Using a Fabry-Perot Etalon to Obtain the Spectrum of a Sodium Lamp

Using a Fabry-Perot Etalon we obtained the two sodium D lines. From the spectrum we determined that the counting number of lines is proportional to their radii squared. Using the width of the line we were able to determine the finesse of the etalon to be 9.2 to within +/- 0.67 implying a high resolution. Calculating the finesse gave us information to determine that the reflectance of our etalon is .71 +/-.02.

I. Introduction

In this experiment we used the Fabry-Perot etalon to measure the two spectral D lines (588.9 nm and 589.6 nm) of a sodium lamp. From this we will show that the radii squared of the rings are proportional to the order number, and from our pictorial results (spectra) we will estimate the finesse of the etalon.

II. Theory

The circular shape of the spectra you get from an etalon is due to the varying transmissions that are caused by interferences between the various reflections of light between the two high parallel glass plates, and its circular symmetry. Those that are in phase are constructive, that is their path difference is an integer multiple of λ (which corresponds to what we see). The destructive interference produces a minimum transmission[1]. The path difference is given by

$$\Delta = 2d\cos\theta \qquad (1)$$

As such you will get the following equation for the constructive interference:

$$P\lambda = 2dn\cos\theta \qquad (2)$$

Where P is the order number, d is the distance bewteen the two parallel plates, and n is the index of refraction. Since the camera lens limits the amount of light we can use the small angle approzaimation to reduce equation (2) to

$$P\lambda = 2dn\left(1 - \frac{\theta^2}{2}\right) \qquad (3)$$

The tangent of θ is r/a which is nearly θ itself, therefore we can obtain the following

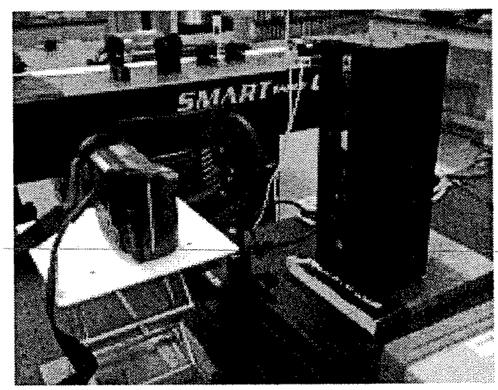
$$p\lambda = 2dn\left(1 - \frac{r^2}{2a^2}\right) \qquad (4)$$

('a' is the distance from the etalon to the lens of the camera.)

III. Experiment/Method

The etalon used in this experiment consists of ~~two parallel glass plates~~ two sides of one plate (quartz glass). We positioned the sodium lamb at one end of the etalon, and took the picture of the resultant spectra from the other (see figure 1). The spectra for the two sodium lines came in pairs. The first ring was given an order number of 'p', and the subsequent rings were given the order numbers of p+1, p+2...p+n.

Figure 1:

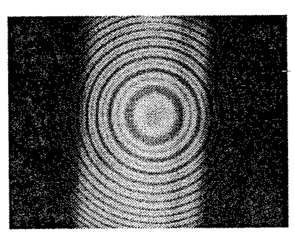


Analyzing the data involves counting the radii of each ring (of both D lines), and plotting them as a function of their order number, as well as using a special a program (gimp) to help find the finesse. detail

IV. Data

After we preformed the experiment we obtained the spectra in figure 2, and from it we were able to obtain some valuable information.

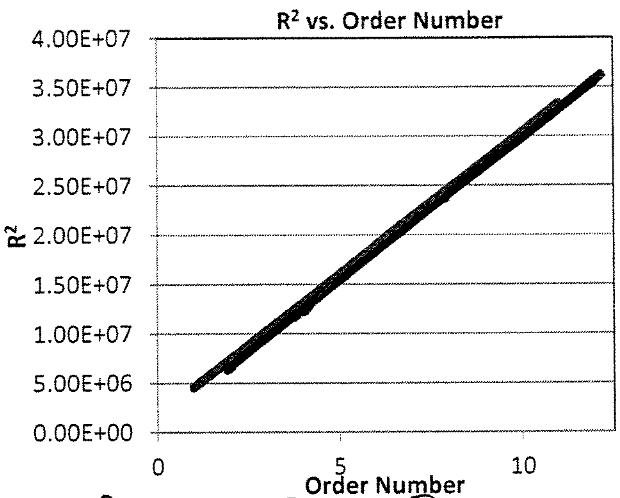
Figure 2:



4 | 2 2/22/15 =8

Once we obtained the measurements for our radii we graphed them as a function of their order numbers and obtained the following relationship

Figure 3:



why is $r^2 \propto p$?

This shows that the radius squared is proportional to the order number.

V. **Analysis**

Looking at figure 3, the two lines seem very similar due to the fact that the wavelengths of sodium are close together. Although these lines look similar, their slopes vary slightly because they have different values of 'p' (and wavelength). For the black line (588.9nm) the slope was 2,881,143 and for the red line (589.5nm) the slope was 2,873,471. significant figures? uncertainties?

From figure 3 we demonstrated experimentally that the radius squared is proportional to the counting number (order number). We can also show that the ratio of the slopes of the two D lines is directly proportional to the ratio of the two wavelengths. Since everything in equation (4) is a constant the ratio of 588.9 nm over 589.5 nm is .99898, and the ratio of the slopes reduces down to 1.0026. The proximity of the two ratios (to within +-0.002) demonstrates that their relationship is indeed directly proportional. – need to know expt. accuracy to draw this conclusion.

For the resolution we got an average finesse of 9.2 +/- 0.67 by measuring (in pixels) the FSR (free spectral range) and dividing it by the bandwidth (also in pixels)[2]. This implies that an etalon with a larger FSR and a smaller bandwidth will have a better resolution. Taking the finesse we were able to solve for the reflectance coefficient of the etalon. Our finesse resulted in a reflectance coefficient of .71 +/- .02.

VI. Conclusion

Using the etalon we were able to look at the spectra of the sodium lamp, and from the spectra we were able to gleam important information. We determined that the radius squared is proportional to the order number. We found that the ratio of the slopes is directly proportional to the ratio of the wavelengths. The finesse of the etalon was calculated to be 9.2 +/- 0.67. From this we were able to calculate the reflectance coefficient to be 0.71 +/- .02.

[1] *"Chapter 8. Optical Interferometry.". N.p., n.d. Web. 15 May 2014. <http://optics.hanyang.ac.kr/~shsong/8-Optical%20interferometry.pdf>.*

[2] *Hecht, Eugene, and Alfred c. "Interference ." Optics. Reading, Mass.: Addison-Wesley Pub. Co., 1974. . Print.*