The use of the Lockin Amplifier for Faraday Rotation

Purpose: Demonstrate the use and utility of the lockin amplifier for its use in signal recovery for determining the Verdet coefficient of a transparent material.

Introducing the lockin amplifier: Suppose you want to measure a small effect, say in the microvolt regime but smaller than the broadband frequency noise in a voltage say which is in the , for example, mV range. One way to extract the signal from the noise is to make it synchronous with an appled stimulus. The idea is that you have a stimulus that causes changes of the size of the small effect and you only look at the change in the noisey signal that is occuring when apply the stimulus, effectively taking the difference of noise+signal minus the noise.

In practice you can think of the lockin amplifier as a signal source ('stimulus') that is pumping the system and then studying only the signal coming back that has the same frequency as the source, rejecting all other parts of the signal at different frequencies. So one can think of the lockin as an especially narrow band frequency filter followed by a linear amplifier with large gain.

In the SR830 lockin you can adjust the narrowness of the frequency filter by adjusting the integration time. The instrument can also display the measured in phase and conjugate, or so-caled quadrature phase signal. Suppose the stimulus coming from the lockin was a $\sin(\omega t)$Then is this setting the instrument is displaying the part of the signal oscillating like $\sin(\omega t)$ (the so-called "in phase" part of the response) and also the part oscillating like $\cos(\omega t)$ (the so-called "quadrature" or sometime euphamistically called the 'out of phase' part of the response.) Suppose the former has an amplitude of C mV and the latter D mV. The instrument can also be set to display the total signal amplitude $R = \sqrt{C^2 + D^2}$ and the overall phase $\phi = Atan(D/C)$ with respect to the stimulus.

Proceedure: We will use a simple diode (no laser!) to measure the Verdet. We do this in the following steps.

0) secure and measure the length of your sample.

1) With the stimulus signal amplified and fed into the solenoid, take a few turns (write down the number of turns) "pickup" coil of wire around a wooden dowel of known diameter and put it in the solenoid, connecting the coils output to the "A" input of the lockin.

2) With the frequency of the stimulus small (say ¡400Hz), record the total signal output in mV. Use Faraday's law of induction to then calibrate the amplitude of the magnetic field in the solenoid under these conditions.

3) Now measure the wavelength of the LED using the low resolution spectrometer.

4) Next remove the pickup coil and insert the sample whose Verdet is to be measured into the solenoid. Make sure that the restof the light is blocked to that the only light that can emerge has to have goen through the sample.

5) Crudely align the LED emission with the solenoid axis/sample/detector. Next place linear polarizers fore and aft of the solenoid.

6) Turn off the stimulus field (driving the coil). Turn the polarizers so there is as large a DC signal as possible on the photodetector. Record that value. Now turn the polarizers so that there is as little signal as possible reaching the photodetector. Record that DC value.

7) Now rotate one of the polarizers so that you are getting exactly half of the large and small signal you recorded in part (6). Then the polarizers axes should be at about 45 degrees with respect to each other.

8) Finally, turn the stimulus field back on and with the lockin on "R, theta" mode (1st harmonic) record the measured R, θ.

Questions and Analysis

1) Use your measurement to estimate the Verdet coefficient of the material.

2) If, after passing through the magnetic field, the light was reflected off a mirror and goes back through the magnet and medium again, would the Faraday rotation be doubled OR would it be zero? Explain.