Boulder School for Condensed Matter and Materials Physics 2025

Lecturer: N.P. Armitage
Optical properties of Quantum Materials

==========

Q 1:
A superconductor's optical conductivity can be written as $\sigma(\omega) = A\delta(0) + i\frac{Ne^2}{m\omega}$. Sketch what this looks like. Using the Kramer's-Kronig relations in Eq. 36 and 37 of my optics notes, what is the constant A?

Q 2:
Using the formalism present in Sec.VI D of the optics lecture notes, show that the if there is ANY reflection symmetries to a material then an optical transmission matrix has the form

$$\hat{T} = \begin{bmatrix} A & B \\ B & D \end{bmatrix}. \tag{1}$$

Use the fact that the reflection matrix in the xz plane is

$$\hat{M}_{xz} = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}. \tag{2}$$

Q 3:
As we have discussed in the class, the optical data that characterizes the interaction of light with a material comes to us in different forms. We can measure the complex transmission (in THz time domain spectroscopy), reflectivity, dc resistivity, and high frequency ellipsometry among others. These parameters can depend on the dielectric constant in different ways. For instance as discussed in class the reflectivity of a surface is

$$R = \left|\frac{1-\sqrt{\epsilon}}{1+\sqrt{\epsilon}}\right|, \tag{3}$$

where ϵ is the dielectric constant. The dc resistivity is

$$\rho_{dc} = \frac{1}{\sigma_{dc}(0)} = \mathrm{Re}\Big[\frac{4\pi}{i\omega(1-\epsilon(0))}\Big]. \tag{4}$$

It can be challenging to combine all these measures into single global complex dielectric function that is constrained by all of them. One way to do that is to set up some general complex dielectric function of many "oscillators" and allow their parameters to vary until the best global fit is obtained. More oscillators can be added until adequate agreement with the whole data set is obtained.

RefFIT is a data analysis program designed to fit optical spectra, such as reflectivity, transmission, ellipsometry and Kerr and Faraday rotation using the Drude-Lorentz, Fano, Tauc-Lorentz and many other dielectric-function models.

Find Reffit at this Dropobox link. Download reffit.exe.

`https://www.dropbox.com/scl/fo/0oimyaavkk2jzze0kru65/ACIMgeAYuaveNh5DIgjW6nQ?rlkey=sx63hauq42ulpmp38d17xg`
`dl=0`

Unfortunately at this time it only works on PCs. Also in this folder is sample data you will use for the tutorial. Please go to page 25 of the manual and complete the parts of the tutorial in Sec. 3.1 and 3.2. You will need data that is folders Part 1 and Part 2. For this problem please make plots of your resulting fits and the output dielectric function