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Fabrication and Characterization of Cost Effective Fabry-Perot Etalon

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Abstract

The present study focuses on the fabrication and characterization of cost-effective Fabry- Perot etalon. The etalon was fabricated using window glass and was characterized using sodium lamp, mercury lamp and He-Ne laser. The variation of bandwidth, order and free spectral range (FSR) by varying the thickness of glass plate between etalon plates is studied.

Keywords*: Fabry- Perot etalon, Reflecting mirrors, Free spectral range (FSR)*

INTRODUCTION

A Fabry-Perot Etalon or simply an Etalon is a valuable tool in high-resolution spectroscopy and is the simplest form of Fabry-Perot Interferometer in which the distance between the two mirrors is kept fixed. It represents a significant improvement over the Michelson interferometer. If the gap between Etalon mirrors is varied mechanically by moving one of the mirrors, the instrument is called an Interferometer. If the mirrors are held fixed and adjustment screws are provided for parallelism, then it is called Etalon. The multiple reflections of light rays inside the partially reflecting mirrors strengthen the constructive and destructive interferences of the transmitted light resulting in much sharper rings compared to the Michelson interferometer. A lot of research has been carried out using Etalon [1, 2]. The coupling of a microtoroid resonator with Etalon has been studied by Wei Liang et al. [3]. The present study focuses on the fabrication and characterization of cost-effective Fabry-Perot etalon.

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EXPERIMENTAL

The purpose of this study is to fabricate Fabry Perot etalon in a cost-effective way. Here etalon is made of window mirror glass (in which one side is a mirror, so the surrounding lighting conditions dictate the mirror effect). The performance of the proposed etalon was characterized using sodium lamp, mercury lamp and laser. Due to the poor optical quality of window mirror glass, it was very difficult to attain the fringes in an air medium. So we have started our work with a transparent glass plate as the medium between the etalon, and also it helped to attain the uniform thickness between the etalon (figure 1 and 2). The spectrometer is placed on a table in a dark room, and the collimator is adjusted for parallel rays. The sodium vapour lamp is placed in front of the collimator. Light is allowed to fall on the collimator slit. The slit is made wide so that maximum light passes through it. The microscope is brought in line with a collimator. The least count of a microscope is noted. A glass plate of thickness of about 1mm is placed between the etalon plates. The prism table is removed, and etalon is placed in its position.



Figure 1: Fabrication of etalon set up.



Figure 2: Etalon with transparent sheet

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RESULTS AND DISCUSSIONS

We have observed the fringes using different light sources such as sodium lamp, mercury lamp and He--Ne laser. The obtained interference pattern using sodium lamp, Mercury lamp and He-Ne laser is shown in figure 3, 4, and 5 respectively.

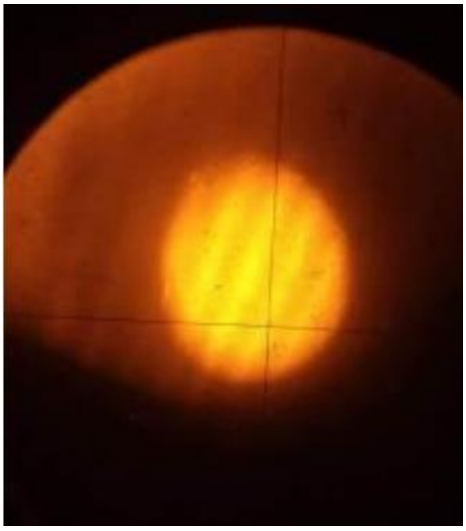


Figure 3: Interference pattern of etalon using sodium vapour lamp

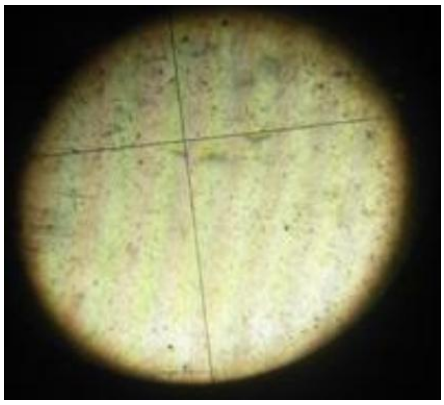


Figure 4: Interference pattern of etalon using mercury vapour lamp

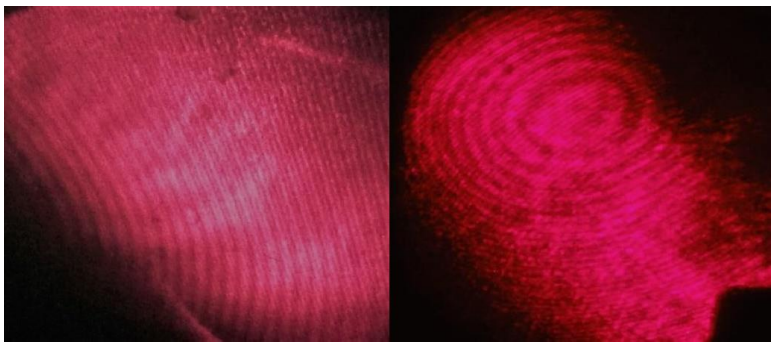


Figure 5: Interference pattern of etalon using laser

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The He-Ne laser is mounted on a stand in a dark room. The microscope eyepiece is arranged in front of the laser for the diverging laser beam, about 20 cm from it. A screen is placed about 80 cm from the laser. The laser beam passes through the eyepiece and then falls on the screen. (figure 6 and 7). Etalon is mounted between eyepiece and screen. (Now, the air is the medium between etalon plates). By adjusting the distance between the etalon and eyepiece, and adjusting knurled screws of the etalon, alternate dark and bright circular fringes are obtained on the screen. Using fine adjustments of knurled screws, the fringes are made distinct and clear.

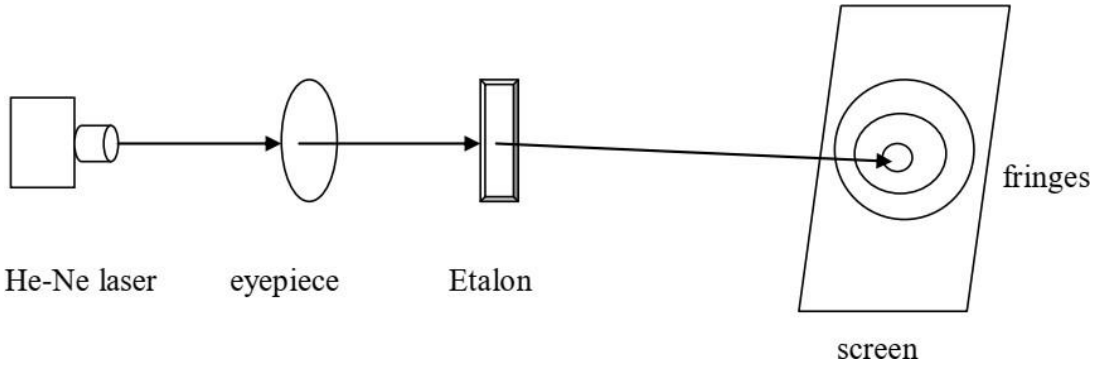


Figure 6: Schematic representation of experimental set up of etalon using laser.



Figure 7: photograph of experimental set up of etalon using laser.

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To study the variation of band width, order and free spectral range (FSR) by varying the thickness of glass plate between etalon plates

(a) Band width

Light rays undergo interference between the etalon plates and alternate bright and dark fringes are observed through a microscope. By adjusting the knurled screws of etalon the fringes are made dark. The vertical crosswire of the microscope is made to coincide with any dark fringe and the reading is taken (Total reading=MSR+ (VSR×LC)). This is repeated for 2, 3, 4, 5, 6, 7, 8, 9, 10 dark fringe and hence fringe width can be calculated. The experiment is repeated by varying the thickness of the glass plate. The observed fringes are shown in figure 8.

A transparent sheet (overhead projector - OHP sheet) is placed between the etalon plates. The thickness of the OHP sheet is calculated using a screw gauge. The observed fringes are shown in figure 5.

The experiment is repeated with OHP sheets of different thickness. Knowing the value of order 'N', refractive index 'n' of OHP sheet can be calculated.

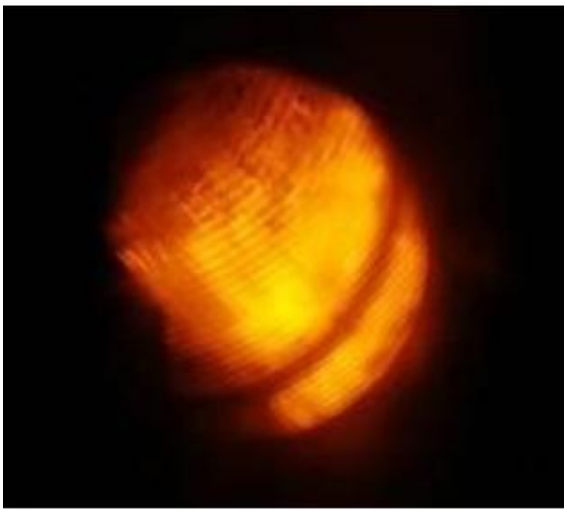


Figure 8: Interference pattern of etalon using sodium vapour lamp when OHP sheet placed between etalon

We have examined the bandwidth of the interference pattern by varying the thickness of the glass plate. The bandwidth decreased with the thickness that is clearly tabulated in table 1 and depicted in figure 9.

Table 1: Variation of thickness of glass plate with the bandwidth

Thickness(d) (mm)	Bandwidth(β) (mm)
1	.1528
2	.106
3	.0932
4	.0924
5	.0904

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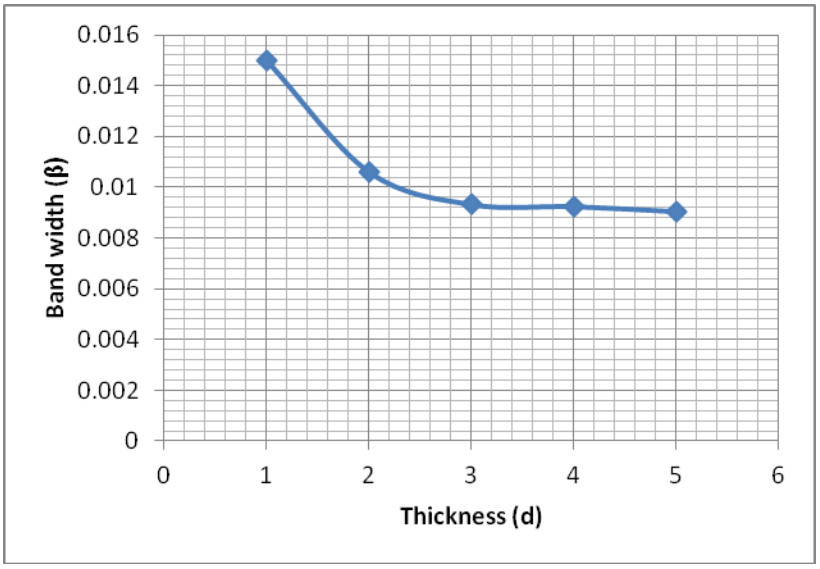


Figure 9: Variation of thickness of glass plate with the bandwidth

(ii) Order

The order of the fringe in Etalon is different from the spectral order in the grating. In the case of grating, the spectrum peak of sidebands is denoted as 1 or 2 etc. In Etalon, the order of the ring specifies a particular ring, and its value is very high. The order is indicative of a particular ring, or in other words, it indicates the ring formation due to a cone of light rays incident on the Etalon. We have found that as the thickness of the glass plate increases with the order.

The condition for producing maximum transmission is given by,

$N\lambda=2nd\cos\theta$

Where N is the order, n is the refractive index of medium between mirrors, d is the distance of separation between mirrors, λ is the wavelength of light used (For sodium vapour lamp, λ=589.3nm) θis the angle of incidence.

For glass, n=1.5

For normal incidence, θ=0,

Therefore, order $N=2nd/\lambda$

The results are tabulated in table 2. The variation of order with thickness of glass plate is shown in figure 10.

Table 2 Variation of order with thickness of glass plate

Thickness d(mm)	Order
1	5090
2	10181
3	15272
4	20362
5	25453

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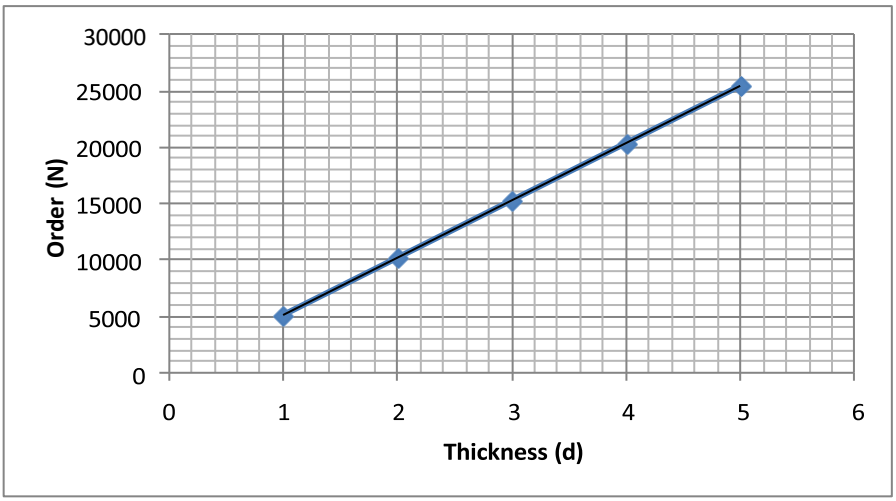


Figure 10: Variation of order with thickness of glass plate

(iii) Free spectral range (FSR)

Free Spectral Range (λ_{fsr}) is the difference in wavelength between adjacent nodes that give constructive interference [4].

We have,

$\lambda_{fsr} = \frac{\lambda}{m}$, where m is the mode, λ is the wavelength

Also we have

$m = \frac{2d}{\lambda}$, where d is the Fabry-Perot separation

Combining above equations, we get:

$m = \frac{2d}{\lambda}$, where d is the Fabry-Perot separation

Combining above equations, we get:

$$\lambda_{fsr} = \frac{\lambda^2}{2d}$$

The results are found in table 3 and figure 11.

Table 3: Variation of FSR with thickness of glass plate:

Thickness d(mm)	λ_{fsr}
1	1.157×10^{-10}
2	5.78×10^{-11}
3	3.856×10^{-11}
4	2.89×10^{-11}
5	2.314×10^{-11}

(iv) Study of variation of order with bandwidth:

We have found that the order increased with the thickness and fringe width decreased with the thickness. From these data we analyzed that the order decreased with fringe width. So the value N β is a constant (table 4).

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Table 4: Variation of order with bandwidth

Bandwidth(β) (cm)	Order(N) (lines/cm)
.01528	5090
.0106	10181
.00932	15272
.00924	20362
.00904	25453

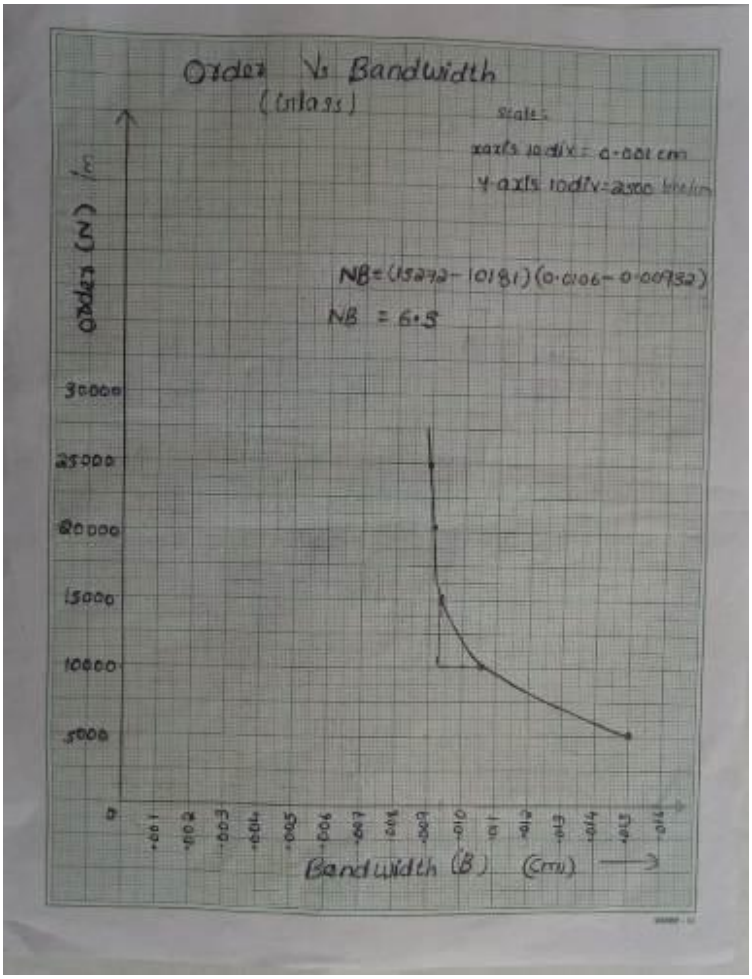


Figure 11: Variation of Bandwidth with the order of fringes

Study of calculation of refractive index of transparent film (an approximate method) is tabulated in table 5.

From the graph, it is assumed that Nβ is a constant

$N\beta = 6.5$

From this, order N of OHP sheet can be calculated using equation,

$N\lambda = 2nd\cos\theta$

Since, $\theta = 0$ for normal incidence

We have $n = N\lambda/2d$

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Table 5: an approximate method for the study of refractive index

Thickness of OHP sheet (micrometer)	Bandwidth β (centimeter)	Order N (lines/metre)	Refractive index n $n = \frac{N\lambda}{2d}$
86.67	.01052	617.87≈ 618	2.10
131.66	8.76×10^{-3}	742.009≈ 742	1.414
181.667	7.48×10^{-3}	868.98≈ 869	1.66

The OHP sheet typically made of cellulose acetate. The refractive index of cellulose acetate is 1.475. So our result is almost comparable with the theoretical value.

CONCLUSION

A low-cost Fabry Perot interferometer using a window mirror was constructed and was characterized. It was found that the fringe width decreases with an increase in thickness of glass plate between etalon plates, and order 'N 'is calculated. Also studied the fringes of OHP sheet of varying thickness and calculated the refractive index of the sheet. The fringes were examined using different sources such as He-Ne laser, mercury vapour lamp.

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