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DETERMINATION OF EMISSION WAVELENGTHS USING DIFFRACTION GRATINGS

Abstract:

Diffraction gratings effectively offset the trajectory of light waves based on their wavelength. Since gas emission tubes offer consistent identifiable frequencies of light, diffraction gratings can be used to determine the frequencies of these spectral lines. We determined for the mercury emission tube that our average error was 2.4%. For the hydrogen tube our average error was 1.4%.

Introduction:

Diffraction gratings produce multiple evenly spaced fringes when light is passed through a slit and projected through the grating. This means that for images passed through a grating, multiple images are generated, known as the first order image then second order and so on. For smaller grating separation, the distance between the fringes becomes larger, as observed in Jung's double slit experiment. We use a diffraction grating with known density of 600 lines in a millimeter or 1/600 mm/line. Due to such a small grating separation, it is difficult to measure the higher order images, therefore when we use the grating equation, we can set the order n to 1.

$$n\lambda = \mathrm{d} \sin \theta$$

Where d is the separation of slits, λ is the wavelength of light and θ is the angle of diffraction. This means that we can use a device that produces consistent wavelengths of light, calculate those wavelengths using the grating equation and compare those to the experimentally verified wavelengths. For our light source, we are using gas emission tubes which produce exact frequencies of light due to electrons jumping in discrete (quantum) energy levels.

Experimental Procedure:

The apparatus was composed of a high voltage power supply paired with a gas discharge tube, a diffraction grating and ruler with a slit in the middle. The materials were positioned such that light from the gas discharge tube went through the slit and some measured distance (L) away was the diffraction grating. For two separate gas discharge tubes, the following was observed: the distance between the center of the ruler and the apparent spectral lines when looking through the diffraction grating. These values (recorded as x_L and x_R) were averaged and used to determine the wavelength of the observed spectral line. Each spectral line's calculated wavelength was compared to the accepted literature values of the wavelengths. The %-errors were noted.

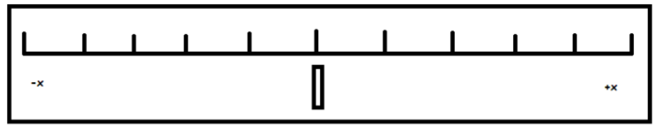

Figure 1: Ruler with slit. The markings denote interval spacing so the observed distance can be calculated.

Results and Data:

The following data were observed for the mercury emission tube.

Color	X_R (m)	X_L (m)	$1/2(X_R+X_L)$	sin θ	λ (nm)	Accepted λ (nm)	%-error
Violet	0.076	0.079	0.078	0.250	417	435	4.14
Blue	0.082	0.086	0.084	0.270	449	N/A	
Green	0.104	0.110	0.107	0.336	560	577	2.95
Orange	0.111	0.117	0.114	0.355	592	579	2.24
Red	0.127	0.120	0.132	0.401	669	672	0.45

Sin θ was calculated from $\sin \tan\text{^}(-1) \quad 〚x/L〛$ where x is the average of the perceived distance from the first order image to the image. From there we apply the grating equation with d = 1/600 mm/line to determine the wavelength of the first order image. Then the wavelength is paired against the literature values and percent error is calculated with $|\text{Aceepted} - \text{Measured}|/\text{Accepted} = \text{error}$. The average error observed for the mercury tube was 2.4%.

The following data were observed for the hydrogen emission tube.

Color	X_R(m)	X_L(m)	$1/2(X_R+X_L)$	sin θ	λ (nm)	Accepted λ (nm)	%-error
Violet	0.076	0.079	0.080	0.25	417	410	1.71
Violet	0.081	0.083	0.082	0.264	439	434	1.15
Blue	0.091	0.093	0.093	0.296	493	486	1.44
Red	0.126	0.135	0.130	0.399	665	657	1.22

The average error observed for this data was 1.4%.

Conclusion:

The use of diffraction gratings is useful not only as a demonstration of the wave behavior of light but also to decompose light into its corresponding wavelengths. In this lab we were able to take known chemicals, excite their electrons such that they produced known frequencies of light, then measured those frequencies of light using the grating equation. The results were consistent with the literature and we obtained an average combined error of 1.9% for both experiments.