Study of Hydrogen Balmer Series and determination of Rydberg constant

1 Aim

The aim of this experiment is to measure the wavelengths of the Balmer series of visible emission lines from hydrogen discharge tube and to determine therefrom, the Rydberg constant.

2 Theory

Hydrogen gas in a discharge tube emits a series of lines which lie in various regions of the electromagnetic spectrum. Some of these lines lie in the visible part of the spectrum. This latter series is called the Balmer series. It was quantified by a Swiss teacher J. Balmer in 1885. By trial and error, he fitted the wavelengths of these lines with the formula,

$$\frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{n^2}\right] \tag{1}$$

where $n = 3, 4, 5, ..$ and R is a constant. In SI units, its value is $R = 1.09 \times 10^7 m^{-1}$. In 1889, J.R. Rydberg suggested a much more general formula, which could explain several series of spectra with

$$\frac{1}{\lambda} = R\left[\frac{1}{{n_f}^2} - \frac{1}{n_i^2}\right] \tag{2}$$

with integers n_f and n_i satisfy $n_f < n_i$. For Balmer series, we have $n_f = 2$. The individual lines of this series are summed up in the following table.

Symbol	n_i	Wavelength (λ)
H_α	3	656.28 nm
H_β	4	486.13 nm
H_γ	5	434.05 nm
H_δ	6	410.17 nm

Then in 1913, N. Bohr suggested a revolutionary model of the atom where the electrons moved in circular orbits and when they jumped from a higher orbit to a lower orbit, they emitted spectral lines. Combining Plank's and Einstein's suggestions and adding some bold assumptions (stationary orbits) of his own, he was able to derive the Eq. (2), where now the parameter R is known as Rydberg constant and can be assigned a value as $R = me^4/8{\epsilon_0}^2h^3c$, where m and e are mass and charge of the electron.

3 Procedure

1. Focus the telescope for an object at infinity. Adjust the focus knob so that the viewed object is in clear focus.
2. Place the light source about 1 cm from the collimator slit. The slit should be barely open.
3. Look through the eye piece and adjust the eye piece (only) so that the cross-wire is clearly visible.
4. Rotate the arm of the telescope so that it is directly in line with the collimator. The telescope should remain focused at infinity for all settings.
5. Turn the light source on and view the slit of the collimator.
6. Use the focus knob to adjust the collimator focus and obtain a sharp image of the slit.
7. Place the diffraction grating in the mount without touching the glass, such that it is at right angles to the axis formed by the collimator and the telescope.
8. Looking straight through the telescope, one sees the direct image of the slit. By using the fine adjustment, align the vertical cross-wire with the left edge of the slit image and note the reference reading.
9. Rotate the arm of the telescope to the left or right, at a time and slits of color violet, turquoise and red become visible. These first order images are followed by second order images at still higher angular deviations. The lines correspond to three of the Balmer lines corresponding to $n_i = 5, 4, 3$.
10. Note the angular position of the different lines of a given order of diffraction.

4 Calculations

Prepare the following table and enter the values of various readings.

n_i	Order m	θ_R (degrees)	θ_L (degrees)	θ_L (corrected)	θ_R (rad)	θ_L (rad)	$(1/\lambda)$	$(1/4 - 1/n_i^2)$
5	1							
4	1							
3	1							

To calculate λ, use the relation $d \sin\theta = m\lambda$, where θ is the diffraction angle and d is the grating spacing. Plot a graph between the last two columns of the table. Then Eq. (2) suggests that the graph should be a straight line with the slope giving the Rydberg constant R.

Make a similar table for second order diffraction, $m = 2$, and plot another graph.

5 Precautions

1. The setting of telescope should not be disturbed after it has been focused for infinity.
2. Do not touch the grating on the glass surface.
3. Do not touch the hydrogen tube when it is on or hot, as it is powered by a **high voltage**.