This experiment investigates the Zeeman Effect, focusing on the splitting of neon's spectral lines when an external magnetic field is applied. The objectives are to examine the discrete space quantization of angular momentum relative to the B field, determine the Bohr magneton (μ_B) and its associated uncertainty, and analyze the polarization of the emitted light. The Bohr magneton is a fundamental physical constant that represents the magnetic moment of the electron arising from its angular and orbital moment. An experimentally determined value within uncertainty of the scientifically accepted value (often expressed as unity in certain unit systems [3]) is expected.

To perform this, a neon discharge tube will be placed between the poles of an electromagnet with a varying current to linearly scale the magnetic field strength applied to the tube. By doing this, the splitting of neon's spectral lines will be observed. To isolate the spectral lines and observe polarity, a Fabry-Perot interferometer along with a tunable filter will be used.

The interferometer will first be tuned using the free spectral range (FSR) formula for a standing-wave resonator of length d, given by $\Delta\lambda = \frac{c}{2d}$ [4]. Neon is used in this experiment with a prominent yellow line of 585 nm, therefore the FSR range will be set to the known value of 30.0 GHz, corresponding to approximately d $=$ 1 cm [1]. The magnetic field must also be properly oriented with the spectrometer to ensure the beam path aligns with the quantization axis, introducing a level of uncertainty. The necessary magnetic field strengths can be found by solving for B using the Zeeman effect relation $\Delta E = g\mu_B m_l B$ [2], spanning the minimum to maximum energy differences for the experiment.

To calibrate the magnetic field accurately, B will be plotted versus the current applied to the electromagnet using a Hall probe and a straight line will be fit to determine the relationship and uncertainty. The plan is to collect 5 - 10 data points over a reasonable field range of $0 - 1$ T to ensure an accurate fit.

To measure the Bohr magneton experimentally, a spectral line will be selected with a Landé g-factor of 1, identified by the appearance of a central π line and $\sigma^{\pm}$ lines, indicating the normal Zeeman effect [5]. Then the energy shift from the central line to the $\sigma^{\pm}$ lines will be recorded against applied magnetic field. Since the shift is given by $|\Delta E| = \mu_B B$ for normal Zeeman lines, plotting ΔE against B and performing a linear fit yields μ_B directly from the slope. The ΔE value is determined by observing images and using the relations $\Delta\lambda = \lambda_\pi^2/2d$ [1] and $E = hf$.

Multiple measurements at each magnetic field setting will be taken to average random errors. If the 585 nm line is not clear to accurately read, the next neon emission line will be selected as a fallback option. One lab session will be dedicated to calibrating the magnetic field, one for setting up the interferometer, and one for collecting all the data. This allows a one-lab session buffer in case a session is unsuccessful.

This experiment involves various power supplies; therefore, all voltage and current safety standards must be met. Power sources must be handled with care, especially with regard to high-voltage or current supply. Additionally, precautions must be taken so that no light beams or lasers are directed near users' eyes. Care must also be taken with the apparatus when adjusting components to not break wires, structures, or neon light tubing. Arrangement of interferometer components should have minimized environmental influence to avoid destabilizing laser and lens alignment.

References

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