Exercise 421
Examination of light polarization by reflection phenomena

Krzysztof Palka and Dominik Odrowski

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Abstract

This report present the measurement of Brewster's angle for a given material. It shows relation of level of ray polarization depending on incident angle of unpolarized light.

1 Introduction

The aim of this exercise was determining of Brewster's angle for given material and, depending on obtained results, calculation of index of reflection.

2 Theory and measurement

The light polarized randomly (unpolarized) is characterized by electric filed at any given point perpendicular to the direction of travel of the waves but changes directions randomly. We can treat unpolarized light as combination of two perpendicular components (polarization S and P) which oscillate perpendicular to component of the electric field $\vec{E}$ (Fig. 1[1]).

Reflected ray is at least partially polarized. When ray incident on dielectric surface with angle θ_B (Fig. 2[2]), that:

$$\tan \theta_B = n \tag{1}$$

where n is the index of reflection of dielectric, then θ_B is called Brewster's angle and reflected ray is linearly polarized (electric field vectors on Fig. 2

[1] [HRW], p. 901

[2] Ibid., p. 912

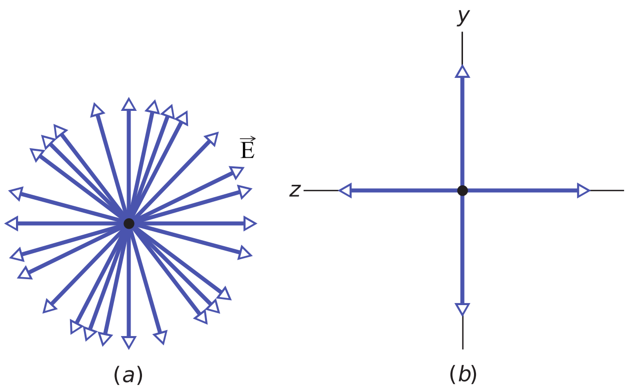

Figure 1: polarization (a) could be simplified as (b).

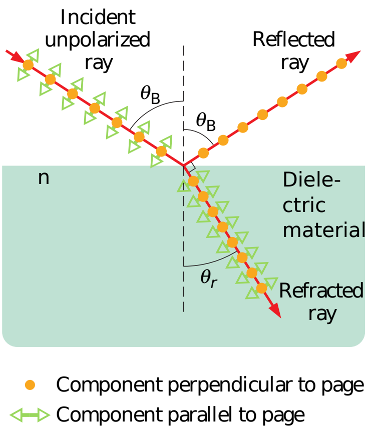

Figure 2: direction of oscillations of incident, reflected and refracted rays.

oscillate perpendicular to the page). Incident rays oscillate in perpendicular and parallel directions, so they are unpolarized. Reflected ray behave in similar way, but magnitudes of particular components of electric field oscillations are unequal and that ray is called partially polarized. If incident angle is not equal Brewster's angle, then Reflected ray is also called partially polarized, and level of polarization K can be obtained form equation 2

$$K = \frac{I_S - I_P}{I_S + I_P} \tag{2}$$

Where I_S and I_S are intensities of lights with polarization S and P, according to figure 2 respectively perpendicular and parallel to plane determined by diagram.

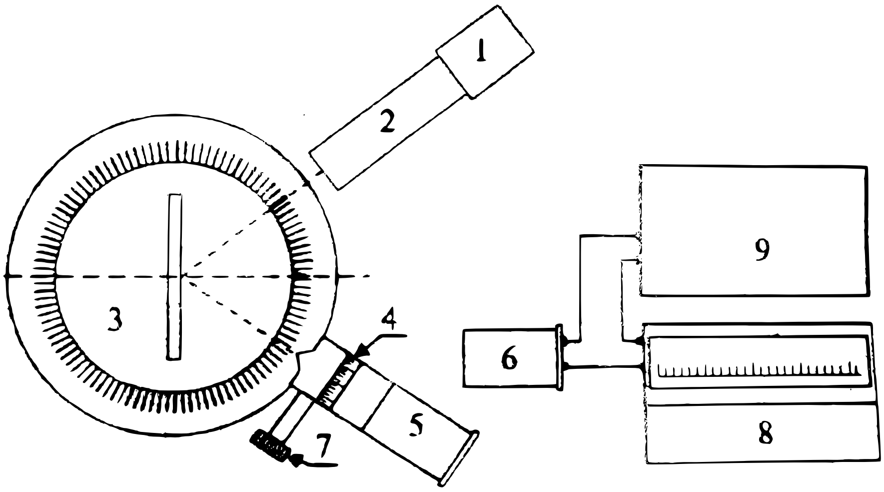

Figure 3: Diagram of the experimental set-up. It consists of swivel table (3) with angular scale of precision $\Delta\alpha = \pm 1°$ and 2 arms. illumination (1) with collimator (2) is placed on fixed arm, analyser (4) and telescope on which could be placed eyepiece (5) or photodetector (6) are mounted on movable arm. Electric circuit consists of photoresistor which is used as photodetector (6), power supply unit (9) and microamperemeter (8).

3 Results

The results of our measurement are presented in Table 1. It contains values of current flowing through photoresistor of light with polarization S and P for a given angle read from microamperemeter. It contains also level of polarization for a given angle calculated from equation 2. Figures 4 and 5 presents obtained values on a graph. Uncertainty of horizontal axis is $\pm 1°$ because of scale of goniometer. Figure 6 presents level of polarization calculated from equation 2 and measurement uncertainty calculated form equation 4 where Δi is measurement uncertainty of current flowing through photodetector. Maximum level of polarization was noticed at the angle 56°, so according to equation 1 index of reflection of examined material is $n = \tan 56° \approx 1.48$. Because the light is not monochromatic, this is average index of refraction. After consideration of equation 4, the level of polarization for angle 56° would looks like $K = 0.989 \pm 0.004$. To obtain uncertainty of index of reflection we use formula 5. So overall result of measuring index on reflection would look like.

$$n = 1.48 \pm \Delta n = 1.48 \pm \frac{2 \cdot 1.48}{\sin(2 \cdot 56°)} 0.0349 = 1.48 \pm 0.11 \qquad (3)$$

Table 1: Measured results: quantities I_S and i_P read form mikroamperometer for setted angle α and level of polarization calculated form equation 2

$\alpha[°]$	$i_S[A]$	$i_P[A]$	K
20	19.0	10.9	0.271
30	26.0	7.5	0.552
40	31.2	3.0	0.825
50	49.0	0.6	0.976
52	63.7	0.5	0.984
54	59.4	0.5	0.983
55	63.8	0.4	0.988
56	74.6	0.4	0.989
57	69.9	0.5	0.986
58	88.0	0.5	0.989
60	96.2	0.7	0.986
70	161.2	14.8	0.832
80	209.1	69.1	0.503

$$\Delta K = \frac{2\Delta i}{i_S + i_P} \tag{4}$$

$$\Delta n = \frac{2n}{\sin 2\alpha_B}\Delta\alpha_B \tag{5}$$

4 Conclusions

Even small change of values obtained form microamperometer leads to setting of wrong Brewster's angle. In conditions of measurement where there is not dark, mikroamperometer's indication could be easily disturbed, and as it is shown on fig. 6 values of K in range $50° - 60°$ are very similar, so we could read not exactly Brewster's angle, but angle with similar polarization.

References

[HRW] Fundamentals of physics (2011) [ebook]. David Halliday, Robert Resnick, Jearl Walker. 9th ed. ISBN 978-0-470-46908-8

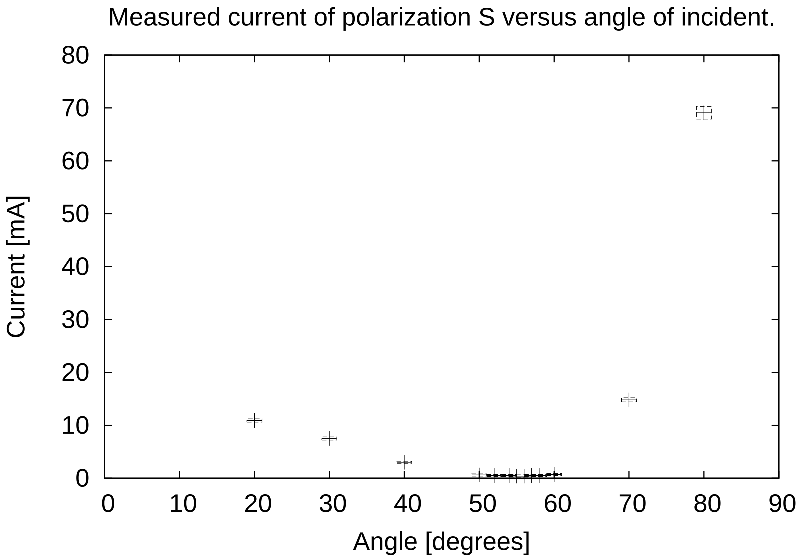

Figure 4: graph of current of polarization S versus angle of incident, with measurement uncertainty of microamperometer $\pm(1.5\% + 1)$ for resolution 0.1

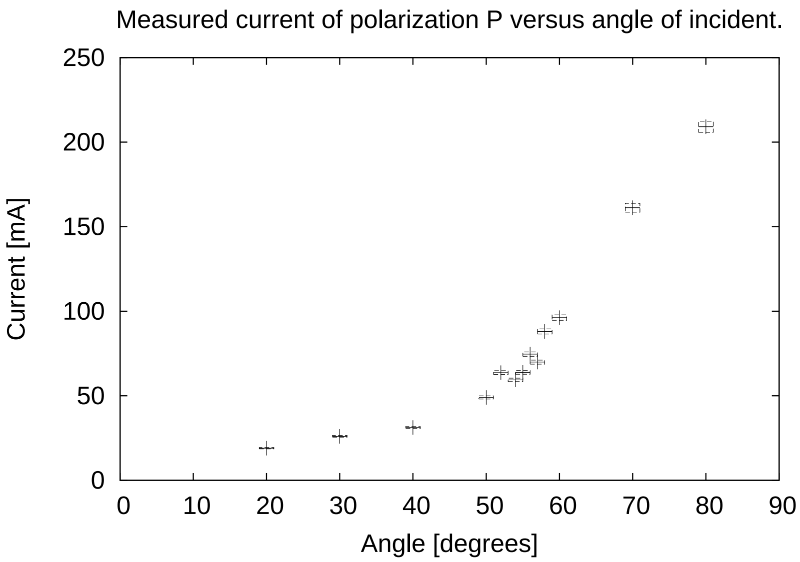

Figure 5: graph of current of polarization P versus angle of incident, with measurement uncertainty of microamperometer $\pm(1.5\% + 1)$ for resolution 0.1

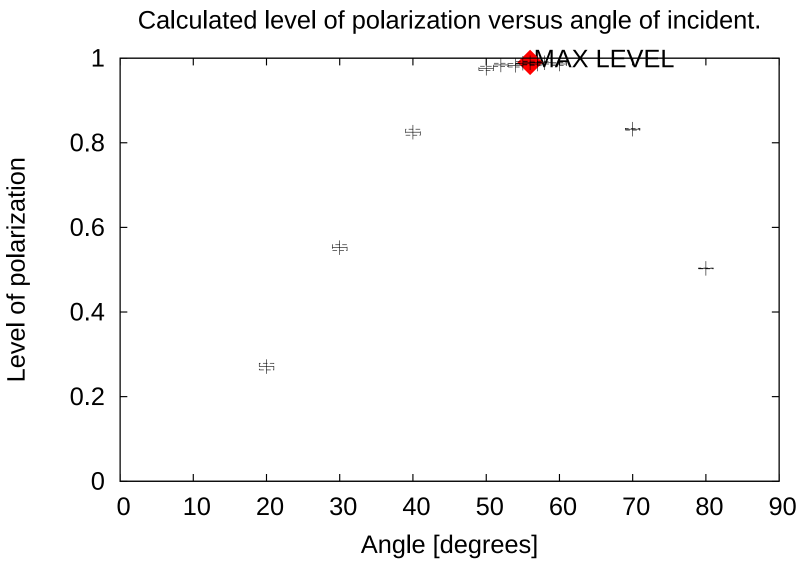

Figure 6: Calculated level of polarization K versus angle of incident.