

1. INTRODUCTION

This device was designed for modern physics labs of colleges and graduate schools. It demonstrates the influence of a magnetic field on light, known as “Zeeman Effect”, and reveals the behavior of electrons in light-emitting atoms and its quantum nature. By use of appropriate computer software students can collect and analyze data to determine the e/m ratio. This device can also be used to conduct many other experiments that require a Fabry-Perot etalon.

The determination of e/m ratio is a comprehensive experiment, which requires knowledge in optics, mechanics, electromagnetism, modern physics and computer operations. Traditional Zeeman effect apparatus needs more skills in operation and measurement. With its new and integrated design this device is easier to setup and operate so that students can focus on the understanding of the principles and theories.

2. OPERATIONAL CONDITIONS

1. Temperature: $0\sim 40^{\circ}\text{C}$;
2. Relative humidity: $\leq 85\%$;
3. Free from vibrations or electromagnetic interference possible to influence the performance.
4. Power: 110V AC 50HZ

3. SPECIFICATIONS

1. Electromagnet

Magnetic Field $B = 1.3$ Tesla

2. Fabry-Perot etalon

Aperture ϕ 40mm

Distance Between Quartz Plates 2 mm

Central Wavelength 589.3nm

Resolution $\lambda / d \lambda \geq 2 \times 10^5$

High-reflection Bandwidth 100nm

3. Interference Filter

Central Wavelength 546.1 nm

Transmission Bandwidth ≤ 10 nm

Peak Transmission Rate $\geq 50\%$

4. THEORY

The splitting up of the spectral lines of a substance when it is placed as an emitting source in a magnetic field is called Zeeman effect.

Atoms have magnetic moments, which assume quantized orientations. Magnetic moments will acquire additional energy in a magnetic field. For different orientations in the magnetic field, magnetic moments can have different additional energies. Therefore an energy level will split into several sub-levels with different energies. Correspondingly, a spectral line from the light source will split into several lines.

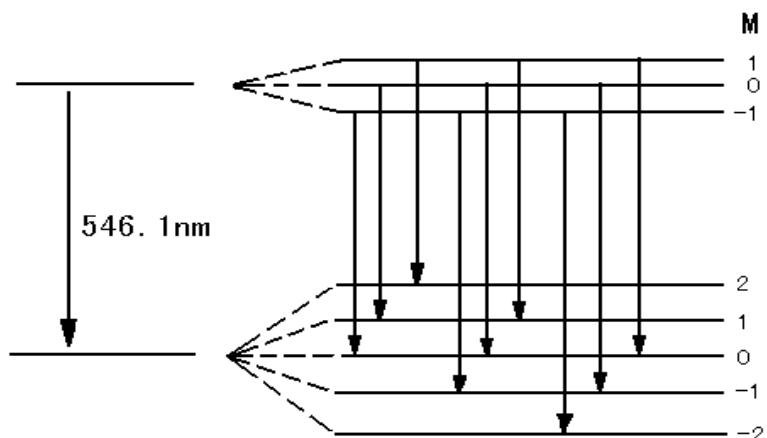


Fig.1

Transitions from high-energy states to low-energy states occur when a mercury light source emits a spectral line of 546.1nm in an external magnetic field. See Fig.1. Since transitions are governed by the selection rule $\Delta m=0$ or ± 1 (Δm is the difference between magnetic quantum numbers due to transition), only 9 transitions are allowed. The number of spectral lines that appear also depends on the state of their polarization. When observed from a direction perpendicular to the magnetic field, spectral lines are linearly polarized; when observed from a direction parallel to the magnetic field, spectral lines are circularly polarized. Table 1 lists the spectral lines observed from different directions.

Table 1

Selection Rule	Perpendicular to Field	Parallel to Field
$\Delta m=0$	Linearly Polarized (π)	No Light
$\Delta m=+1$	Linearly Polarized (σ^+)	Left Circularly Polarized (σ^+)
$\Delta m=-1$	Linearly Polarized (σ^-)	Right Circularly Polarized (σ^-)

When observed in a direction perpendicular to the magnetic field, all 9 spectral lines in Fig.1 will appear. See Fig.2. They include 3 π lines that are polarized parallel to the magnetic field (located at the center) and 6 σ lines that are polarized perpendicular to the magnetic field. The overlapping of these

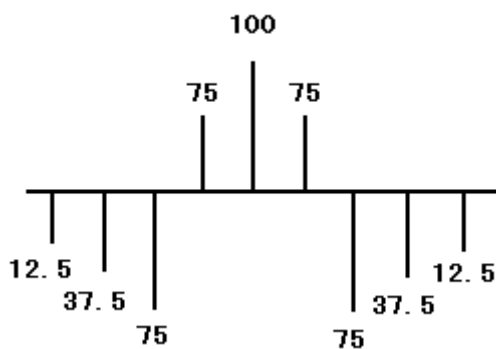


Fig. 2

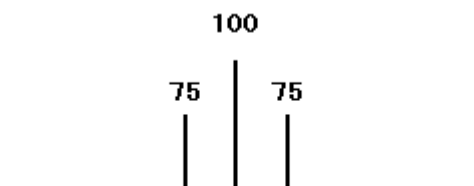


Fig. 3

lines makes the observation difficult. Since the orientations of these two types of spectral lines are perpendicular to each other, a polarizer can be used to filter out the 6 σ lines, so that only 3 π lines will be seen. See Fig. 3.

Spectral line emitted from a mercury source splits in the magnetic field produced by an electromagnet. A lens is used to form the light from the source into a parallel beam. Some or all of the lines will pass through the polarizer for observation. An interference filter is used to select the components of the spectral line with a wavelength of 546.1nm. For the measurement of very small difference in wavelengths a multiple-beam interferometer - Fabry-Perot etalon - is needed. The ring pattern produced by the Fabry-Perot is recorded with a CCD camera and fed to a computer. The result can be analyzed with a special -purpose program. See Fig.4.

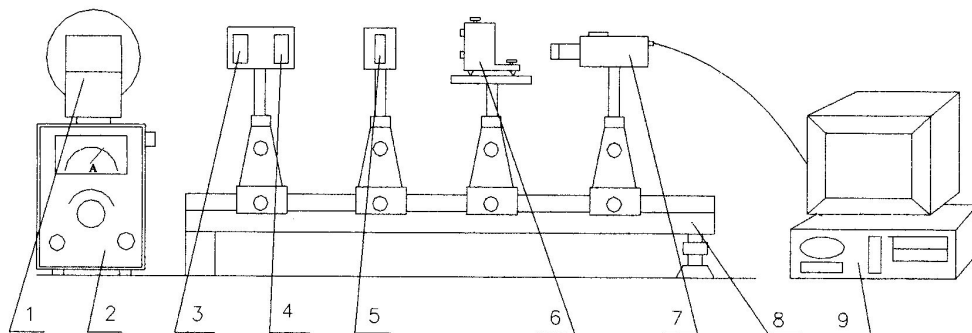


Fig.4.

1	Electromagnet	2	Control Unit	3	Lens
4	Polarizer	5	Interference Filter	6	Fabry-Perot etalon
7	CCD Camera	8	Optical Bench	9	Computer

5. OPERATIONS

1. Set up the device on a table as shown in Fig.4.
2. Insert the mercury lamp into the stand between the coils. Connect the lamp to the binding posts at the front of the electromagnet with its leads. See Fig.5.

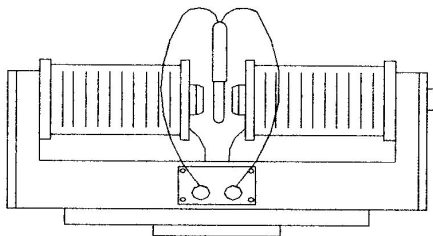


Fig.5.

3. Plug the video cable of the CCD camera into the “video in” outlet of the computer. Connect its power cables to the 12VDC power pack.
4. Plug the power cords of the control unit and the power pack into a wall outlet.
5. Turn on the mercury lamp. Align the lens, the interference filter and the Fabry-Perot so that the light beam will be received by the CCD.

6. Turn on the computer and run the program “Intelligent Data Processing Software for Zeeman Effect Apparatus”. Click on “Preview”, adjust the positions of the lens, the interference and the Fabry-Perot etalon until clear circles show up on the screen.
7. Turn on the switch for the electromagnet. Gradually turn up the magnetizing current until 9 split lines appear on the screen.
8. Rotate the polarizer to obtain the 3 π lines and 6 σ lines separately.
9. Use the software to analyze the spectral lines. See “Instructional Manual for Intelligent Data Processing Software for Zeeman Effect Apparatus” .
10. It is important to the success of the experiment that the plates of the Fabry-Perot etalon be parallel. This can be achieved with the following procedure.

Coarse Adjustment: A group of concentric circles can be seen when you look at the mercury lamp through the etalon. If the circles move as your eyes move towards any of the three fine adjustment screws, the plates are not parallel. You need to adjust all three screws until the circles do not move with your eyes.

Fine Adjustment: During experiments the fine adjustment screws need to be further adjusted for the clearest image on the screen.
11. In order to observe the spectral lines in a direction parallel to the magnetic field, the electromagnet needs to be turned 90°. Loosen the lock screw of the electromagnet mount on top of the control unit, rotate it by 90°, and pull the core out. Add a quarter-wave plate to the opening to turn the circularly polarized light into linearly polarized light. Rotate the polarizer by 45° . One of the two spectral lines will disappear. Turn the polarizer in the opposite direction. The other line will disappear while the first line reappears. That proves the two lines are left and right circularly polarized respectively.

6. PACKING LIST

1. Optical Bench	1 each
2. Electromagnet with Control	1 set
3. Mercury Lamp	2 each
4. Lens and Polarizer with Holder	1 set
5. Interference with Holder	1 set
6. Fabry-Perot etalon with Holder	1 set
7. CCD Camera with Power Pack and Holder	1 set
8. Image Capture Card and Driver CD	1 set
9. Data Processing Software CD	1 set
10. Video Cable	1 each
11. Power Cord	1 each
12. Instructional Manual for the Apparatus	1 each
13. Instructional Manual for the Software	1 each
14. QC Certificate	1 each

7. OPTIONAL ACCESSORIES

1. Computer
2. Quarter-wave Plate

8. MAINTENANCE

1. The device should be placed in a dry and clean room with good ventilation. Cover the unit when it is not used.
2. Apply lubricant to the surface of the optical bench periodically to prevent it from rusting.
3. When not in use, the Fabry-Perot etalon should be stored in a sealed container with desiccators. Desiccators should be replaced periodically to keep the unit from mould.
4. Do not touch any optical part with hand. When dust or dirt exists, use a special brush to remove the dust, and then carefully clean the surface with cotton balls soaked in 1:1 solution of denatured alcohol and ether.
5. Increase the magnetizing current slowly. It is preferable that the pointer is kept in the blue area on the meter. Do not leave the pointer in the yellow area for long, because a strong current would produce excessive heat in the electromagnet to damage it.
6. To prolong the life of the mercury lamp, avoid turning it on and off frequently.