Institut für Physik

Humboldt-Universität zu Berlin

Physical Lab Class II

Protocol of Experiment

O11 – Polarization by Reflection

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1 Description of Experiment and Physical Background

When a beam of light falls on a bounding surface between two media, it will be split into two beams: one refracted on the surface and going through the thicker medium (following the law of refraction) and one reflected on the surface, continuing in the thinner medium. Knowing the laws of refraction

$$n_1 \ \sin(\alpha_\mathrm{e}) = n_2 \ \sin(\alpha_\mathrm{g}), \qquad \text{here: } n_2 > n_1 \tag{1}$$

and reflection ($\alpha_\mathrm{e} = \alpha'_\mathrm{e}$) one can make prognoses for the ways of the beams. Here, n_1 and n_2 are the media's refractive indices, α_e is the angle of incidence, α_g the angle of refraction and α'_e the reflecting angle.
However, the given laws cannot make any assumptions conferring to the light's intensity, why we have to consider the light's polarization. In this experiment, a polarized laser beam fell on the surface of a half cylinder of glass. There it was reflected and refracted. We had to take two series of measurements, in which we measured the voltage on a light sensor, where the reflected beam ended, against the incident angle. For the first series we used a linear polarizer, which polarized the beam perpendicular to the plane of incidence. All quantities referring to this measurement will have an index *s*. In the second series the linear polarizer polarized the light's electric field parallel to the plain of incidence; all those variables will have an index *p*. One of the aims of this experiment is to proof the relation between the incoming angle and the reflectivity of the glass

$$\sqrt{R_\mathrm{s}} = \left|\frac{\sin(\alpha_\mathrm{e} - \alpha_\mathrm{g})}{\sin(\alpha_\mathrm{e} + \alpha_\mathrm{g})}\right| \tag{2}$$

$$\sqrt{R_\mathrm{p}} = \left|\frac{\tan(\alpha_\mathrm{e} - \alpha_\mathrm{g})}{\tan(\alpha_\mathrm{e} + \alpha_\mathrm{g})}\right| \tag{3}$$

and

$$\sqrt{R_\mathrm{i}} = \sqrt{\frac{U_\mathrm{ri}}{U_\mathrm{e}}}, \qquad \mathrm{i} = \mathrm{s, p}. \tag{4}$$

Furthermore, we have to detect Brewster's angle α_B, where the intensity of the reflected beam (and the reflectivity of the glass) is 0, if the incoming beam is polarized parallel to the plane of incidence. At least, we must calculate the refractive index of the cylinder with the equation

$$n_2 = n_1 \cdot \tan(\alpha_\mathrm{B}). \tag{5}$$

More information about the experiment is given in [1], p. 74-77.

2 Measurements and Analysis

2.1 Light's Intensity against the Angle of Incidence

We began the experiment measuring the voltage $U_\mathrm{ri}(\alpha_\mathrm{e})$ on the light sensor with a digital voltmeter. Firstly it was necessary to calibrate the light sensor's gain. With an open blind we set up the measured voltage to zero, to make sure the scattered light will not effect the measurement. The uncertainty of the voltage was given as

$$u_U = 2 \text{ Digits} + 0.03 \cdot U.$$

Using a rotatable light sensor we measured the double angle of incidence whose uncertainty is

$$u_\alpha = 0.5°,$$

why the uncertainty of the incident angle is

$$u_{\alpha_\mathrm{e}} = 0.25°.$$

At first we measured the maximum voltage without the half cylinder, and get

$$U_\mathrm{e} = (4.9 \pm 0.2) \text{ V},$$

so we can calculate the squareroot of reflectivity using the equation (4). The reflectivity's uncertainty is calculated with the Gaussian error propagation to

$$u_{\sqrt{R_\mathrm{i}}} = \sqrt{\left(u_{U_\mathrm{r}} \frac{\partial \sqrt{Ri}}{\partial U_\mathrm{r}}\right)^2 + \left(u_{U_\mathrm{e}} \frac{\partial \sqrt{Ri}}{\partial U_\mathrm{e}}\right)^2}.$$

You can find the partial derivatives in 5.1.1. From these calculations we get the following table 1.

		perpendicular polarization				parallel polarization			
α_e [°]	u_{α_e} [°]	U_rs [V]	u_{U_rs} [V]	$\sqrt{R_\mathrm{s}}$	$u_{\sqrt{R_\mathrm{s}}}$	U_rp [V]	u_{U_rp} [V]	$\sqrt{R_\mathrm{p}}$	$u_{\sqrt{R_\mathrm{p}}}$
5.0	0.25	0.77	0.03	0.40	0.01	0.78	0.03	0.40	0.01
7.5	0.25	0.70	0.02	0.38	0.01	0.76	0.02	0.39	0.01
10.0	0.25	0.76	0.02	0.40	0.01	0.84	0.03	0.41	0.01
12.5	0.25	0.81	0.03	0.41	0.01	0.80	0.03	0.40	0.01
15.0	0.25	0.88	0.03	0.43	0.01	0.79	0.03	0.40	0.01
17.5	0.25	0.87	0.03	0.42	0.01	0.68	0.02	0.37	0.01
20.0	0.25	0.95	0.03	0.44	0.01	0.62	0.02	0.36	0.01
22.5	0.25	0.96	0.03	0.44	0.01	0.60	0.02	0.35	0.01
25.0	0.25	1.05	0.03	0.47	0.01	0.59	0.02	0.35	0.01
27.5	0.25	1.11	0.04	0.48	0.01	0.56	0.02	0.34	0.01
30.0	0.25	1.18	0.04	0.49	0.01	0.54	0.02	0.33	0.01
32.5	0.25	1.23	0.04	0.50	0.01	0.49	0.02	0.32	0.01
35.0	0.25	1.37	0.04	0.53	0.01	0.44	0.02	0.30	0.01
37.5	0.25	1.42	0.04	0.54	0.01	0.36	0.01	0.27	0.01
40.0	0.25	1.61	0.05	0.57	0.01	0.28	0.01	0.24	0.01
42.5	0.25	1.69	0.05	0.59	0.01	0.220	0.009	0.21	0.01
45.0	0.25	1.85	0.06	0.62	0.01	0.125	0.006	0.160	0.005
47.5	0.25	2.08	0.06	0.65	0.02	0.119	0.006	0.156	0.005
50.0	0.25	2.21	0.07	0.67	0.02	0.053	0.004	0.104	0.004
52.5	0.25	2.31	0.07	0.69	0.02	0.025	0.003	0.072	0.004
54.5	**0.25**	-	-	-	-	**0.008**	**0.002**	**0.04**	**0.01**
55.0	**0.25**	2.77	0.09	0.75	0.02	**0.006**	**0.002**	**0.04**	**0.01**
56.0	**0.25**	-	-	-	-	**0.010**	**0.002**	**0.05**	**0.01**
57.5	0.25	2.98	0.09	0.78	0.02	0.021	0.003	0.066	0.004
60.0	0.25	3.5	0.1	0.85	0.02	0.075	0.004	0.124	0.004
62.5	0.25	4.0	0.1	0.90	0.02	0.208	0.008	0.21	0.01
65.0	0.25	4.4	0.2	0.95	0.02	0.44	0.02	0.30	0.01
67.5	0.25	4.9	0.2	1.00	0.02	0.73	0.02	0.39	0.01
70.0	0.25	4.9	0.2	1.00	0.02	1.30	0.04	0.52	0.01
72.5	0.25	4.9	0.2	1.00	0.02	2.13	0.07	0.66	0.02
75.0	0.25	4.9	0.2	1.00	0.02	3.1	0.1	0.80	0.02
77.5	0.25	4.9	0.2	1.00	0.02	4.7	0.2	0.99	0.02
80.0	0.25	4.9	0.2	1.00	0.02	4.9	0.2	1.00	0.02
82.5	0.25	4.9	0.2	1.00	0.02	4.9	0.2	1.00	0.02
85.0	0.25	4.9	0.2	1.00	0.02	4.9	0.2	1.00	0.02

Table 1: Voltage and Reflectivity

Here you can see that the voltage and the reflectivity is constant for high angles. Probably the measured maximum voltage is wrong, but we will compare it with the theoretical curve in section 2.4 and discuss this comparison in section 3. A graphical analysis in QtiPlot delivers figure 1. Note that the mentioned values are not displayed in the figure.

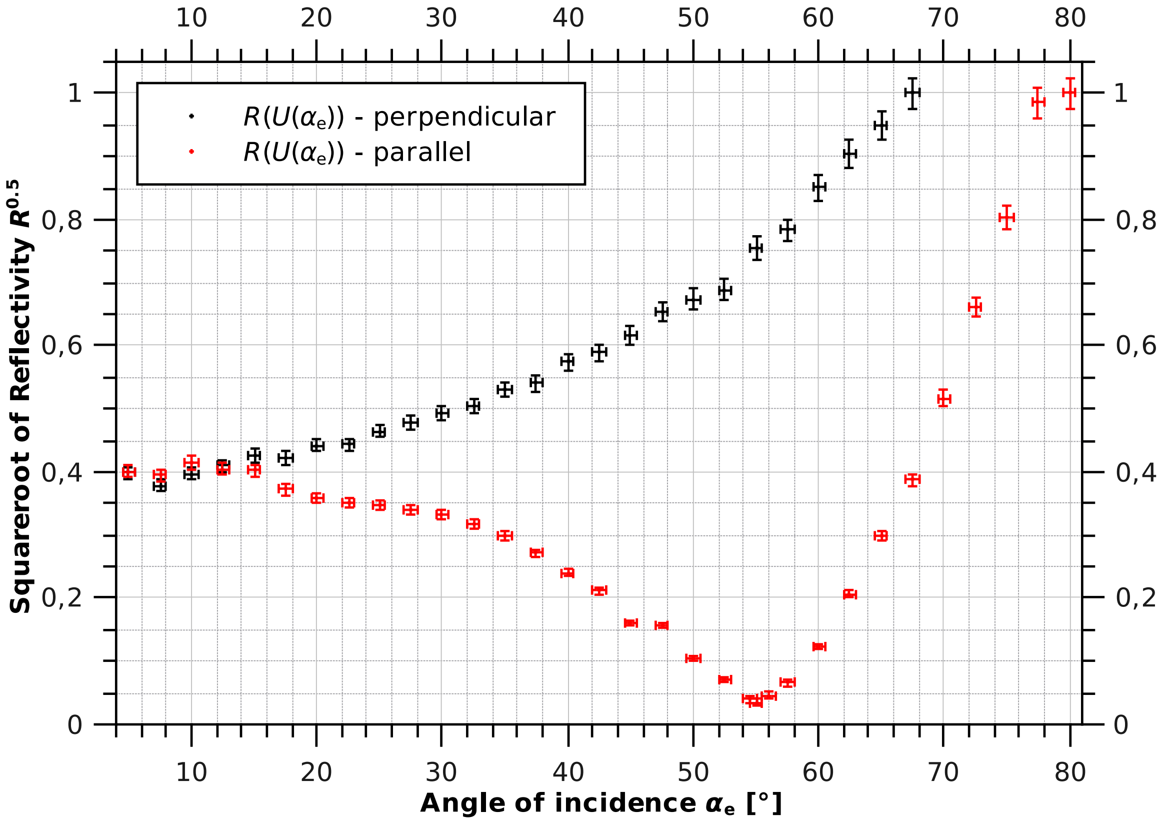

Figure 1: Reflectivity against incident angle

2.2 Brewster's angle

According to figure 1 and table 1 Brewster's angle is valid for

$$55.0^\circ < \alpha_B < 56.0^\circ.$$

Due to that and the uncertainty of α_e we estimate Brewster's angle as

$$\alpha_B = (55.5 \pm 1.0)^\circ.$$

2.3 Half Cylinder's Refractive Index

According to [3] the refractive index of air is $n_1 = 1.00029$. Now we are able to calculate the half cylinder's refractive index by using equation (5). The quantity's uncertainty is given by $u_{n_2} = u_{\alpha_B} \cdot \left| \frac{\partial n_2}{\partial \alpha_B} \right| = u_{\alpha_B} \frac{1}{\cos^2 \alpha_B}$ why the final result is

$$n_2 = 1.46 \pm 0.06.$$

2.4 Theoretical Reflectivity through Refractive Angle

After detecting the reflectivity by measuring the light's intensity, we want to check our results by calculating the theoretical curves using equations (2) and (3). Therefore it is necessary to know α_g, which is given by the law of refraction (1) as

$$\alpha_g = \arcsin\left(\frac{n_1}{n_2}\ \sin(\alpha_e)\right)$$

and its uncertainty, using the Gaussian error propagation

$$u_{\alpha_g} = \sqrt{\left(u_{n_2} \frac{\partial \alpha_g}{\partial n_2}\right)^2 + \left(u_{\alpha_e} \frac{\partial \alpha_g}{\partial \alpha_e}\right)^2},$$

the partial derivatives are placed in section 5.1.2. Knowing the angle of refraction it is possible to calculate the squareroot of reflectivity. But it is also necessary to detect the uncertainties, which are again given by the Gaussian error propagation:

$$u_{\sqrt{R_\mathrm{s}}} = \sqrt{\left(u_{\alpha_\mathrm{e}} \frac{\partial \sqrt{R_\mathrm{s}}}{\partial \alpha_\mathrm{e}}\right)^2 + \left(u_{\alpha_\mathrm{g}} \frac{\partial \sqrt{R_\mathrm{s}}}{\partial \alpha_\mathrm{g}}\right)^2}, \text{ and}$$

$$u_{\sqrt{R_\mathrm{p}}} = \sqrt{\left(u_{\alpha_\mathrm{e}} \frac{\partial \sqrt{R_\mathrm{p}}}{\partial \alpha_\mathrm{e}}\right)^2 + \left(u_{\alpha_\mathrm{g}} \frac{\partial \sqrt{R_\mathrm{p}}}{\partial \alpha_\mathrm{g}}\right)^2}.$$

Again, you will find the partial derivates in the appendix (5.1.3). Now we get the results of table 2.

				perpendicular		parallel	
α_e [°]	u_{α_e} [°]	α_g [°]	u_{α_g} [°]	$\sqrt{R_\mathrm{s}}$	$u_{\sqrt{R_\mathrm{s}}}$	$\sqrt{R_\mathrm{p}}$	$u_{\sqrt{R_\mathrm{s}}}$
5.0	0.25	3.4	0.4	0.19	0.08	0.18	0.08
7.5	0.25	5.1	0.4	0.19	0.05	0.18	0.05
10.0	0.25	6.9	0.4	0.19	0.04	0.18	0.04
12.5	0.25	8.6	0.5	0.19	0.03	0.18	0.03
15.0	0.25	10.2	0.5	0.19	0.03	0.18	0.03
17.5	0.25	11.9	0.6	0.2	0.03	0.17	0.02
20.0	0.25	13.6	0.6	0.2	0.02	0.17	0.02
22.5	0.25	15.2	0.7	0.21	0.02	0.16	0.02
25.0	0.25	16.9	0.7	0.21	0.02	0.16	0.02
27.5	0.25	18.5	0.8	0.22	0.02	0.15	0.01
30.0	0.25	20.1	0.8	0.22	0.02	0.15	0.01
32.5	0.25	21.7	0.9	0.23	0.02	0.14	0.01
35.0	0.25	23.2	1.0	0.24	0.02	0.13	0.01
37.5	0.25	24.7	1.0	0.25	0.02	0.12	0.01
40.0	0.25	26.2	1.1	0.26	0.02	0.11	0.01
42.5	0.25	27.7	1.2	0.27	0.02	0.10	0.01
45.0	0.25	29.1	1.2	0.29	0.02	0.08	0.01
47.5	0.25	30.4	1.3	0.3	0.02	0.07	0.01
50.0	0.25	31.8	1.4	0.32	0.02	0.05	0.01
52.5	0.25	33.0	1.4	0.33	0.02	0.03	0.01
54.5	0.25	34.0	1.5	-	-	0.01	0.01
55.0	0.25	34.3	1.5	0.35	0.03	0.00	0.01
56.0	0.25	34.7	1.5	-	-	0.00	0.01
57.5	0.25	35.4	1.5	0.38	0.03	0.02	0.01
60.0	0.25	36.5	1.6	0.40	0.03	0.05	0.02
62.5	0.25	37.6	1.7	0.43	0.03	0.08	0.02
65.0	0.25	38.5	1.7	0.46	0.03	0.12	0.02
67.5	0.25	39.4	1.8	0.49	0.03	0.16	0.03
70.0	0.25	40.2	1.8	0.53	0.04	0.21	0.04
72.5	0.25	41.0	1.9	0.57	0.04	0.27	0.04
75.0	0.25	41.6	1.9	0.62	0.04	0.33	0.05
77.5	0.25	42.1	1.9	0.67	0.04	0.40	0.06
80.0	0.25	42.6	2.0	0.72	0.05	0.49	0.07
82.5	0.25	43.0	2.0	0.78	0.05	0.59	0.09
85.0	0.25	43.2	2.0	0.85	0.06	0.7	0.1

Table 2: Reflectivity against refractive angle

A graphical analysis in QtiPlot delivers figure 1.

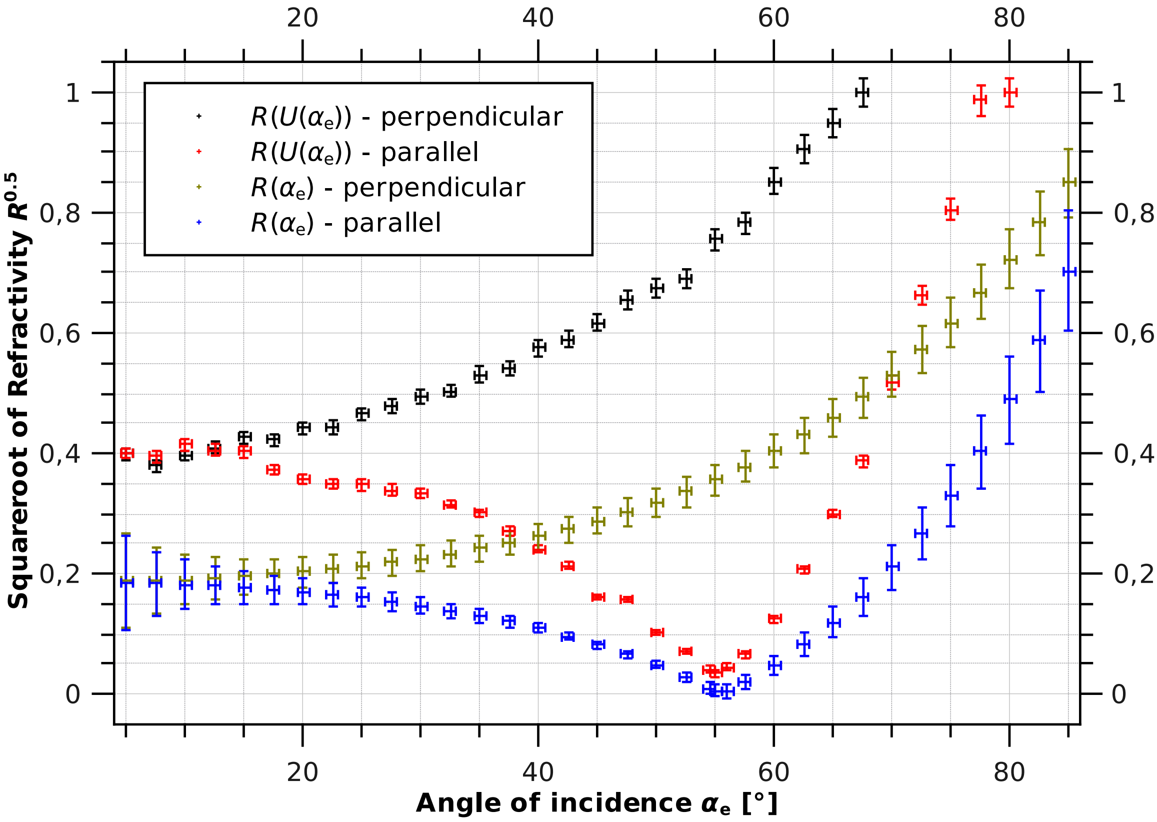

Figure 2: Theoretical and experimental results

3 Discussion and Possible Sources of Error

As you can see in figure 1, the measured voltages are pending for small angles. This can be explained by the fact, that in this region the light sensor was vis-á-vis the room's window, whose jalousie was partly open. I guess the scattered light from this direction was higher than the measured value at the beginning of the experiment. Apparently the light sensor is not good enough to filter out scattering light.

Furthermore the experimental curves are extended by a factor 2 in comparison to the theoretical curves (figure2) . That is why I guess the maximum voltage to be round about a quadrupel of the measured value $U_e = 4.9\,\mathrm{V}$. This assumption is supported by the fact that the intensity is constant for high angles. Probably the light sensor was too sensitive for high intensities.

However, the detection of Brewster's angle should not be effected by the extended squareroot of reflectivity because the multiplication by 2 only effects the ordinate coordinates. In spite of the wrong maximum voltage we can assume the detected Brewster's angle $\alpha_B = 55.5°$ as correct within its uncertainty $u_{\alpha_B} = 1.0°$.

Considering the calculated refractive index $n_2 = 1.46 \pm 0.06$, I guess the half cylinder was made from crown glass ($n_C \approx 1.5$) or polymethyl methacrylate (plexiglas, $n_P \approx 1.49$).

To get more solid results I recommend to use an AC voltage light sensor and a laser which switches off and on with a frequency. Using this arrangement, scattering light would not have such a big effect on the measurements.

4 References

[1] Script: "Physikalisches Grundpraktikum - Elektrodynamik und Optik" by Dr. Uwe Müller, Berlin 2005

[2] Script: "Physikalisches Grundpraktikum - Einführung in die Messung, Auswertung und Darstellung experimenteller Ergebnisse in der Physik" by Dr. Uwe Müller, Berlin 2007

[3] "Luft" - http://de.wikipedia.org/wiki/Luft#Andere, Wikipedia Foundation, 11/07/2009

5 Appendix

5.1 Partial Derivatives

5.1.1 Reflectivity against Voltage

$$\sqrt{R} = \sqrt{\frac{U_\mathrm{r}}{U_\mathrm{e}}}$$

$$\frac{\partial\sqrt{R}}{\partial U_\mathrm{r}} = \frac{1}{2}\sqrt{\frac{1}{U_\mathrm{r}U_\mathrm{e}}}$$

$$\frac{\partial\sqrt{R}}{\partial U_\mathrm{e}} = -\frac{1}{2}\sqrt{\frac{U_\mathrm{r}}{U_\mathrm{r}^3}}$$

5.1.2 Angle of Refraction against Refractive Index of Glass and Angle of Incidence

$$\alpha_\mathrm{g} = \arcsin\left(\frac{n_1}{n_2}\ \sin(\alpha_\mathrm{e})\right)$$

$$\frac{\partial\alpha_\mathrm{g}}{\partial\alpha_\mathrm{e}} = \frac{n_1\cos(\alpha_\mathrm{e})}{n_2\ \sqrt{1-\frac{n_1^2\ \sin^2(\alpha_\mathrm{e})}{n_2^2}}}$$

$$\frac{\partial\alpha_\mathrm{g}}{\partial n_2} = -\frac{n_1\sin(\alpha_\mathrm{e})}{n_2^2\ \sqrt{1-\frac{n_1^2\ \sin^2(\alpha_\mathrm{e})}{n_2^2}}}$$

5.1.3 Reflectivity against Angle of Incidence and Angle of Refraction

$$\sqrt{R_\mathrm{s}} = \frac{\sin(\alpha_\mathrm{e}-\alpha_\mathrm{g})}{\sin(\alpha_\mathrm{e}+\alpha_\mathrm{g})}$$

$$\frac{\partial\sqrt{R_\mathrm{s}}}{\partial\alpha_\mathrm{e}} = \frac{\sin(2\alpha_\mathrm{g})}{\sin^2(\alpha_\mathrm{e}+\alpha_\mathrm{g})}$$

$$\frac{\partial\sqrt{R_\mathrm{s}}}{\partial\alpha_\mathrm{g}} = -\frac{\sin(2\alpha_\mathrm{e})}{\sin^2(\alpha_\mathrm{e}+\alpha_\mathrm{g})}$$

$$\sqrt{R_\mathrm{p}} = \frac{\tan(\alpha_\mathrm{e}-\alpha_\mathrm{g})}{\tan(\alpha_\mathrm{e}+\alpha_\mathrm{g})}$$

$$\frac{\partial\sqrt{R_\mathrm{p}}}{\partial\alpha_\mathrm{e}} = \frac{\sin(2\alpha_\mathrm{e})\cos(2\alpha_\mathrm{g})}{\cos^2(\alpha_\mathrm{e}-\alpha_\mathrm{g})\sin^2(\alpha_\mathrm{e}+\alpha_\mathrm{g})}$$

$$\frac{\partial\sqrt{R_\mathrm{p}}}{\partial\alpha_\mathrm{g}} = \frac{\sin(2\alpha_\mathrm{g})\cos(2\alpha_\mathrm{e})}{\cos^2(\alpha_\mathrm{e}-\alpha_\mathrm{g})\sin^2(\alpha_\mathrm{e}+\alpha_\mathrm{g})}$$

5.2 Data Record

Messdatenprotokoll O11 – Polarisation durch Reflexion

Tobias Perna, 528983
Benjamin Maier, 529225
27.10.09
Versuchsplatz 1

Spannungsfehler 2 digit + 3% * MW

Startspannung
U_es [V] 4,860 0,1658

2*\alpha_e [°]	\alpha_e [°]	u_\alpha_e [°]	\alpha_e [rad]	u_\alpha_e [rad]	U_rs [V]	Messbereich	u_U_rs [V]		
10	5,0	0,5	0,09	0,01	0,773	0,001	0,0252	4,860	0,4
15	7,5	0,5	0,13	0,01	0,699	0,001	0,0230	4,860	0,38
20	10,0	0,5	0,17	0,01	0,764	0,001	0,0249	4,860	0,4
25	12,5	0,5	0,22	0,01	0,814	0,001	0,0264	4,860	0,41
30	15,0	0,5	0,26	0,01	0,884	0,001	0,0285	4,860	0,43
35	17,5	0,5	0,31	0,01	0,867	0,001	0,0280	4,860	0,42
40	20,0	0,5	0,35	0,01	0,951	0,001	0,0305	4,860	0,44
45	22,5	0,5	0,39	0,01	0,956	0,001	0,0307	4,860	0,44
50	25,0	0,5	0,44	0,01	1,051	0,001	0,0335	4,860	0,47
55	27,5	0,5	0,48	0,01	1,109	0,001	0,0353	4,860	0,48
60	30,0	0,5	0,52	0,01	1,182	0,001	0,0375	4,860	0,49
65	32,5	0,5	0,57	0,01	1,234	0,001	0,0390	4,860	0,5
70	35,0	0,5	0,61	0,01	1,372	0,001	0,0432	4,860	0,53
75	37,5	0,5	0,65	0,01	1,422	0,001	0,0447	4,860	0,54
80	40,0	0,5	0,7	0,01	1,605	0,001	0,0502	4,860	0,57
85	42,5	0,5	0,74	0,01	1,685	0,001	0,0526	4,860	0,59
90	45,0	0,5	0,79	0,01	1,847	0,001	0,0574	4,860	0,62
95	47,5	0,5	0,83	0,01	2,080	0,001	0,0644	4,860	0,65
100	50,0	0,5	0,87	0,01	2,208	0,001	0,0682	4,860	0,67
105	52,5	0,5	0,92	0,01	2,306	0,001	0,0712	4,860	0,69
110	55,0	0,5	0,96	0,01	2,767	0,001	0,0850	4,860	0,75
115	57,5	0,5	1	0,01	2,983	0,001	0,0915	4,860	0,78
120	60,0	0,5	1,05	0,01	3,520	0,010	0,1256	4,860	0,85
125	62,5	0,5	1,09	0,01	3,980	0,010	0,1394	4,860	0,9
130	65,0	0,5	1,13	0,01	4,370	0,010	0,1511	4,860	0,95
135	67,5	0,5	1,18	0,01	4,860	0,010	0,1658	4,860	1
140	70,0	0,5	1,22	0,01	4,860	0,010	0,1658	4,860	1
145	72,5	0,5	1,27	0,01	4,860	0,010	0,1658	4,860	1
150	75,0	0,5	1,31	0,01	4,860	0,010	0,1658	4,860	1
155	77,5	0,5	1,35	0,01	4,860	0,010	0,1658	4,860	1
160	80,0	0,5	1,4	0,01	4,860	0,010	0,1658	4,860	1
165	82,5	0,5	1,44	0,01	4,860	0,010	0,1658	4,860	1
170	85,0	0,5	1,48	0,01	4,860	0,010	0,1658	4,860	1

Endspannung Offsetunterschied
U_es [V] 4,86 0,1658 0 V

Startspannung		
U_es [V]	4,86	0,1658

2*\alpha_e [°]	\alpha_e [°]	u_\alpha_e [°]	\alpha_e [rad]	u_\alpha_e [rad]	U_rs [V]	Messbereich	u_U_rs [V]
10	5,0	0,5	0,09	0,01	0,778	0,001	0,0253
15	7,5	0,5	0,13	0,01	0,758	0,001	0,0247
20	10,0	0,5	0,17	0,01	0,835	0,001	0,0271
25	12,5	0,5	0,22	0,01	0,797	0,001	0,0259
30	15,0	0,5	0,26	0,01	0,786	0,001	0,0256
35	17,5	0,5	0,31	0,01	0,676	0,001	0,0223
40	20,0	0,5	0,35	0,01	0,624	0,001	0,0207
45	22,5	0,5	0,39	0,01	0,597	0,001	0,0199
50	25,0	0,5	0,44	0,01	0,587	0,001	0,0196
55	27,5	0,5	0,48	0,01	0,560	0,001	0,0188
60	30,0	0,5	0,52	0,01	0,538	0,001	0,0181
65	32,5	0,5	0,57	0,01	0,485	0,001	0,0166
70	35,0	0,5	0,61	0,01	0,439	0,001	0,0152
75	37,5	0,5	0,65	0,01	0,357	0,001	0,0127
80	40,0	0,5	0,7	0,01	0,280	0,001	0,0104
85	42,5	0,5	0,74	0,01	0,220	0,001	0,0086
90	45,0	0,5	0,79	0,01	0,125	0,001	0,0058
95	47,5	0,5	0,83	0,01	0,119	0,001	0,0056
100	50,0	0,5	0,87	0,01	0,053	0,001	0,0036
105	52,5	0,5	0,92	0,01	0,025	0,001	0,0028
110	55,0	0,5	0,96	0,01	0,006	0,001	0,0022
109					0,008		
112					0,010		
115	57,5	0,5	1	0,01	0,021	0,001	0,0026
120	60,0	0,5	1,05	0,01	0,075	0,001	0,0043
125	62,5	0,5	1,09	0,01	0,208	0,001	0,0082
130	65,0	0,5	1,13	0,01	0,437	0,001	0,0151
135	67,5	0,5	1,18	0,01	0,731	0,001	0,0239
140	70,0	0,5	1,22	0,01	1,299	0,001	0,0410
145	72,5	0,5	1,27	0,01	2,133	0,001	0,0660
150	75,0	0,5	1,31	0,01	3,145	0,001	0,0964
155	77,5	0,5	1,35	0,01	4,720	0,010	0,1616
160	80,0	0,5	1,4	0,01	4,860	0,001	0,1478
165	82,5	0,5	1,44	0,01	4,860	0,001	0,1478
170	85,0	0,5	1,48	0,01	4,860	0,001	0,1478

Endspannung U_es [V]	4,86	0,1658
Brewsterwinkel	55,0	0,96
n2	1,4	