

### 1. Motivation

If polarized light, whose  $\vec{E}$  vector oscillates in the plane of incidence, falls on a glass slide, then for a certain angle of incidence no light is reflected.

The Brewster law links this angle with the refractive index, which can be simply determined in this way.

### 2. Basics / theory

- Licht als elektromagnetische Welle  
(Staudt Skript II, Kap. 8.1 oder E. Hecht, Optik, Kap. 3.2, 3.4)
- Unterschied geometrische Optik/Wellenoptik  
(Staudt Skript II, Kap. 8.1 oder E. Hecht, Optik, Kap. 4.2.3, 5.1)
- Polarisierung von Licht  
(Staudt Skript II, Kap. 8.3.1 oder E. Hecht, Optik, Kap. 8.1, 8.5, 8.6)
- Reflexion und Brechung in Glas  
(Staudt Skript II, 8.2.1 oder E. Hecht, Optik, Kap. 4.2)
- Fresnelsche Formeln  
(Anhang oder Demtröder Experimentalphysik 2, Kap. 8.5.3 oder E. Hecht, Optik, Kap.8.6.1)
- Brewstersche Gesetz  
(Staudt Skript II, Kap. 8.3 oder E. Hecht, Optik, Kap. 8.6)

### Questions

- When are the optical phenomena described by geometrical optics? When is the wave property of light needed for the explanation? How is a light wave described? How is light produced?
- What is linearly polarized light? How is natural light polarized and how can linearly polarized light be produced from it? How can polarized light be evidenced?
- How does the Snellius refraction law read? What is total reflection and when does it arise?
- What do the Fresnel formulas describe? What happens if in the formula given in the appendix A we take  $\alpha+\beta=90^\circ$ ?
- How does the Brewster law read? What can be determined with it?

### 3. Description of the experiment

In the experiment a beam of parallel light is produced by using a halogen lamp, a lens and a fixed slit (see figure NG.1). This light beam is directed through a polarization foil on a reflection glass, which is in the center of the reflection table (see illustration NG.2). In addition on the reflection table there is a light measuring instrument (photo resistor with voltage measuring instrument) mounted on a mobile arm.

Displacement of the mobile arm with the angle  $\Phi$  modifies the incidence and reflection angle of the light beam on the reflection glass by  $\Phi/2$ . Therefore the intensity of the reflected beam can be measured for different angles of incidence and, in particular, the Brewster angle can be analysed.

#### 4. Measurements

1. Set up the experimental equipment as described in the appendix B.
2. For a measuring glass the following measurements have to be performed:
  - (a) Show that the measured intensity has a minimum within the range of  $80^\circ$  to  $40^\circ$ .
  - (b) Measure the intensity within the range of  $72^\circ$  to  $40^\circ$  in steps of  $2^\circ$ . The sensitivity of the light measuring instrument should be selected in such a way that it indicates reasonable values everywhere.
  - (c) Measure the intensity within the range around the minimum in  $1^\circ$  steps. The size of the range should be selected in such a way that the measuring instrument indicates reasonable values everywhere, where one has to choose the next more sensitive working range (compared with the previous measurement).
  - (d) Measure the intensity within the range of  $\pm 1^\circ$  around the minimum in steps of  $0.25^\circ$  (if possible again select the next more sensitive working range).
3. For 4 other measuring glasses the minimum should be determined 2 to 3 times. Position the table in such a way that the measuring instrument indicates a minimum and read off the angle as exactly as possible. Estimate in each case an error (e.g. from the precision of the angle scale and/or the width of the minimum) and write down the type of glass.

#### 5. Tasks for evaluation

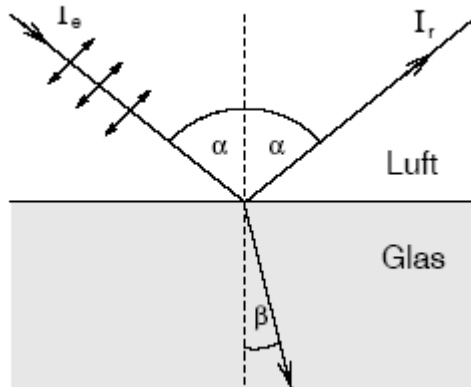
- To measurement 2: Represent the measured intensities with respect to the angles as curves on graphic paper (3 curves in 1 diagram).
- Determine for the glass from measurement 2 and each of the four glasses from measurement 3 the average refractive index, respectively. Indicate an error in each case.

#### 6. Appendix A: Theory of the Fresnel formulas

The complete theory of reflection, refraction and polarization of light in isotropic media is described by the Fresnel formulas (A. Fresnel, 1821). The formulas can be derived directly from the wave property of light.

For linearly polarized light, whose  $\vec{E}$  vector oscillates in the plane of incidence and which falls on the boundary surface between two dielectric media, the following formula applies to the intensity of the reflected beam:

$$I_r = I_e \left( \frac{\tan(\alpha - \beta)}{\tan(\alpha + \beta)} \right)^2$$



## 7. Appendix B: Adjustment of the experimental setup

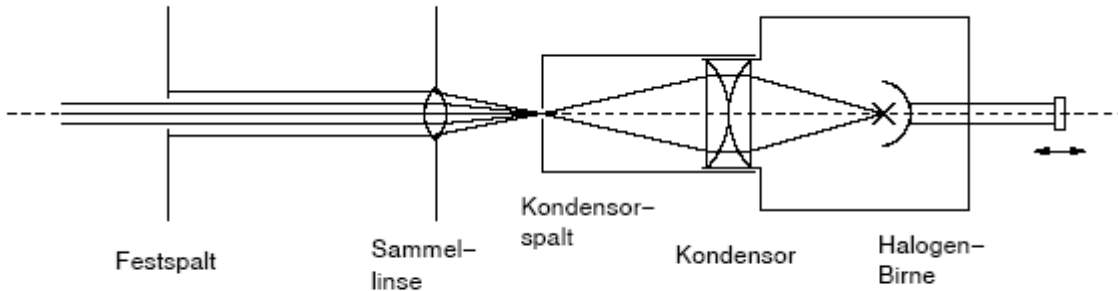


Abbildung NG.1: Lampenanordnung

### 7.1 Adjustment of the lamp arrangement

The lamp arrangement should be adjusted in such a way that as much light as possible is emitted. Subsequently you should perform the following steps:

1. Positioning the convergent lens:  
The convergent lens is in the correct position, if the condenser slit of the lamp is sharply projected by the convergent lens on a screen (e.g. the wall).
2. Adjustment of the lamp onto the optical axis:  
The lamp is correctly aligned, if the image of the slit is filled as completely as possible with the halogen bulb filament. In addition the lamp has to be aligned mechanically in such a way that both filaments are as visible as possible. (The filaments can be sharply illustrated on the screen by shifting the bulb along the optical axis.)
3. Adjustment of the halogen bulb on the optical axis:  
By a further shift of the halogen bulb on the optical axis the light efficiency can be still increased. In order to determine the optimal position, one keeps a sheet of paper directly in front of the condenser lens slit and shifts the bulb in such a way that the spot becomes as bright as possible. (Then the spot should be as white as possible; in case of deviation from maximum intensity it changes the colour in one direction in bluish, and in the other direction in yellowish. The reason for this effect is the chromatic Abberation of the condenser).
4. Finally the given slit is put in front of the lens on the optical bank.

### 7.2 Adjustment of the reflection table

The reflection table is placed in such a way in front of the lamp arrangement, that the light is incident in (the direction of) the fixed arm. The reflection table has to be adjusted in such a way that the light from the lamp is incident parallel to the surface of the reflection table and in the correct direction.

In order to check this the two marked glass plates will be used. The U-holder with the transparent glass is put into hole 1 and the U-holder with the matt glass into hole 3 of the reflection table, such that the notch of the bar at the top edge is sitting on a hole (fingernail sample). The mobile arm has to be set to the  $90^0$  mark on the reflection table (i.e. it laves in extension of the fixed arm).

The reflection table is adjusted correctly if the light beam goes through the rectangle of transparent glass and fits exactly into the rectangle of the matt glass.

For more exact adjustment a reflection glass is placed in such a way in the center of the reflection table (inscription upward) that the glass rests at the stop position (edge guide).

The mobile arm is set to the  $45^\circ$  mark. The light beam should again fit exactly into the rectangle of the matt glass. To this end in addition to readjustment of the reflection table one can also readjust the reflection glass.

Finally it is examined whether the position of the light beam remains within the rectangle of the matte glass if the angle is varied between  $45^\circ$  and  $70^\circ$ .

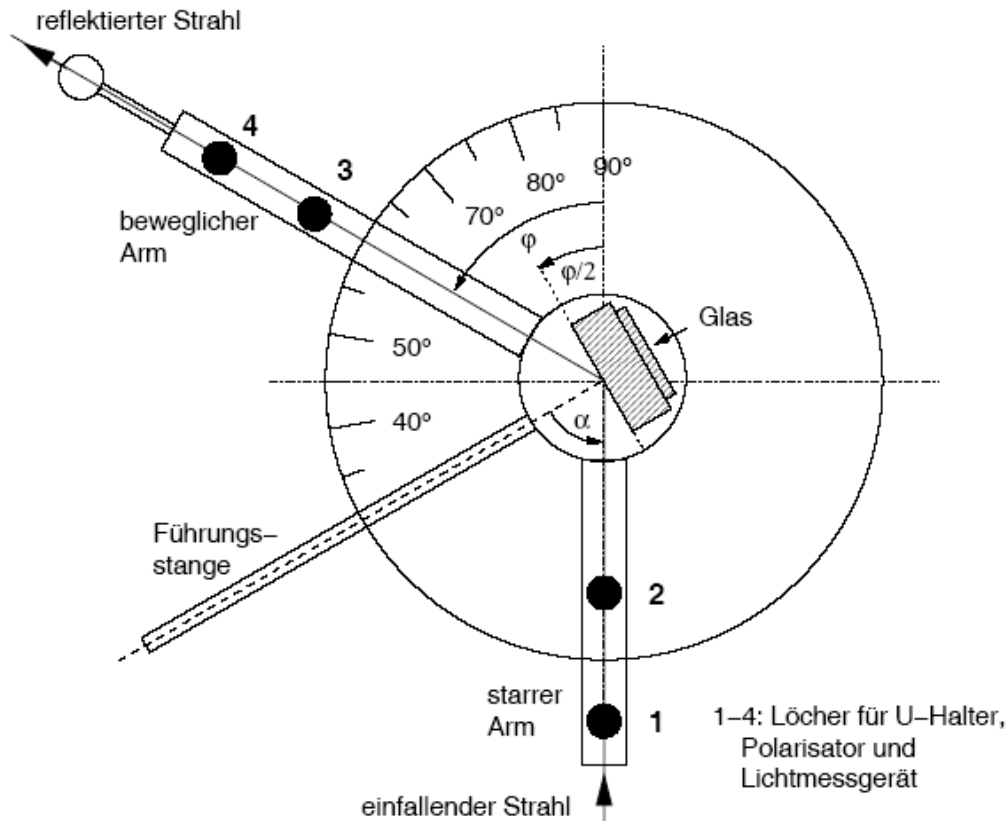


Figure NG.2: Reflection table

### 7.3 Adjustment of the light measuring instrument

For the measurements the polarization foil is inserted in hole 1 of the reflection table and the correct polarization angle is adjusted. The light measuring instrument is inserted in such a way into the holes 3 and 4 that the light beam falls exactly on the surface of the photoresistor. The light measuring instrument is connected with the voltmeter and attached with the coaxial connector to the 60 V DC voltage supply.

The light measuring instrument supplies within its measuring range voltage between 0 V and approx. 5 V. With higher voltages the equipment is in saturation, i.e. indicates that the voltage does not change any longer with increasing light intensity. The sensitivity of the light measuring instrument can be changed with the lower rotating button of the equipment. Firstly, for the light measuring instrument the least sensitive working range should be selected.

Finally the light measuring instrument can be approximately adjusted on zero with the upper rotating button (for this adjustment no light should fall on the measuring instrument!).