Pogany 1928

The apparatus kindly provided by the Carl Zeiss company was set up in Budapest with the support of the Elizabeth Thompson Science Fund. Both institutions deserve my heartfelt thanks. In a previous publication, I reported on the repetition of the Sagnac experiment. In this experiment, a mirror polygon is used. The light reflected on this propagates along a closed polygonal path. The light beam introduced into the apparatus is separated into two coherent beams by a semi-transparent silver layer, which, after traversing the polygonal light path in opposite directions, are brought to interference. Now, if the mirror polygon rotates, the interference fringes shift relative to their rest position by an amount measured in stripe widths of

$$\Delta = 4\omega F/\lambda c \ ,$$

where ω is the angular velocity of rotation, F is the enclosed area of the light path, λ is the wavelength of light measured in vacuum, and c is the speed of light in vacuum.

Comparing the position of the interference fringes during clockwise rotation with that during counterclockwise rotation results in a fringe shift that reaches twice the above amount, thus

$$\Delta = 8\omega F/\lambda c \ ,$$

In the Sagnac experiment, the polygonal light path is in air. However, formula (2) holds for any medium, and as can be seen, the fringe shift cannot change if the light path is wholly or partially shifted into a more refractive substance, such as glass or water, since the refractive index does not appear in (2).

The Harress experiment, which preceded the Sagnac experiment, differs from the latter precisely in that in the Harress apparatus, the light path was in glass. In my initial attempts to repeat the Harress-Sagnac experiment with greater precision, I also started from the Harress arrangement. From this, the apparatus described in the previous publication emerged, with which I also carried out the measurements reported there. In the mentioned measurements, the two interfering light beams propagated in air, so the experiment was actually a repetition of the Sagnac experiment. However, the apparatus was built so that more refractive substances could be inserted into the light path. In the original Harress apparatus, the crown consisting of 10 glass prisms served not only to accommodate the light path, but one side of each prism was used as a mirror, and therein lay the greatest disadvantage of the arrangement. The prisms of relatively large mass deformed under the influence of centrifugal force during rotation, and their reflecting surfaces astigmatically reflected the light. When conducting the light path in glass, this error can be avoided by using right-angled glass parallelepipeds, through which the light enters and exits perpendicularly through opposite parallel surfaces. Such glass bodies could be installed in the apparatus I used to repeat the Sagnac experiment, between mirrors S_1 and S_2, or S_3 and S_4, (Fig. 1).

With these approximately 32 cm long glass bodies, there was a concern that they would bend due to the influence of centrifugal force. If the end faces are no longer parallel, they act as prisms and deflect the light. Therefore, in my initial attempts, instead of glass bodies, liquid chambers with rubber walls were used, which were closed at both ends with thick, parallel glass plates. The steel frames of the closing glass plates were attached to the base or cover plate of the apparatus with thick cones, and the thick-walled rubber tube connecting these frames was supported by a steel tube surrounding the rubber tube and independently attached to the base plate. Thus, the rubber tube could deform only slightly due to centrifugal force, and the stresses arising in it could not exert any relevant torque on the frames of the closing glass plates. In some experiments, lead pipes were used instead of rubber pipes. Unfortunately, the experiments with the liquid chambers yielded no results, although I tried various liquids from alcohol and water through different oils to glycerin. With each liquid filling, the interference fringes changed their width, shape, and orientation continuously, depending on the viscosity of the liquid, so that measurement was out of the question. Some liquids, such as alcohol and water, became opaque due to chemical or electrochemical influences in the chambers, even though the metal parts of the chambers were thickly electroplated with gold on the inside.

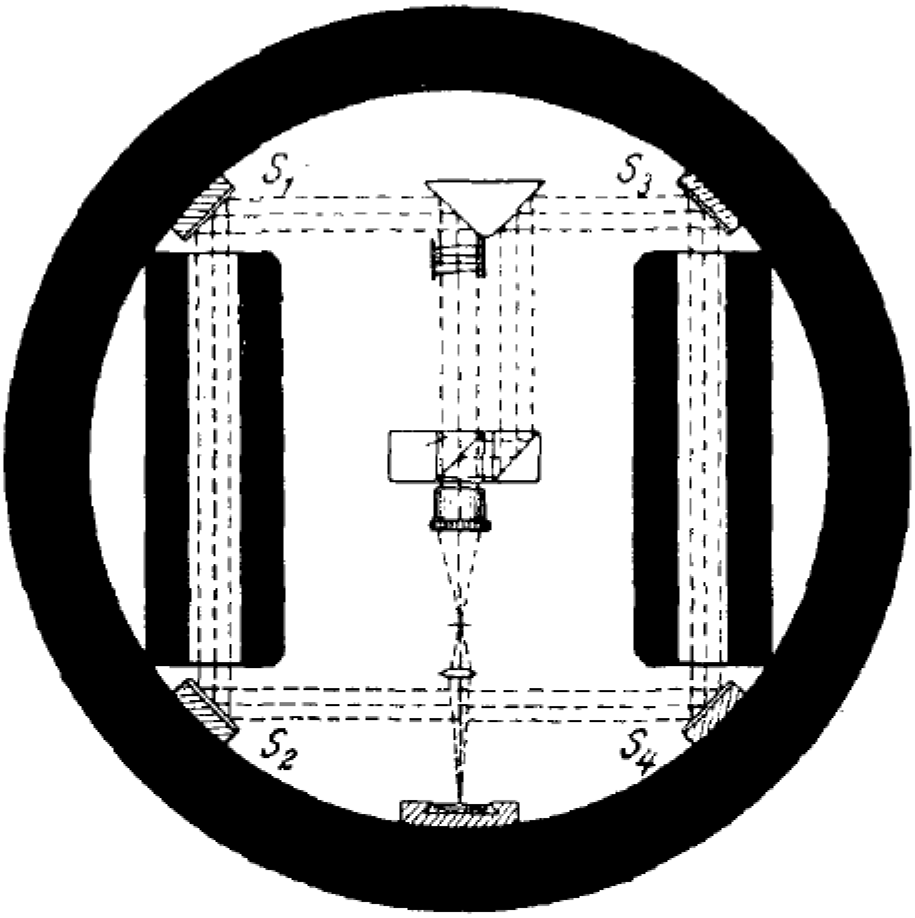

Fig. 1

The steel frames of the closing glass plates were attached to the base or cover plate of the apparatus with thick cones, and the thick-walled rubber tube connecting these frames was supported by a steel tube surrounding the rubber tube and independently attached to the base plate. This allowed the rubber tube to deform only slightly due to centrifugal force, and the stresses arising in it could not exert any relevant torque on the frames of the closing glass plates. In some experiments, lead pipes were used instead of rubber pipes. Unfortunately, the experiments with the liquid chambers yielded no results, although I tried various liquids from alcohol and water through different oils to glycerin. With each liquid filling, the interference fringes changed their width, shape, and orientation continuously, so that measurement was out of the question.

Some liquids, such as alcohol and water, became opaque due to chemical or electrochemical influences in the chambers, even though the metal parts of the chambers were thickly electroplated with gold on the inside. Finally, there was nothing left but to install glass bodies between the mirrors. For this purpose, they were housed in Siemens-Martin steel frames, which were then attached to the base and cover plate of the apparatus by 8 thick cones each. The experiments showed that the glass bodies installed therein withstand rotation. In Fig. 2, Plate X, two images of the stripe system in opposite directions of rotation and at 1500 revolutions per minute can be seen. The resulting stripe shift is approximately 0.9 stripe widths. The measurement results are found in the tables below.

T is the duration of one revolution, T′ is the mean value for two consecutive combined images, b and b′ are the stripe widths.

Tabelle 1

24. März 1927

Platten Nr.	T_{sec}	$\bar{T}_{\text{sec}}$	b_{mm}	$\bar{b}_{\text{mm}}$	X_0	$\frac{X_{01} - X_{02}}{\bar{b}} = \Delta_{\bar{T}}$	Δ
63	0,0500		1,882		11,176		
		0,0499		1,891		$\frac{1,258}{1,891} = 0,665$	0,663
64	0,0498		1,900		9,918		
		0,0506		1,907		$\frac{1,311}{1,907} = 0,687$	0,695
65	0,0514		1,915		11,229		
		0,0511		1,925		$\frac{1,374}{1,925} = 0,713$	0,728
66	0,0509		1,936		9,855		
		0,0507		1,938		$\frac{1,413}{1,938} = 0,729$	0,739
67	0,0506		1,941		11,268		
		0,0505		1,948		$\frac{1,407}{1,948} = 0,722$	0,729
68	0,0505		1,955		9,861		
		0,0509		1,956		$\frac{1,346}{1,956} = 0,688$	0,700
69	0,0513		1,958		11,207		
						Mittel:	0,709

Tabelle 2

25. März 1927

Platten Nr.	T_{sec}	$\overline{T}_{\text{sec}}$	b_{mm}	$\overline{b}_{\text{mm}}$	X_0	$\frac{X_{01}-X_{02}}{\overline{b}} = \Delta_{\overline{T}}$	Δ
70	0,0500		1,869		7,856		
		0,0498		1,883		$\frac{1,398}{1,883} = 0,742$	0,739
71	0,0496		1,897		9,254		
		0,0499		1,898		$\frac{1,338}{1,898} = 0,705$	0,703
72	0,0502		1,899		7,916		
		0,0500		1,909		$\frac{1,361}{1,909} = 0,713$	0,713
73	0,0498		1,920		9,277		
		0,0500		1,928		$\frac{1,424}{1,928} = 0,738$	0,738
74	0,0502		1,936		7,853		
		0,0502		1,934		$\frac{1,412}{1,934} = 0,730$	0,733
75	0,0503		1,933		9,265		
		0,0502		1,943		$\frac{1,455}{1,943} = 0,749$	0,752
76	0,0501		1,954		7,810		
		0,0500		1,946		$\frac{1,451}{1,946} = 0,745$	0,745
77	0,0499		1,938		9,261		

Mittel: 0,732

Tabelle 3

26. März 1927

Platten Nr.	T_{sec}	$\bar{T}_{sec}$	b_{mm}	$\bar{b}_{mm}$	X_0	$\frac{X_{01} - X_{02}}{b} = \Delta_{\bar{T}}$	Δ
78	0,0495		1,868		−3,721		
		0,0495		1,880		$\frac{1,292}{1,880} = 0,687$	0,680
79	0,0496		1,892		−5,013		
		0,0496		1,898		$\frac{1,329}{1,898} = 0,700$	0,694
80	0,0496		1,904		−3,684		
		0,0494		1,915		$\frac{1,387}{1,915} = 0,724$	0,715
81	0,0493		1,926		−5,071		
		0,0496		1,928		$\frac{1,359}{1,928} = 0,705$	0,699
82	0,0499		1,931		−3,712		
		0,0498		1,930		$\frac{1,354}{1,930} = 0,701$	0,698
83	0,0498		1,930		−5,066		
		0,0496		1,938		$\frac{1,378}{1,938} = 0,711$	0,705
84	0,0494		1,946		−3,688		
		0,0493		1,949		$\frac{1,497}{1,949} = 0,768$	0,757
85	0,0493		1,953		−5,185		
		0,0492		1,949		$\frac{1,485}{1,949} = 0,762$	0,750
86	0,0492		1,946		−3,700		

Mittel: 0,712

Tabelle 4

29. April 1927

Platten Nr.	T_{sec}	$\bar{T}_{sec}$	b_{mm}	$\bar{b}_{mm}$	X_0	$\frac{X_{01}-X_{02}}{\bar{b}} = \Delta_{\bar{T}}$	Δ
96	0,0396		2,326		−5,529		
		0,0398		2,328		$\frac{2,117}{2,328} = 0,909$	0,904
97	0,0401		2,330		−3,412		
		0,0397		2,363		$\frac{2,209}{2,363} = 0,935$	0,928
98	0,0394		2,397		−5,621		
		0,0393		2,391		$\frac{2,202}{2,391} = 0,921$	0,905
99	0,0392		2,385		−3,419		
		0,0398		2,394		$\frac{2,044}{2,394} = 0,854$	0,850
100	0,0405		2,403		−5,463		
		0,0402		2,409		$\frac{2,097}{2,409} = 0,870$	0,874
101	0,0399		2,416		−3,366		
		0,0400		2,415		$\frac{2,200}{2,415} = 0,911$	0,911
102	0,0400		2,415		−5,566		
		0,0401		2,419		$\frac{2,194}{2,419} = 0,907$	0,909
103	0,0402		2,419		−3,372		
						Mittel:	0,897

Tabelle 5

3. Juni 1927

Platten Nr.	T_{sec}	$\bar{T}_{sec}$	b_{mm}	$\bar{b}_{mm}$	X_0	$\frac{X_{01}-X_{02}}{\bar{b}} = \Delta_{\bar{T}}$	Δ
106	0,0395		2,559		−5,665		
		0,0396		2,555		$\frac{2{,}379}{2{,}555} = 0{,}931$	0,921
107	0,0397		2,552		−3,286		
		0,0398		2,566		$\frac{2{,}326}{2{,}566} = 0{,}906$	0,901
108	0,0399		2,580		−5,612		
		0,0400		2,587		$\frac{2{,}348}{2{,}587} = 0{,}907$	0,908
109	0,0402		2,595		−3,264		
		0,0399		2,592		$\frac{2{,}377}{2{,}592} = 0{,}917$	0,915
110	0,0396		2,590		−5,641		
						Mittel:	0,911

Tabelle 6

4. Juni 1927

Platten Nr.	T_{sec}	$\bar{T}_{sec}$	b_{mm}	$\bar{b}_{mm}$	X_0	$\frac{X_{01}-X_{02}}{\bar{b}} = \Delta_{\bar{T}}$	Δ
112	0,0393		2,678		−3,621		
		0,0396		2,673		$\frac{2,456}{2,673} = 0,919$	0,910
113	0,0398		2,669		−6,077		
		0,0398		2,692		$\frac{2,469}{2,692} = 0,917$	0,912
114	0,0398		2,715		−3,608		
		0,0398		2,715		$\frac{2,482}{2,715} = 0,914$	0,909
115	0,0399		2,715		−6,090		
		0,0402		2,722		$\frac{2,422}{2,722} = 0,890$	0,894
116	0,0404		2,729		−3,668		
		0,0400		2,718		$\frac{2,302}{2,718} = 0,847$	0,847
117	0,0395		2,706		−5,970		
		0,0396		2,721		$\frac{2,459}{2,721} = 0,903$	0,894
118	0,0396		2,737		−3,511		
		0,0397		2,746		$\frac{2,559}{2,746} = 0,932$	0,925
119	0,0397		2,756		−6,070		
						Mittel:	0,898

Mittel: 0,898

Tabelle 7

5. Juni 1927

Platten Nr.	T_{sec}	$\bar{T}_{sec}$	b_{mm}	$\bar{b}_{mm}$	X_0	$\frac{X_{01}-X_{02}}{\bar{b}} = \Delta_{\bar{T}}$	Δ
126	0,0402		2,602		−3,491		
		0,0400		2,593		$\frac{2,292}{2,593} = 0,884$	0,884
127	0,0398		2,584		−5,783		
		0,0397		2,602		$\frac{2,377}{2,602} = 0,913$	0,906
128	0,0396		2,621		−3,406		
		0,0396		2,619		$\frac{2,379}{2,619} = 0,908$	0,899
129	0,0396		2,618		−5,785		
		0,0398		2,628		$\frac{2,377}{2,628} = 0,904$	0,899
130	0,0399		2,639		−3,408		
		0,0399		2,643		$\frac{2,405}{2,643} = 0,910$	0,908
131	0,0398		2,646		−5,813		

Mittel: 0,899

Tabelle 8

17. Juni 1927

Platten Nr.	T_{sec}	$\overline{T}_{\mathrm{sec}}$	b_{mm}	$\overline{b}_{\mathrm{mm}}$	X_0	$\frac{X_{01} - X_{02}}{\overline{b}} = \Delta_{\overline{T}}$	Δ
132	0,0397		3,730		− 6,969		
		0,0397		3,723	·	$\frac{3,345}{3,723} = 0,898$	0,891
133	0,0396		3,716		− 3,624		
		0,0394		3,726		$\frac{3,397}{3,726} = 0,912$	0,898
134	0,0391		3,735		− 7,021		
		0,0397		3,734		$\frac{3,419}{3,734} = 0,916$	0,909
135	0,0402		3,733		− 3,602		
		0,0400		3,754		$\frac{3,423}{3,754} = 0,912$	0,912
136	0,0398		3,775		− 7,025		

Mittel: 0,902

Tabelle 9

Tabelle 9

25. Juni 1927

Platten Nr.	T_{sec}	$\bar{T}_{sec}$	b_{mm}	$\bar{b}_{mm}$	X_0	$\frac{X_{01}-X_{02}}{\bar{b}} = \Delta_{\bar{T}}$	Δ
137	0,0400		1,099		−4,470		
		0,0399		1,103		$\frac{0,985}{1,103} = 0,893$	0,891
138	0,0398		1,106		−3,485		
		0,0399		1,106		$\frac{0,986}{1,106} = 0,891$	0,889
139	0,0401		1,106		−4,471		
		0,0401		1,109		$\frac{0,993}{1,109} = 0,895$	0,897
140	0,0401		1,111		−3,478		
		0,0401		1,113		$\frac{0,997}{1,113} = 0,896$	0,898
141	0,0401		1,114		−4,475		
		0,0401		1,115		$\frac{0,996}{1,115} = 0,893$	0,895
142	0,0400		1,116		−3,479		
		0,0400		1,117		$\frac{1,041}{1,117} = 0,932$	0,932
143	0,0400		1,118		−4,520		
		0,0400		1,118		$\frac{1,042}{1,118} = 0,932$	0,932
144	0,0400		1,118		−3,478		
		0,0399		1,121		$\frac{1,088}{1,121} = 0,971$	0,969
145	0,0398		1,123		−4,566		

Mittel: 0,913

Tabelle 10

28. Juni 1927

Platten Nr.	T_{sec}	$\bar{T}_{sec}$	b_{mm}	$\bar{b}_{mm}$	X_0 .	$\frac{X_{01} - X_{02}}{\bar{b}} = \Delta_{\bar{T}}$	Δ
146	0,0401		1,111		−4,394		
		0,0401		1,111		$\frac{0,987}{1,111} = 0,888$	0,890
147	0,0401		1,110		−3,407		
		0,0400		1,114		$\frac{1,042}{1,114} = 0,935$	0,935
148	0,0399		1,117		−4,449		
		0,0400		1,119		$\frac{1,027}{1,119} = 0,918$	0,918
149	0,0400		1,120		−3,422		
		0,0400		1,121		$\frac{0,993}{1,121} = 0,886$	0,886
150	0,0399		1,121		−4,415		
		0,0400		1,122		$\frac{1,018}{1,122} = 0,907$	0,907
151	0,0400		1,123		−3,397		
		0,0400		1,126		$\frac{1,060}{1,126} = 0,941$	0,941
152	0,0399		1,128		−4,457		
		0,0400		1,127		$\frac{1,031}{1,127} = 0,915$	0,915
153	0,0400		1,126		−3,426		
						Mittel:	0,913

Mittel: 0,913

Tabelle 11

1. Juli 1927

Platten Nr.	T_{sec}	$\bar{T}_{sec}$	b_{mm}	$\bar{b}_{mm}$	X_0	$\frac{X_{01} - X_{02}}{\bar{b}} = \Delta_{\bar{T}}$	Δ
154	0,0402		1,104		−3,406		
		0,0402		1,104		$\frac{0,981}{1,104} = 0,889$	0,893
155	0,0402		1,103		−4,387		
		0,0401		1,105		$\frac{1,016}{1,105} = 0,919$	0,921
156	0,0399		1,107		−3,371		
		0,0399		1,110		$\frac{1,011}{1,110} = 0,911$	0,909
157	0,0399		1,112		−4,382		
		0,0399		1,113		$\frac{1,004}{1,113} = 0,902$	0,900
158	0,0399		1,114		−3,378		
		0,0399		1,117		$\frac{1,035}{1,117} = 0,927$	0,925
159	0,0399		1,120		−4,413		
		0,0400		1,122		$\frac{1,029}{1,122} = 0,917$	0,917
160	0,0401		1,123		−3,384		
		0,0401		1,124		$\frac{1,037}{1,124} = 0,923$	0,925
161	0,0401		1,125		−4,421		

Mittel: 0,913

Tabelle 12

21. Juli 1927

Platten Nr.	T_{sec}	$\bar{T}_{sec}$	b_{mm}	$\bar{b}_{mm}$	X_0	$\frac{X_{01}-X_{02}}{\bar{b}} = \Delta_{\bar{T}}$	Δ
162	0,0395		0,929		−4,271		
		0,0397		0,932		$\frac{0,854}{0,932} = 0,916$	0,909
163	0,0399		0,935		−3,414		
		0,0399		0,934		$\frac{0,830}{0,934} = 0,889$	0,887
164	0,0399		0,933		−4,247		
		0,0399		0,935		$\frac{0,834}{0,935} = 0,892$	0,890
165	0,0399		0,936		−3,413		
		0,0399		0,937		$\frac{0,845}{0,937} = 0,902$	0,900
166	0,0399		0,939		−4,258		
						Mittel:	0,896

Tabelle 13

23. Juli 1927

Platten Nr.	T_{sec}	$\bar{T}_{sec}$	b_{mm}	$\bar{b}_{mm}$	X_0	$\frac{X_{01}-X_{02}}{\bar{b}} = \Delta_{\bar{T}}$	Δ
167	0,0399		0,939		−4,294		
		0,0400		0,941		$\frac{0,880}{0,941} = 0,935$	0,935
168	0,0401		0,942		−3,414		
		0,0401		0,946		$\frac{0,837}{0,946} = 0,885$	0,887
169	0,0400		0,949		−4,251		
		0,0401		0,951		$\frac{0,846}{0,951} = 0,890$	0,892
170	0,0401		0,953		−3,405		
		0,0401		0,955		$\frac{0,860}{0,955} = 0,901$	0,903
171	0,0400		0,957		−4,265		
		0,0401		0,957		$\frac{0,846}{0,957} = 0,884$	0,886
172	0,0401		0,957		−3,419		
		0,0401		0,962		$\frac{0,880}{0,962} = 0,915$	0,917
173	0,0401		0,966		−4,299		
						Mittel:	0,903

In two consecutive shots, the apparatus rotated in opposite directions. When evaluating the plates, the position of the interference fringes was determined in relation to a thread spun together with the stripe system, which was photographed and parallel to the fringes.

If the position of the 0-th interference fringe is denoted as X_0, then the position of the k-th fringe is:

$$X_k = X_0 \pm kb$$

where b represents the fringe width. The values of X_k measured with the Abbe comparator were used to calculate X_0 and b using the method of least squares.

Δ_T represents the displacement measured in fringe widths corresponding to the rotation time T'. Δ corresponds to T = 0.04 seconds, or in Tables 1-3 to T = 0.05 seconds. During the determination of X_k with the comparator, each interference fringe was set ten times. The photographic plate was 20 mm wide, so there were approximately 6-6 fringes from the wider interference fringes and about 19 fringes from the narrower ones on the plate, providing enough equations to determine X_0 and b. As evident from the tables, the fringe width gradually increased during a series of captures, averaging an increase of 0.2% between two consecutive captures, thus influencing the result, depending on which fringe was identified as the 0-th fringe. Apparently, the fringe with a phase difference of 0 remained unchanged in its position relative to the thread despite the slowly increasing fringe width. To determine the 0-th fringe, the fringe systems of consecutive captures were drawn on millimeter paper. The resulting Figure 3 immediately shows the 0-th fringe.

The captures were made using the Heraeus point lamp with the green mercury line λ = 546 nm wavelength, with an exposure duration of 1 minute. For this wavelength and 1500 revolutions per minute, the value according to Formula (2) is:

$$\Delta = 0.906 \ ,$$

and for 1200 revolutions per minute, the value is:

$$\Delta = 0.725 \ ,$$

When compiling the values obtained from each series of captures made consecutively on the same day, so is obtained:

1200 Umdreh. pro Min.		1500 Umdreh. pro Min.	
Δ	$\Delta - \Delta_m$	Δ	$\Delta - \Delta_m$
0,709	−0,009	0,897	−0,007
0,732	+0,014	0,911	+0,007
0,712	−0,006	0,898	−0,006
		0,899	−0,005
		0,902	−0,002
		0,913	+0,009
		0,913	+0,009
		0,913	+0,009
		0,896	−0,008
		0,903	−0,001
		0,904	—
		0,906	+0,002
$\Delta_m = 0{,}718$		$\Delta_m = 0{,}904$	

The obtained mean values agree within 1% of the calculated values.