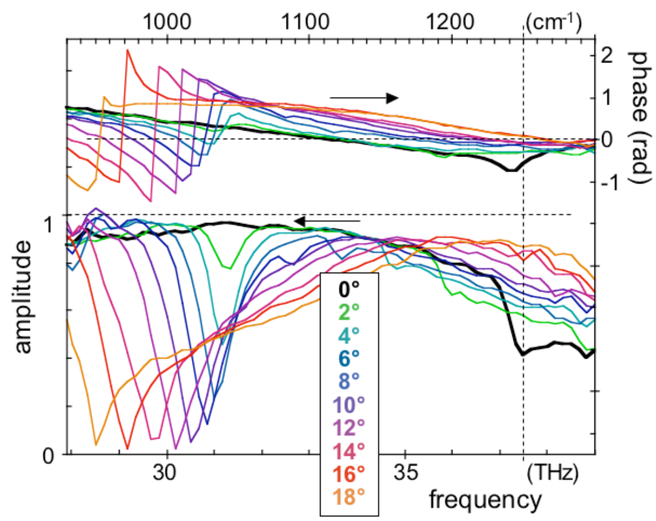
II. Setup And Results

Our novel asymmetric FTIR is a straight-forward extension of our recently introduced comb-FTIR.[3] It is based on the interference of two coherent frequency-comb beams which are derived by frequency-difference generation in thin GaSe crystals, from two near-visible laser beams with periodic pulses of 10 fs length. The essence is that the periodicities of the pulses differ by some ppm, and therefore, detecting the superimposed pulse trains results in self-scanned interferograms which occur regularly, without involvement of any moving part.[4] As shown in the following sketch our instrument uses a wavefront-combining mirror for superimposing both mid-infrared beams (8-12 µm wavelength, depicted magenta). The beams have narrow widths of a few mm to accomodate a small sample. The HgCdTe detector records interferograms, and a visible light detector (CC) serves to define the white-light-peak time position, which marks the time of overlap of the visible pulses, to serve as time reference for the phase spectrum.

The high collimation of the sample beam, with convergence angle < 1°, allows meaningful exploration of angle-dependent transmission spectra.



We show below the examples of a thin metal mesh with 8 µm period. Only at non-normal incidence, the material develops a sharp absorption dip which is accompanied by a characteristic phase signature.



This method suggests itself to characterize metamaterials for comparison with theory, and in particular, to obtain unambigous evidence of negative refraction.

References

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