5. Objectives of Experiments

1) Observe Zeeman effect, understand atomic magnetic moment and spatial quantization in atomic physics;
2) Observe the splitting and polarization of a Mercury spectral line at 546.1 nm;
3) Calculate the electron charge-mass ratio based on Zeeman splitting amount;
4) Learn how to use a Fabry-Perot etalon;
5) Measure the magnetic field in the central region of an electromagnet with a Tesla meter, analyze its linear range;
6) Measure the Verdet constant of a sample using light extinction method.

6. Experimental Procedures

A. Setup and adjustment

1) The diode laser is mounted on a kinematic holder and fixed on a mini magnetic base. Please attach the magnetic base to the side of the magnet frame as shown in Figure 6. Align the laser beam to make it pass through the central hole in both magnet poles by carefully adjust its position and direction.
2) The electromagnet placed on a rotary platform is positioned by a limit slot to ensure the axis of the rotation coincides with the center of the magnet gap;
3) The laser beam can be used to align the optical components on the rail to make them coaxial on the rail. For Zeeman effect experiment, the sequence of components on the rail from left to right is as follows: condensing lens, interference filter, F-P etalon, polarizer scale disk, imaging lens, and reading microscope (or CCD camera with lens).
4) Ensure correct wire and cable connections. The power output of the mercury lamp and the signal input of the Teslameter probe are on the rear panel of the controller unit. Connect light power meter (socket "Detector" on the front panel) to the photo detector located on the scale disk with the provided coaxial cable. (The photo detector needs to be removed from the scale disk in Zeeman effect experiment).
5) Turn on power, zero the Teslameter and the light power meter (**Note**: the probe of the Teslameter should be far away from any magnetic field source and the photo detector should be blocked when zeroing).

*Note: The two coils of the electromagnet are connected to the power supply **in parallel**. If the magnetic field between the magnet poles is weak when the displayed current is high, it means the current flowing directions in the two coils are in opposite directions. Under such case, exchange the two leads of either of the two coils (please refer to the document of "**Magnet Assembly & Stage Use**").*

The power supply has automatic thermal protection. If it is automatically turned off, wait for a few minutes to allow it cooled down before turning it on again. Do not operate it at large current for a long period of time, i.e. reducing current after each measurement or during idle of the experiment. Radiator at the rear panel should NEVER be blocked out. Do not exceed 30V of voltage or 5A of current under any case.

B. Faraday effect

1) Refer to Figure 6, orientate the electromagnet longitudinally, i.e. the magnetic field is along the optical axis (the rail). Turn on the diode laser. Align the laser beam to make it pass through the central hole in both magnet poles by carefully adjust its position and direction.

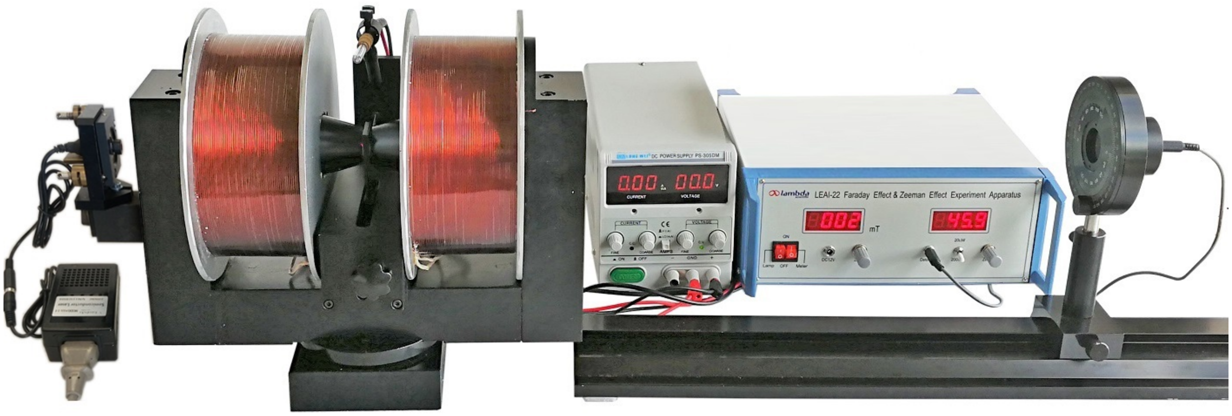

Figure 6 Experimental setup of Faraday effect

2) Adjust the height of the scale disk to let the laser beam enter the small aperture to reach the photo detector. Turn the dial on the disk, the reading of the power meter should change.
3) Introduce the glass sample inside the sample stage by turning the knob, and let the laser beam fully pass through the sample. (There are two samples pre-installed, an acrylic glass with a small positive Verdet constant and a MR3-2 magneto-optic glass with a larger negative Verdet constant).
4) Turn the dial on the scale disk to rotate the polarizer. Since the laser beam is polarized, the reading of the light power meter should change with the rotation of the polarizer. When the reading of the power meter reaches minimum (reduce scale range of the power meter to increase sensitivity), the polarization of the laser is perpendicular to the polarizer. Read angle θ_1 on the vernier disc.
5) Turn on the power supply for the electromagnet to apply a magnetic field to the sample, the reading of the power meter will increase due to Faraday effect. Rotate the polarizer to minimize the reading on the light power meter. Read angle θ_2 on the vernier disc.
6) Turn off the diode laser, lower glass sample, shift the slide of the sample stage, place the probe of the Teslameter at the center of the magnet gap, and read the magnetic field intensity B.
7) Measure the thickness of the sample using a caliper (about 6 mm), calculate the Verdet constant of the sample using formula $\Delta\theta=\theta_2-\theta_1=VBd$.

C. Transverse Zeeman effect

1) Following the above experiment, firstly keep the electromagnet in longitudinal direction and the diode laser is on. Refer to Figures 5 and 7, place other optical components on the rail (at this time do not place the mercury lamp in between poles),

adjust their height to let the laser beam hit on their centers; then turn off the diode laser and remove it from the magnet frame. Rotate the electromagnet 90° to set it in transversal direction; position the mercury lamp in the center between the poles and turn on the mercury lamp. Remove the polarizer from the optical path.

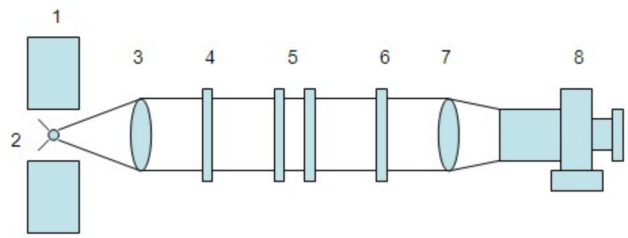

Figure 7 Schematic of Transversal Zeeman experiment setup

1. Magnet	2. Mercury lamp	3. Condensing Lens	4. Filter
5. F-P etalon	6. Polarizer	7. Imaging Lens	8. Microscope

2) Moving the microscope to the back focal plane of the imaging lens, interference fringes should be observed through the eyepiece. Finely adjust the F-P direction or tilt to achieve optimal fringe pattern. Note: though the F-P etalon was pre-adjusted at factory, its parallelism may be altered during transportation. Prior to experiment, the instructor needs to confirm or adjust the F-P device to be in good parallelism. Without the instructor's permission, students should not re-adjust the parallelism of the F-P device.

3) Turn on the power supply of the electromagnet, set current at a mediate value (e.g. 3A). Spectral splitting phenomenon can be seen through the microscope for each group of interference rings. By adjusting the intensity of the magnetic field through the current applied to the electromagnet, spectral splitting gets wider with an increase in the magnetic field. Now place the polarizer into the optical path and rotate it to different angles respectively, polarization states of π and σ components can be observed with relative angle differences 0°, 45°, or 90°.

4) By rotating the polarizer, three split rings of each interference order can be seen clearly through the microscope, as shown in Figure 8. Use the reading microscope to measure the diameter of the three rings, written as D_b (i.e. D_{m-1}), D_a and D_m. Use the magnetic field meter (Teslameter) to measure the magnetic induction B in the central area of the magnet. Substitute the data into (26) and (27), the wave number difference and electron charge/mass ratio can be calculated.

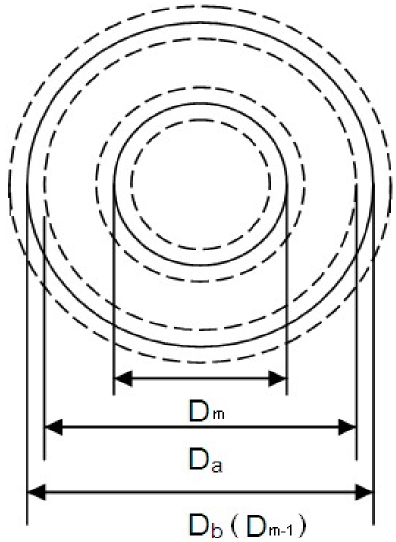

Figure 8 Split rings of Mercury green line at 546.1 nm after applying magnetic field

5) If CCD camera, USB frame grabber, and analysis software are ordered, the microscope and the imaging lens as seen in Figure 6 should be replaced with the CCD (with lens) to acquire the image that is then analyzed using the analysis software. **Note:** the small aperture may be added to the polarizer if CCD gets saturation. Please read software instruction in Appendix with a demo video provided from the CD.

   Note: for first time use, one needs to install the USB driver for the frame grabber (blue box), please refer to “Installation Note of USB Driver for MV-U2000 Frame Grabber” on the provided CD.

Note: ideally, the lamp should be at the focal point of the condensing lens to form a collimated beam for the F-P etalon. However, this arrangement will produce an interference pattern of non-uniform brightness, i.e. a narrow vertical strip of the lamp tube. So, in practice, it is better to place the condensing lens either closer or farther from the lamp, and then find proper positions as well as proper orientations of other components to achieve uniform, sharp, bright, and symmetrical interference pattern.

There are many factors may have influences on the interference image quality. Careful alignment of the optical path is needed. Be patient and thoughtful to observe the change of the interference image during adjustment of the optical path.

Reference data (for information purpose only; not the performance criteria of apparatus)

By applying a magnetic field, observe the transverse effects, and measure the diameter of the split rings with a reading microscope. Data is recorded in the table below (unit: mm):

	D_b (D_{m-1})	D_a	D_m
Left side reading	1.410	1.546	2.936
Right side reading	7.284	7.146	5.688
diameter	5.874	5.600	2.752

Use the Teslameter to measure the magnetic field at central region, B=1.301 T; with F-P gap d=2.000 mm; and M_2g_2-M_1g_1=1/2;

Substitute the data into equation (27), we get

e/m=1.6923×10^{11} (C/kg)

The recognized value is: e/m=1.7588×10^{11} (C/kg), so the measurement error is: 3.8%.

D. Longitudinal Zeeman effect

1) Refer to Figure 9, rotate the magnet by 90° to let the open hole of the magnet face the optical rail.
2) Finely adjust the Mercury lamp to let most light passing through the open hole of the magnet pole.
3) Since the hole in the magnet pole is small, the Mercury light passing through the hole is approximately collimated; the condensing lens is not needed and should be removed from the rail. Set other components to build the same setup as the previous experiment.
4) Adhere the λ/4 wave plate with built-in magnets onto the open hole of the magnet, so that the left and right circularly polarized light beams are now converted to two linearly polarized light beams perpendicular to each other. The white mark line on the mount indicates the direction of the slow axis of the λ/4 wave plate.

   Note: the direction of slow axis is marked using a red dot on the edge of the glass plate inside the mount. It was pre-aligned with the white line on the mount at factory.

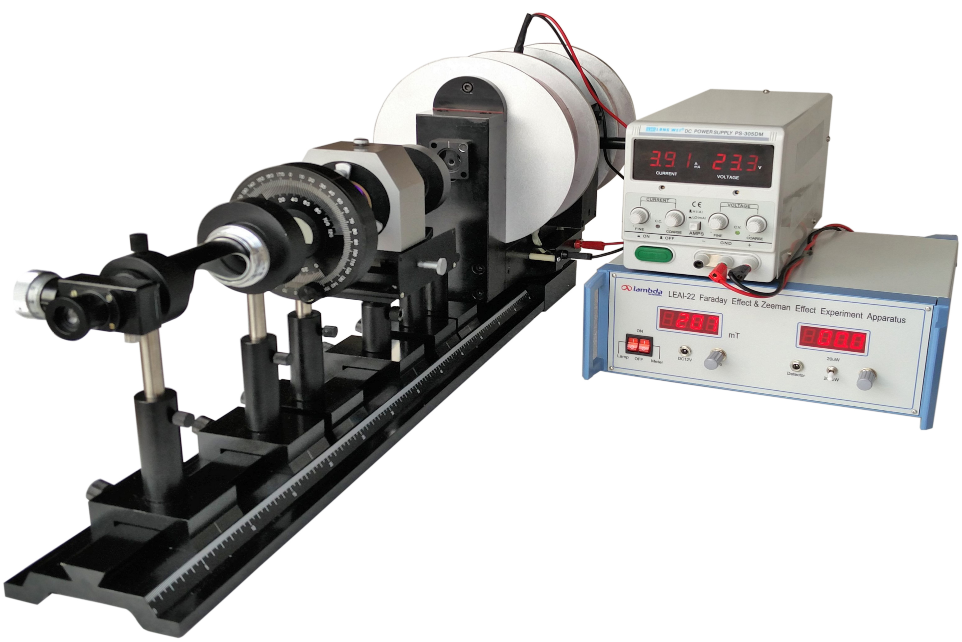

Figure 9 Experimental setup of longitudinal Zeeman effect

5) Rotate the polarizer slowly and continuously while observing the disappearance and reappearance of the split spectral lines. This observation confirms that the two groups of split spectral lines are left and right circularly polarization beams, respectively.