**PHY224A : Building a Diffraction Grating Spectrometer**

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## Aim

To build a 1D diffraction grating optical spectrometer and observe the absorption spectrum of Mercury Lamp and LED.

## Apparatus

1-D Diffraction Grating, 2 Convex Lenses, CCD Camera, Mercury Lamp, Mobile Phone LED, Adjustable Optical Slit, 5 Optical Posts, 5 Mounting Bases, 5 Post Holders, Optical Breadboard and some solutions.

## Theory

A spectrometer is a device that can measure the wavelengths of light emitted from a source. One basic requirement for a spectrometer is that it can spatially separate different wavelengths. There are two common options for separating different wavelengths of light: prisms and diffraction gratings. Prisms separate wavelengths because the glass has an index of refraction which depends on wavelength. The different colors get refracted at different angles.

Diffraction grating is a thin film of clear glass or plastic that has a large number of lines per (mm) drawn on it. A typical grating has density of 250 lines/mm. Using more expensive laser techniques, it is possible to create line densities of 3000 lines/mm or higher. When light from a bright and small source passes through a diffraction grating, it generates a large number of sources at the grating. The very thin space between every two adjacent lines of the grating becomes an independent source. These sources are coherent sources meaning that they emit in phase waves with the same wavelength. These sources act independently such that each source sends out waves in all directions. As shown in Fig. 1, on a screen a distance D away, points can be found whose distance differences from these sources are different multiples of  causing bright fringes. One difference between the interference of many slits (diffraction grating) and double slit experiment is that a diffraction grating makes a number of principle maxima along with lower intensity maxima in between. The principal maxima occur on both sides of the central maximum for which a formula similar to double slit interference holds true which is given by

$$dsin(\theta) = n\lambda \tag{1}$$



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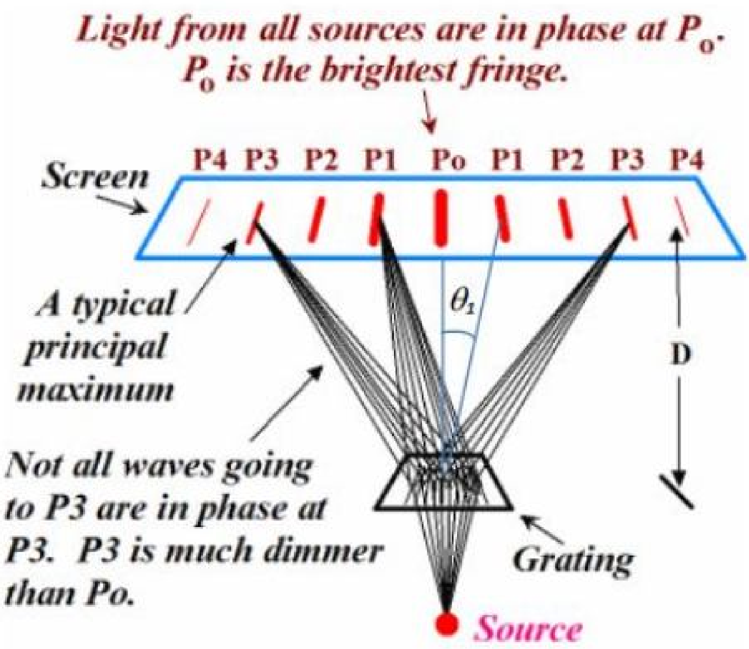


Figure 1: Working of Diffraction Grating

In this equation, d is the spacing between every two lines (same as every two sources). If there are N lines per mm of the grating, then d, the space between every two adjacent lines or (every two adjacent sources) is

$$d = \frac{1}{N}(mm) \tag{2}$$

Based on Eq.(1), if the light source has different colors (different wavelengths), shorter wavelength color will have smaller diffraction angle compared to longer wavelength for the same order of principle maximum. Thus we will see a spectrum in such case. The angular spacing for different colors will increase for higher order maxima.

The "grating equation" gives the relationship between the incident angle of the beam and angle of the n-th order diffracted beam for a particular wavelength of light , and grating spacing.

$$a(sin\theta_{r,n} - sin\theta_i) = n\lambda \tag{3}$$

## Procedure

We setup the optical elements as shown in the above figure.The first element is the Mercury Lamp. Light from the mercury lamp falls on the slit which is used to restrict the amount of light entering our setup. This light is then collimated using a convex lens of focal length 10 cm which is placed in a way such that the slit is at its focus.The



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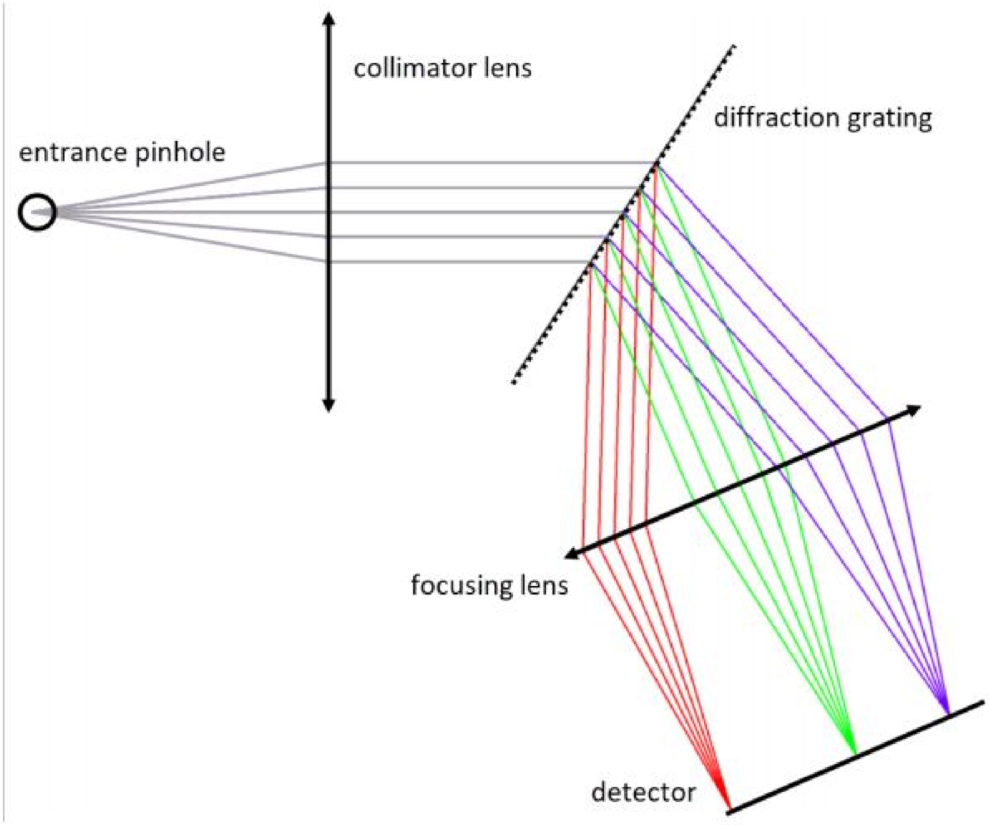


Figure 2: Schematic of a Diffraction Grating Spectrometer

Figure 3: Spectrometer Setup



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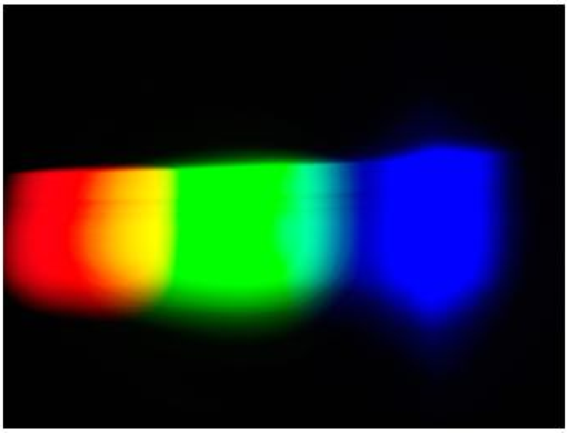

Figure 4: LED Spectrum Colored

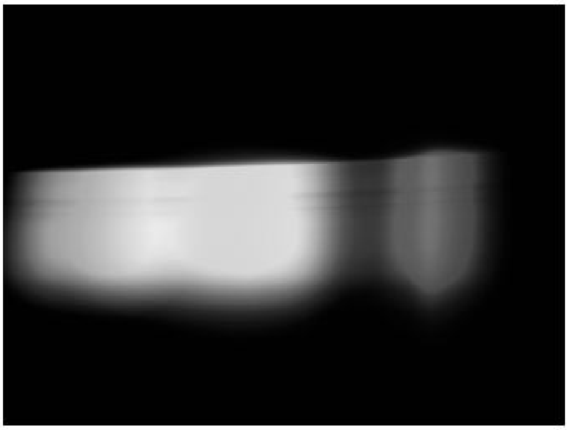

Figure 5: LED Spectrum BW

collimated light now falls on the diffraction grating which separates the light into its constituent wavelengths at different emergent angles.This light is then focused using a convex lens of focal length 5 cm, on a CCD camera placed at the focus of the lens. The camera is then rotated to find the first order diffraction spectrum.

## Data

The Data is acquired using ToupView Software with the help of CCD Camera. The analysis on the data to get the plots has been done using MATLAB.



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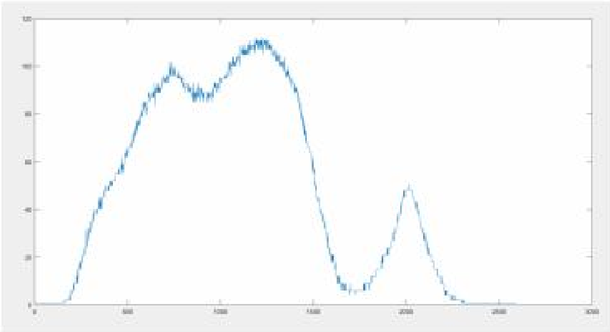

Figure 6: LED Spectrum Plot

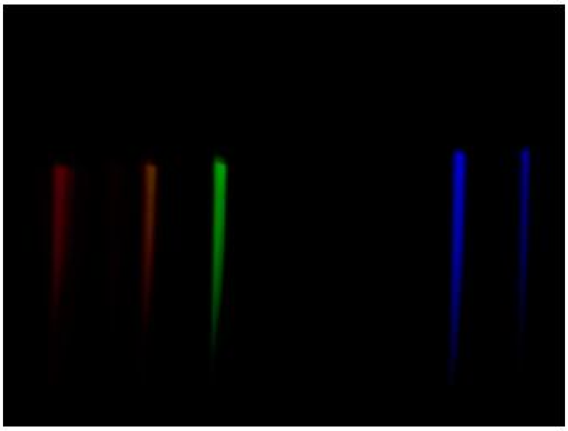

Figure 7: Mercury Lamp Spectrum

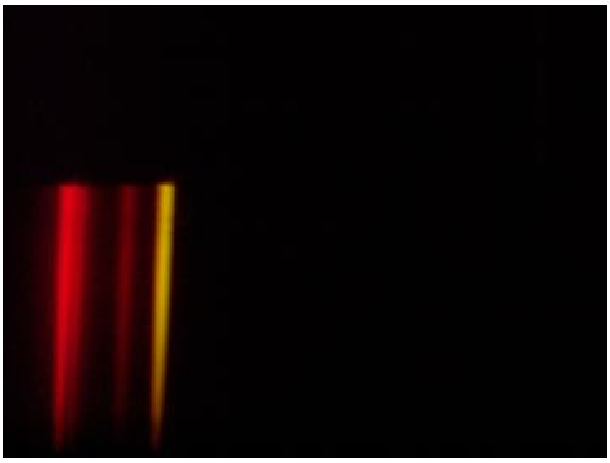

Figure 8: Methyl Orange Spectrum Colored



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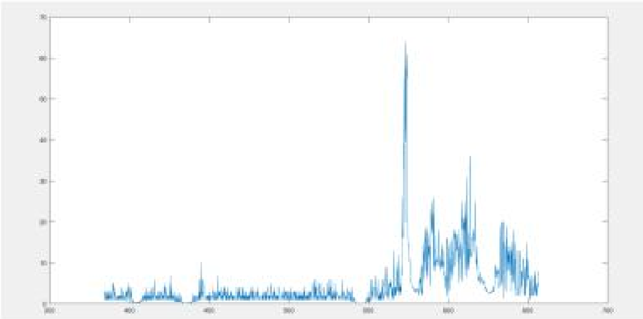

Figure 9: Methyl Orange Spectrum Plot

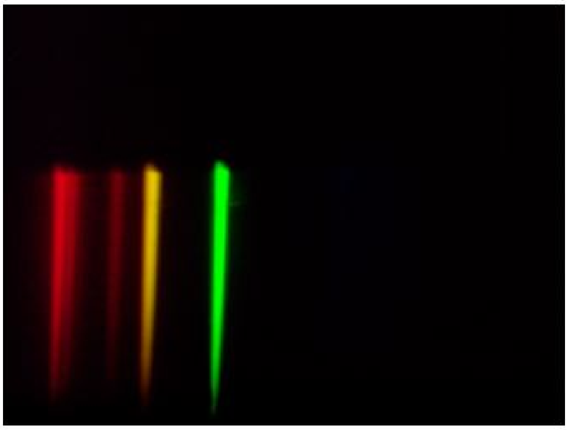

Figure 10: Ferric Chloride Spectrum Colored

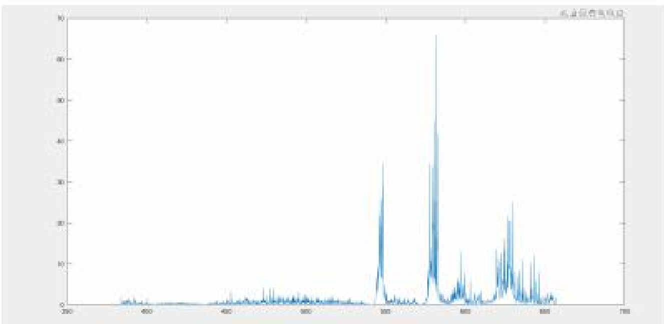

Figure 11: Ferric Chloride Spectrum Plot

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## Results

All the spectrum observed using our Spectrometer matches the verified data available online which confirms the functioning of our Spectrometer.

## Precautions

- All apparatus must be tightly fixed to the optical bench.
- All lenses used must be clean
- The source slit should be narrow, perhaps a few times wider than the hairline.
- Care must be taken in handling of all the optical equipments.
- Always hold the optical elements at the edges, or on the non-optical surfaces.
- Never hold the optical components away from the table where they can drop.
- The entire experiment must be performed in a dark room so to eliminate stray light.
- Careful handling of chemical solutions.
- The CCD camera must be handled with care.

## Difficulties Faced

- Aligning the CCD camera and lens.
- Coding in MATLAB.
- Converting the colour images to grayscale.

## Suggestions

- Having prior knowledge of MATLAB is helpful for data acquisition and analysis.
- Ready availability of chemical solutions having distinguishable spectrum.
- A big cardboard box can be used to cover the entire setup to eliminate any stray light.

## References


- E. Hecht, Optics (Addison-Wesley / Pearson)
- J. Peatross and M. Ware, Physics of Light and Optics, 2015 edition
- https://in.mathworks.com




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