Faraday effect.

Experiment Objective: observing the rotation of the polarization plane of light in a magnetic field.

Tasks:

- observing the rotation of the polarization plane if polarized monochromatic light is passing a flint glass in a magnetic field;
- determining angle of rotation of polarization plane for or different values of the magnetic field induction B;

Optical elements and apparatus:

- ✓ small optical bench (1);
- ✓ halogen lamp in the housing (2) and power unit (3);
- ✓ holder and the heat filter (4);
- ✓ multimeter (5);
- ✓ polaroids: polarizer (6) and analyzer (8);
- ✓ semitransparent mirror (7);
- ✓ electromagnet windings (9);
- ✓ magnet (10);
- ✓ mirror (11);
- ✓ sample (flint glass) (12);
- ✓ Combi B-Sensor S (1, Fig.2);
- ✓ Mobil CASSY Lab (2, Fig.2);
- ✓ cable (3, Fig.2);
- ✓ filters for different wavelengths (supplied and installed in the holder 4);

In 1845 Faraday discovered the following phenomena: If a transparent isotropic materials is placed in a strong magnetic field and linearly polarized light is transmitted in the direction of the magnetic field the plane of polarization of linearly polarized light rotates by an angle φ when passing through the transparent material. Historically, the observations of Faraday was the first evidence that the optical and magnetic phenomena are related.

Faraday experiments and then more precise Verde measurements have shown that the angle of rotation φ is proportional to the magnetic flux density B and the length l of the medium through which the light is transmitted:

$$\varphi = R \cdot l \cdot B. \tag{1}$$

The proportionality constant R is called Verdet's constant. R depends on the wavelength of the light, on the type of substance and on the physical conditions.

The Verdet's constant is depended on wavelength as following:

$$R = \frac{A}{\lambda^2} + \frac{C}{\lambda^4}. \quad (2)$$

where A and C are constants.

Substance that rotates the plane of polarization in a clockwise direction for an observer looking in the direction of the magnetic field, agreed to consider positive and counterclockwise - negative.

A characteristic feature of the plane of polarization rotation in a magnetic field is that the direction of rotation is associated only with the direction of the magnetic field and does not depend on the direction of light propagation. This fact can be used to amplify the observed effect by lengthening the path of the light beam in a substance with multiple reflection.

A general view of the installation is shown in Fig. 1.

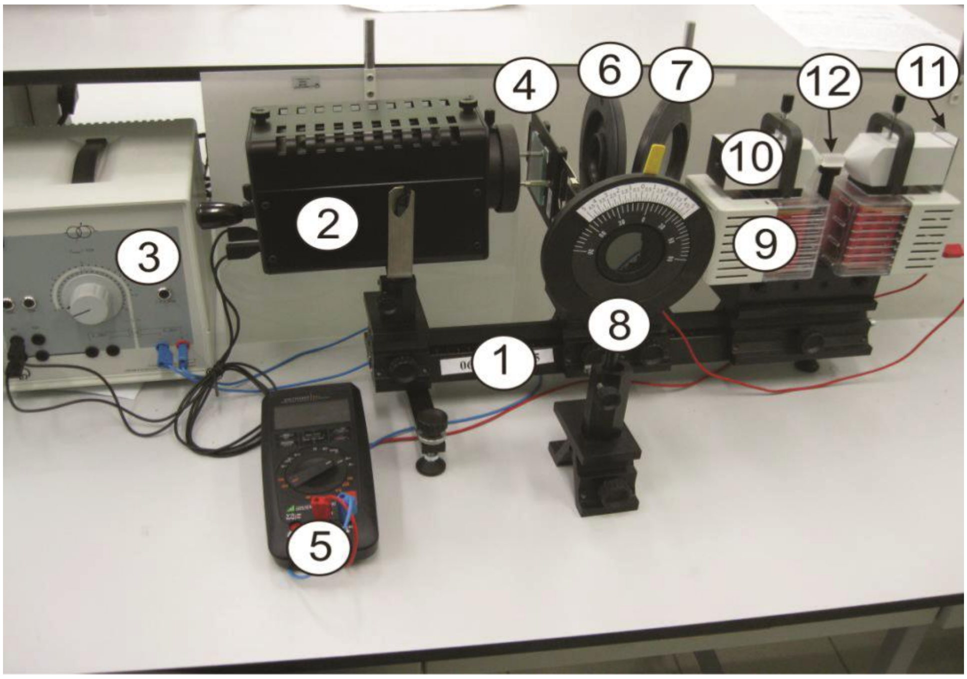

Fig.1. Experimental setup.

Light from the source (2) passes through the color filter, heat filter which are fixed in a holder (4) (bluish filter permanently mounted in a holder is a heat filter), polarizer (6), semitransparent mirror (7), magnet bore (10), sample (flint glass) (12) and is reflected from a mirror which rotates the beam in the opposite direction. The beam passes through the sample again, and then is reflected by the semitransparent mirror (7) and passes through the analyzer (8). Visual field illuminance is visually observed on the side of the analyzer. Thus, in a particular installation the light passes sample (flint) twice so the angle of rotation of the plane of polarization is increased and the measurement accuracy increases.

The magnetic field in the electromagnet gap is created by the current passing from the power supply (3) through its winding (9). Current strength is measured by multimeter (5). The magnitude of the magnetic field B can be varied by current regulator on the power supply. The magnetic field induction is measured by the Mobil CASSY Lab (2 in Fig.2 and Fig.4). The magnetic field sensor is located at the end of the Combi B-Sensor S probe (1 in Fig.2).

<u>Procedure:</u>

<u>Exercise 1. Calibration of the magnetic field.</u>

1. Set the regulator (3) on the power supply to the zero position.
2. Turn on the power supply (3).
3. Remove the sample (12) from the sample stage.
4. Connect the Combi B-Sensor S (1) to the Mobile CASSY (2) using the extension cable (3) (Fig. 2).

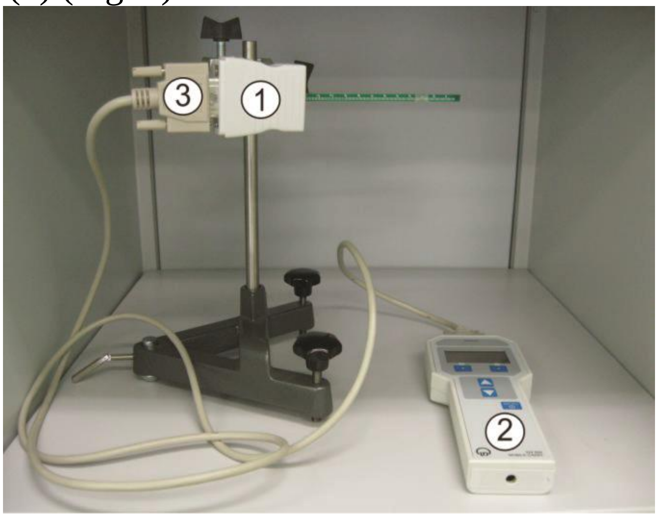

Fig.2. Combi B-Sensor S with Mobil CASSY.

5. Place the tangential B probe of the Combi B-Sensor S between the pole pieces as shown in Fig.3.

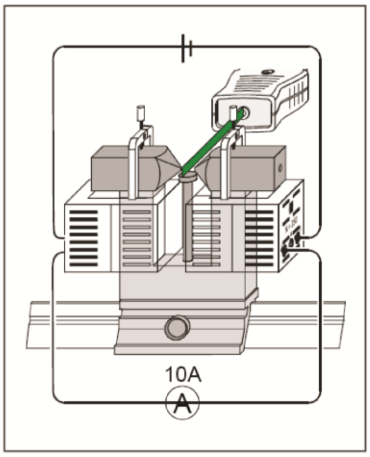

Fig.3. Calibration of the magnetic field schematically.

6. Turn on the Mobil CASSY sensor by pressing the button 1 (Fig.4). You will see a background magnetic field value. It is caused by external magnetic fields. In further measurements of magnetic field induction, this value should be subtracted from all obtained values *B*.
7. By changing the current *I* through the coil of the electromagnet from 0 to 10A in steps of 1A, register the values of the magnetic field *B* for different values of *I*.

8. Turn off the Mobil CASSY sensor. *Note! Mobil CASSY sensor is switched off by pushing the two buttons - 1 and 2 (Figure 4).*

Fig.4. Mobil CASSY sensor.

9. Remove the sensor probe of Combi B-Sensor S from the magnetic field.
10. Turn off the power supply.
11. Plot the $B(I)$ dependence.
12. Set the regulator (3) on the power supply to the zero position.

Exercise 2. Observing the dependence of the Faraday rotation angle φ on the magnetic field induction B.

1. Turn on the power supply.
2. Insert the green filter in the diagram slider.
3. Place the flint on the place stage (12 in Fig.1).
4. Set the polarizer (6) to 90° position.
5. Set a semitransparent mirror to an 45° angle to the axis of the installation so that it was possible to observe a hole in the magnet poles.
6. Rotating the analyzer, get the minimum light intensity passing through the system (cross your polarizer and analyzer).
7. Determine the angle of orientation of the analyzer φ_0
   Note! The limb and vernier scales (located on the analyzer barrel) are used for determination of the orientation angle of the analyzer (Fig.5). The accuracy of the limb scale is 5°. Value of the vernier scale division is 0.25°. Vernier scale has left and right side with respect to zero. If the vernier scale zero is on the left side of the limb scale, the vernier scale reading is made from zero on the left side of the scale. If the vernier scale zero is on the right side of the limb scale, the vernier scale reading is made from zero on the right side of the scale.
   First, determine the limb integer divisions that fit between limb zero and vernier zero. For this number of divisions the angle determined up to 5°. Then find a vernier division, which coincides with the division of the limb. The value of degrees that stands against this division on the vernier scale

should be added to the value obtained by limb scale. For example, in Figure 5 the angle of rotation of the analyzer is 7.5°.

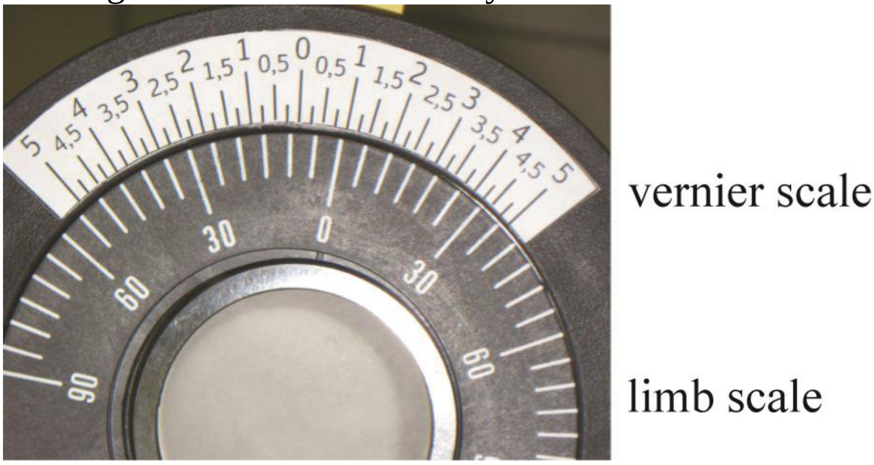

Fig.5. Vernier and limb scales of the analyzer.

8. From the *B*(*I*) plot constructed in the first exercise find the value of the current through the coil of the electromagnet such that the magnetic field induction *B* was ~ 60 mT. At the same time the plane of polarization will rotate and the light will pass through the system and field of vision will be brighter.
9. Again find the minimum intensity by rotating the analyzer. Measure the angle φ_1’ on a scale and on a vernier scale. Determine the angle of rotation of the magnetic field from the ratio:

$$\varphi_1 = \varphi_1' - \varphi_0$$

10. Similarly measure φ_2, φ_3,… φ_n for other values of the magnetic field *B* with 25 mT increment, by varying the current through the electromagnet.
11. Plot the $\varphi(B)$ dependence.