Interference Filters

An interference filter is essentially a Fabry-Perot interferometer of fixed length, which is filled with a dielectric. It allows only certain wavelengths of light to pass because multiple reflections from the two reflecting surfaces of the filter result in constructive interference only for these wavelengths. The wavelength of peak transmission depends not only upon the gap between reflecting surfaces, but also upon the angle between the incident light and the plane of the filter. In this experiment you will study both the shift in the wavelength of peak transmission as a function of this angle, and the variation of transmission as a function of wavelength for normal incidence.

Before You Come to Lab

Read about interference. For a simple introduction, review HRW Chapter 36, especially section 36.7. For a slightly more advanced treatment, look over HL Section 11.5. And for a really good treatment, go to the library and read about interference in an optics text, such as Optics of Thin Films, by Antonin Vasicek. You need to learn how the transmitted wavelength depends on the thickness of the film and the angle of the filter.

I) Set-Up

The spectrum of the light passing through a given filter is analyzed using a scanning monochromator. The slit widths have been properly set and should not be adjusted. The voltage on the photomultiplier should be set to 1 kV. Using an incandescent lamp as the source, a typical PMT current as read on the Keithley picoammeter is 6 - 7 μA (with the no. 645 filter in place). An analog meter is also available for monitoring the intensity of the transmitted light. It will allow you to find the center of the passband more accurately.

II) Bandpass

For each of two filters, measure the shape of the bandpass (intensity *vs.* λ) curve by reading the intensity values from the digital meter and using Excel to plot the results and fit a theoretical curve to them. You may find it useful first to do a scan over the entire visible spectrum, and then to do a fine scan on the peaks. Watch out for artifacts in your data due to second order diffraction in the monochrometer!

$$\frac{I(\lambda)}{I_{max}} = \frac{1}{1 + F\sin^2\left(m\pi\lambda_{max}/\lambda\right)}$$

In this expression, m is the order of interference (a *small* integer), λ_{max} is the wavelength at the peak of the bandpass, and λ is the wavelength at the point of interest. The coefficient of finesse F is a measure of the reflectivity of the films in the filter and is defined as F = r/(1-r), where r is the reflection coefficient of each mirror. Use Microsoft Excel to adjust F and m to obtain the best possible fit between theory and experiment (keep m small).

(OVER)

II) Angular Dependence

The interference filter in front of the monochromator entrance slit can be rotated. You should determine the peak wavelength as a function of angle for at least two filters. Note that the angle of the filter that you measure is **not** the same as the angle that is used in the theoretical description because the filter is "under glass" (why?). Make plots of peak wavelength vs. the measured angle and compare them to the angular dependence predicted by the theoretical result:

$$\left(\frac{\lambda_{max}(\theta)}{\lambda_{max}(0)}\right)^2 = 1 - \frac{1}{n^2}\sin^2\theta$$

In this expression θ is the measured angle of incidence, n is the index of refraction of the glass (assumed to be the same as the index of the material between the partially reflecting films), λ_o is the wavelength of maximum transmission at the angle θ, and λ_z is the wavelength of maximum transmission at θ = 0¡. You should understand how this result is obtained. By plotting your data appropriately you should obtain a straight line which you should then be able to fit by adjusting the value of n in the expression above. Does your value of n make sense?

R.R.C.	2/28/83
S.J.H. rev.	1/14/91
R.R.C. rev.	3/9/94
C.E.C. rev.	5/19/95
C.E.C. rev.	2/27/98