Case study #3 – Applied Optical Spectroscopy - PHY 7233

To submit on (or before) January 20th 2023

You discover in your lab a drawer with a large quantity of an unknown material. There are many pieces of wafer of that same material. All these pieces have a **thickness of 0.90 mm ± 0.02 mm** when measured with a caliper and they are flat on both sides. Luckily, you have access to a time-resolved THz spectroscopy scheme to help you determine what material it is. You perform a reference measurement (when the material is not in the THz beam path) and a sample measurement (when the material is inserted in the THz beam path) and obtain the two following data sets:

i. Unknown_Ref.xlsx
ii. Unknown_Sample.xlsx

where the first column correspond to the time delay between the gating NIR pulse and THz pulse in ps (not the displacement of the translation stage in the experiment)

and the second column is the voltage read on a lock-in amplifier proportional to the THz electric field amplitude. Use the CS3_helpfile.m, it might help to have a look at it even if you are using Python.

1. Plot both time-resolved data on the same graph.

2. Explain why the THz measurement taken through the sample shows two transients separated by 20 ps.

3. In the time domain, select the main region of interest (for example, by multiplying the data with a super Gaussian function centered on the main THz transient), to remove "artifacts". Plot the filtered time-domain data for both the "reference" and "sample" scans in the same figure.

4. Plot the "reference" and "sample" amplitude spectra (on the same graph) (Hint: use the Fourier transform).

5. Extract the refractive index and plot this value in the region between 0.2 and 0.9 THz.

6. Extract the "absorption coefficient α [1/cm]" and plot this value in the region between 0.2 and 0.9 THz.

7. Compare your value to those in the literature: See paper by Grischkowsky et al J. Opt. Soc. Am. B **7**, 2006, 1990 and determine what kind of material it is.

   For the following questions 8 and 9, assume that the THz is generated from optical rectification in a nonlinear crystal and detected via the electro-optical sampling technique discussed in the course.

8. How can we technically increase the spectral bandwidth of the THz system used to produce the time-resolved THz signal shown in "Unknown_Ref.xlsx"?

9. Discuss the challenges related to characterizing a strongly absorptive material with this THz system. How can we overcome these challenges?