Physics 625: Experiment 8
Fourier Transform Spectrometer

1 Purpose and general idea

In this experiment, you will use the Michelson Interferometer, a motorized scanning system, an electronic photodiode detector, and a computerized Pasco data logging system to examine the output of the Michelson. By recording the detector output as a function of the scanning distance, you can infer the spectral distribution function of the light source, i.e. what wavelengths (colors) the light source emits. A laser will have a very narrow spectral distribution function whereas a light bulb will have a broad one.

Let's take the detector to be aligned at the center of the Bull's eye pattern ($\theta = 0$). If one of the arms of the interferometer is scanned a distance $s/2$, we will record an intensity signal $b(s)$ on the detector. As we discussed in class, the spectral distribution function, $B(\sigma)$, is related to $b(s)$ through the Fourier transform $B = F\{b\}$:

$$b(s) = \int_{-\infty}^{\infty} B(\sigma) \exp(i2\pi\sigma s) d\sigma$$
$$B(\sigma) = \int_{-\infty}^{\infty} b(s) \exp(-i2\pi\sigma s) ds$$

where σ is called the *wavenumber* and it is defined to be $\sigma \equiv 1/\lambda = k/2\pi$. You can think of the spectral distribution function $B(\sigma)$ as a measure of the intensity of light emitted near a wavelength of $1/\sigma$. Some useful Fourier transform relationships are shown below:

- Linearity: $F\{\alpha b_1 + \beta b_2\} = \alpha F\{b_1\} + \beta F\{b_2\}$
- Similarity theorem: $F\{b(cs)\} = \frac{1}{c} B\left(\frac{\sigma}{c}\right)$ where c is a constant.
- Shift theorem: $F\{b(s-c)\} = B(\sigma) \exp(-i2\pi\sigma c)$ where c is a constant.
- Parseval's theorem: $\int |b(s)|^2 ds = \int |B(\sigma)|^2 d\sigma$.
- Fourier transform of a product: $F\{b_1 b_2\} = \int B_1(\sigma) B_2(\sigma - \sigma') d\sigma'$ (convolution integral).
- Fourier transform of a Gaussian: $F\{\exp(-\pi c^2 s^2)\} = \frac{1}{c} \exp(-\pi\sigma^2/c^2)$
- Fourier transform of a rectangle function: $F\{rect(cs)\} = \frac{1}{c} sinc(\sigma/s)$.
- Fourier transform of a harmonic: $F\{\exp(i2\pi\sigma_1 s)\} = \delta(\sigma - \sigma_1)$ where δ is the dirac-delta function.

2 Experimental set-up

- Align the Michelson Interferometer using nearly monocromatic light from the sodium lamp.

- Find the zero path length difference between the two arms by observing the white-light fringes.
- Set up a lens and the detector to obtain a signal proportional to the light power in the center of the interference pattern.
- Couple the very slow motor magnetically to the precision screw of the moving platform of the Michelson interferometer. The motor has two directions of motion with both being very slow.
- Use Pasco Data Studio system to plot the light intensity versus time.

3 Measurements

You can examine the light from several sources by using the fiber-optic bundle. This design feature simplifies alignment when you switch sources. First, scan the pattern formed with light from the He-Ne laser for calibration. You should observe well-defined sinusoidal oscillations with good contrast.

Next, scan to determine the central wavelength (λ_0)or wavenumber (σ_0) and the full width at half maximum, $\Delta\sigma$, of the source spectrum for the below six sources. If the signal levels are too low to make a quantitative measurement, comment qualitatively on how the spectrum looks like.

- He-Ne laser.
- Infrared LED, central in the group of three sources.
- Red LED in the group of three sources.
- Green LED in the group of three sources.
- Sodium source. Measure the splitting of the D lines.
- White light.

You may find the Fast Fourier Transform (FFT) that is built into the Pasco software to be useful. To efficiently use the limited number of points, you may need to adjust the Pasco sampling rate and the motor speed so that the system operates close to the Nyquist sampling limit of 2 data points per fringe.