Lab AA652
Experiment 3
Zeeman Effect

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1 Objectives

To calculate the value of Bohr Magneton by studying the Zeeman-splitting of the electronic energy levels of Mercury atom.

2 Instruments

1. Optical bench.
2. Kinematic laser mount.
3. Convex lens with mounts.
4. Fabry-Perot etalon unit.
5. Screen.
6. Mercury discharge tube placed in the gap of tapered pole pieces of an electromagnet.
7. Gaussometer.

3 Measurements

3.1 Table for the squared radii of rings

Least count of micrometer is 0.01mm
t=5mm
Magnetic field B=7900 Gauss
Micrometer Initial reading R_i=8.75mm.

Table 1: Measurements for squared radii of the rings

No. of spectral line	Splitting of spectral line	Split position R_s in mm	Actual radius $R(R_s\text{-}R_i)$ in mm	R^2in mm^2
1	a b c	9.47 9.73 10.00	0.72 0.98 1.25	0.5184 0.9604 1.5625
2	a b c	10.72 10.90 11.12	1.97 2.15 2.37	3.8809 4.6225 5.6169
3	a b c	11.83 12.13 12.35	3.08 3.38 3.60	9.4864 11.4244 12.9600
4	a b c	13.06 13.27 13.45	4.31 4.52 4.70	18.5761 20.4304 22.0900

3.2 Calculation of the average values

3.2.1 Average value of Δ

The average value of Δ is found in the following way,
$\Delta_{12}^a = R_{a2}^2 - R_{a1}^2 = 3.8809 - 0.5184 = 3.3625$
$\Delta_{12}^b = R_{b2}^2 - R_{b1}^2 = 4.6225 - 0.9604 = 3.6621$
$\Delta_{12}^c = R_{c2}^2 - R_{c1}^2 = 5.6169 - 1.5625 = 4.0544$

Mean Δ_{12}=(3.3625+3.6621+4.0544)/3=3.6930

$\Delta_{34}^a = R_{a4}^2 - R_{a3}^2 = 18.5761 - 9.4864 = 9.0897$
$\Delta_{34}^b = R_{b4}^2 - R_{b3}^2 = 20.4304 - 11.4244 = 9.0060$
$\Delta_{34}^c = R_{c4}^2 - R_{c3}^2 = 22.0900 - 12.9600 = 9.1300$

Mean Δ_{34}=(9.0897+9.0060+9.1300)/3=9.0752

Average value of Δ=(Δ_{12}+Δ_{34})/2=6.3841

3.2.2 Average value of δ

Average value of δ is found in the following way,
$\delta_{ab}^1 = R_{b1}^2 - R_{a1}^2 = 0.9604 - 0.5184 = 0.4420$
$\delta_{bc}^1 = R_{c1}^2 - R_{b1}^2 = 1.5625 - 0.9604 = 0.6021$

$\delta_{ab}^2 = R_{b2}^2 - R_{a2}^2 = 4.6225 - 3.8809 = 0.7416$
$\delta_{bc}^2 = R_{c2}^2 - R_{b2}^2 = 5.6169 - 4.6225 = 0.9944$

$\delta_{ab}^3 = R_{b3}^2 - R_{a3}^2 = 11.4244 - 9.4864 = 1.9380$
$\delta_{bc}^3 = R_{c3}^2 - R_{b3}^2 = 12.9600 - 11.4244 = 1.5356$

$\delta_{ab}^4 = R_{b4}^2 - R_{a4}^2 = 20.4304 - 18.5761 = 1.8543$
$\delta_{bc}^4 = R_{c4}^2 - R_{b4}^2 = 22.0900 - 20.4304 = 1.6596$

Average δ=(0.4420+0.6021+0.7416+0.9944+1.9380+1.5356+1.8543+1.6596)/8=1.2209

3.3 Value of Bohr magneton

The separation between wave number,

$$\Delta\bar{\nu} = \frac{\delta}{2t\Delta} = \frac{1.2209}{2 \times 5 \times 10^{-3} \times 6.3841} \simeq 19.1241m^{-1} \tag{1}$$

Now the value of Bohr magneton is calculated as ,

$$\mu_{\mathrm{b}} = \frac{2hc}{B}\Delta\bar{\nu} = \frac{2 \times 6.625 \times 10^{-34} \times 3.0 \times 10^{8}}{7900 \times 10^{-4}} \times 19.1241 = 0.962 \times 10^{-23} amp - m^2 \tag{2}$$

3.4 Error Analysis

From the expression of Bohr magneton it is evident that the errors only come from the measurements of the values of δ and Δ which in turn depend on the squares of the measured radii of the rings.Hence the expression for error estimation is,

$$\Delta\mu_{\mathrm{b}} = \mu_{\mathrm{b}}\sqrt{(\frac{\delta(\delta)}{(\delta)})^2 + (\frac{\delta\Delta}{\Delta})^2} \tag{3}$$

And assuming the least count of the micrometer as the only source of error it can be written,

$$\delta(\delta) = \delta\Delta = 2R\delta R = 0.02Rmm^2 \tag{4}$$

Inserting the above values in equation (7) it is found, $\delta\mu_{\mathrm{b}}$=0.019$\times 10^{-23}$amp-m^2
Hence the final result is μ_{b}=(0.962$\pm$0.019)$\times 10^{-23}$amp-m^2.

4 Conclusions

1. The magnetic field intensity calibration is done using the principle of Hall effect.When the charges flowing through a conductor placed in an external magnetic field experience the Lorentz force q($\vec{v}\times\vec{B}$) an transverse voltage called 'Hall voltage' is generated in the flat conductor due to accumulation of the charges in the conductor whose polarity depends on the polarity of the charge carriers in that particular conductor.This Hall voltage can be measured to find the intensity of the external magnetic field.This same principle is used in digital Gaussometer which is used in this experiment to calibrate the magnetic field of the poles of the electromagnet.

2. The wavelengths of the split lines are very close to each other hence the order of the first fringes of different components have been taken the same while calculating the difference of the wavenumber of the lines here.

3. As is evident from the result Fabry-Perot etalon setup is very useful in high resolution spectroscopy (the frequency shift $\Delta\nu$=μ_{b}B/2h=eB/8πm is very small,hence a high resolution device is needed),in fact depending on the measurements made using the FP setup the error is only about 2% in the obtained value of Bohr magneton.