ON THE MEASUREMENT OF THE INDEX OF REFRACTION BY THE INTERFEROMETER.

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ONE of the simpler applications of the interferometer is that in which the instrument is used for the measurement of the index of refraction. The method, as heretofore presented, is illustrated in Fig. 1, where M is the mirror of the interferometer which is mounted on the movable carriage, and N the thin lamina whose index is to be determined. If M be first adjusted for color fringes then the introduction of N will increase the optical path by the amount $e(\mu - 1)$ where e is the thickness of the lamina N .

Fig. 1.

This increase in path may be measured by counting the number of fringes passed over in restoring the color fringes to the field as seen through N . If n be this number and λ the wave-length of the light used, then,

$$e(\mu - 1) = n\lambda$$

and

$$\mu = 1 + \frac{n\lambda}{e}. \quad (1)$$

Generally, but not necessarily, the light passes through N twice and the above equation becomes,

$$\mu = 1 + \frac{n\lambda}{2e}. \quad (2)$$

The value of n in this case is, of course, twice as great as in equation 1.

The operation of this method may be more fully outlined as follows : *First*, the thickness of the lamina N is carefully measured by

means of a micrometer-screw or optical lever. *Second*, the interferometer is adjusted for color fringes and the lamina is placed in the path of the rays passing to and from the mirror M (Fig. 1) in such a manner as to cut them orthogonally. The mirror M is now advanced until the color fringes appear in the field as seen through N . During the movement of the mirror the number of fringes passed over is counted and the index determined from the data thus secured.

If v = the velocity of light in air,

v' = the velocity of light in the lamina N ,

λ = the wave-length in air of the light used (*e. g.*, Na light),

μ = the index of refraction of N ,

e = the thickness of N ,

n = the number of fringes passed over.

Then $v't = e$, also $vt = e + n\lambda$.

But

$$\frac{vt}{v't} = \frac{v}{v'} = \mu,$$

and hence

$$\mu = \frac{e + n\lambda}{e} = 1 + \frac{n\lambda}{e}. \quad (1)$$

If the light pass through N twice, then,

$$\mu = 1 + \frac{n\lambda}{2e}. \quad (2)$$

The objection to this method lies in the fact that e must be determined by some mechanical device. If the micrometer screw be used there is the liability of compressing the lamina in making the measurement. If on the other hand the optical lever be used a lamina of considerable size and uniformity in thickness must be used. The degree of accuracy of either method of getting e is of course far less than in measuring the retardation by counting fringes.

In the present modification of the old method it is proposed to measure e by means of the same light waves which are used for getting the retardation. The same degree of accuracy is thus had in the determination of all of the terms entering into the final equation.

To accomplish this it is necessary that the lamina be of uniform thickness and that a part of its surface be silvered. The thickness of the silver film is not important, as it is measured and allowed for. To secure uniformity of thickness the lamina is introduced into the path of the interferometer, as shown in Fig. 1. Any inequality in thickness or any strain of any sort is shown by a distortion in the fringes. It is thus very easy to select a lamina of uniform optical structure. Having secured such a lamina it is silvered in the ordinary manner, the silvering being then removed from all of one side and half of the other. It is now pressed against the mirror M as shown in Fig. 2. A gentle pressure is sufficient to make the lamina adhere to the surface of the mirror. Care must be exercised to apply this pressure to the center of the silvered surface S , so that close contact shall be made at this point. In practice it has been found that the fringes, whether chromatic or otherwise, seen from this silvered surface are always circles. This would indicate that the small surface of the lamina is in the form of a concave mirror of very slight curvature.¹

Having the lamina in place there are now three surfaces on which fringes are to be observed, first, from the surface of the mirror M (see Fig. 2) outside of the lamina; second, from the surface M

Fig. 2.

Fig. 3.

through the lamina (P , Fig. 2); third, from the silvered surface of the lamina (S , Fig. 2).

The readings to be taken are as follows: *First*, the chromatic fringes are secured on the mirror M . This will be the position of the ray A , Fig. 3. *Second*, the chromatic fringes are secured from

¹ For circular chromatic fringes see *PHYS. REV.*, Vol. XI., page 310.

the surface of the silver film S . This is the ray C in Fig. 3. The number of fringes counted in passing from M to S is a measure of the thickness of the lamina plus the silver film. *Third*, the count is taken back to M , and lastly the number of fringes is counted until the chromatic fringes are seen coming from M through the lamina. This count gives the retardation due to the lamina.

Fig. 4.

The lamina is now removed and replaced with the silvered side next the mirror as shown in Fig. 4. If now the adjustment be made so as to give the chromatic fringes from the mirror M through

the lamina, and the count be taken from this position (ray D , Fig. 4) until the fringes appear from the silver film (ray E , Fig. 4) the number of fringes passed over gives the thickness of the silver film.

Let :

n_1 = the number of fringes counted in passing from A to C , in Fig. 3.

n_2 = the number of fringes counted in passing from A to B , in Fig. 3.

n_3 = the number of fringes counted in passing from D to E , in Fig. 4.

λ = the wave-length of the light used for getting the fringes.

Then we will have :

$$n_1\lambda = \text{twice the thickness of the lamina and the silver film,}$$

or

$$n_1\lambda = 2(e + e').$$

Also :

$$n_2\lambda = \text{the retardation due to the lamina,}$$

or

$$n_2\lambda = 2e(\mu - 1).$$

Also :

$$n_3\lambda = \text{twice the thickness of the silver film alone,}$$

or

$$n_3\lambda = 2e'.$$

Therefore

$(n_1 - n_3)\lambda =$ twice the thickness of the lamina alone,
or

$$(n_1 - n_3)\lambda = 2e.$$

Finally,

$$n_2\lambda = 2e(\mu - 1) = (n_1 - n_3)\lambda(\mu - 1),$$

or

$$n_2 = (n_1 - n_3)(\mu - 1).$$

So that :

$$\mu = 1 + \frac{n_2}{n_1 - n_3} \quad (3)$$

It is seen that in equation 3 all of the terms are gotten by counting fringes, and are not dependent upon any mechanical device whatever.

In the practical working of the method the following suggestions will be found useful :

I. It will be found convenient to have cross wires placed on the lens which is used for giving parallel light to the interferometer. The images of these cross wires serve as an index in counting the fringes. The intersection of the wires should cut the center of the circular fringes.

II. After the lamina has been placed against the movable mirror it generally happens that the stationary mirror of the interferometer must be readjusted in order to secure the fringes. In making this adjustment three sets of fringes should be simultaneously present, those from the silvered surface of the lamina, those seen through the lamina and those from the free surface of the mirror. This can best be done by first securing the circular fringes from the silvered surface of the lamina and then shifting these about until the others appear.

III. The thickness of the lamina tested by the writers did not exceed .2 mm. The accuracy of the method rather increases with the thickness of the lamina used, though the counting is thereby made more tedious. The thickness of the lamina tested measured a little greater when measured by wave-lengths than when measured by the micrometer. This is to be expected when it is considered that the latter method involves a pressure on the lamina.

The following experimental data will illustrate the results to be obtained by this method. The source of light used was the Na flame.

	n_1	n_2	n_3	μ
<i>Glass.</i>	598	306	11	1.521
	601	307	11	1.520
	601	308	11	1.522
<i>Mica.</i>	379	224	9	1.605
	380	224	9	1.603
	380	223	9	1.601
	382	224	9	1.600
	380	224	9	1.603

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