Project for Course Φ468: Light and Matter interactions and optical constants of Solids

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Terahertz Time Domain Spectroscopy parameter analysis

The goal of this project was to extract the complex refractive index of a 2mm material. A set of measurements was given. The first data file is containing the reference and the second containing the sample measurements. Using programming language Python, I tried to write a code for the data analysis of the project.

Process of data analysis

First, I uploaded the data files and then plotted the two pulses. Then, I passed the measurements to frequency, performing a Fourier Transform (FFT) and plotted them again to see the results.

Afterwards, I divided the two signals to get the experimental Transfer Function (T(f)). I plotted the transfer function's real and imaginary parts to see the relation between them, then plotted the natural logarithm of T(f) versus frequency.

To fit the theoretical transfer function, we assume that $n \gg k$, so that the theoretical (zero reflection) $T(f)_{th}$ is:

$$H_{zero}(\omega) = \frac{T_{10}(\omega) \cdot P_1(\omega, d) \cdot T_{01}(\omega)}{P_0(\omega, d)}$$

where T_{10} and T_{01} are the transmission coefficients.

Unwrapping the phase of the transfer function allowed me to calculate the real part of the refractive index: $n(\omega) = 1 + \frac{\varphi(\omega) c}{\omega d}$, where

i. φ(ω) is the phase of the transfer function
ii. $c = 3 \cdot 10^8\, m/s$ is the speed of light
iii. ω is the frequency and
iv. d = 0.002 m is the sample material's thickness.

I also calculated and plotted the absorbance a(ω) and extinction coefficient, k.

Finally, using the Newton – Raphson method, I tried to fit the theoretical transfer function to the experimental one and extract the complex refractive index, N.

The equations I used for the fitting process are the following:

- $F(\omega)=\ln(\frac{4\bar{n}_0\bar{n}_1}{(\bar{n}_0+\bar{n}_1)^2})-\frac{i\omega d(\bar{n}_1-\bar{n}_0)}{c}$
- $dF=\frac{1}{\bar{n}_1}-\frac{2}{\bar{n}_0+\bar{n}_1}-\frac{i\omega d}{c}$,

where $\bar{n}_0$ and$\bar{n}_1$ are the complex refractive indices of the air and sample material.