AN INTERFEROMETER USING PLANE-POLARIZED LIGHT

By J. W. Beams, L. G. Hoxton, and F. Allison

The problem in which one or both of the light beams in an interferometer must be plane-polarized, often presents itself. Many such instruments have been described and hence a considerable range of choice is possible depending upon the purpose in view. In some types, such as the half-shade interferometer described by Cotton[1] or by Skinner and Tuckerman,[2] where the determination of the variation in optical path depends upon a measure of the change in the ellipticity of polarized light rather than the usual shift of the fringes, a precision as high as one twenty thousandth wave length is claimed. To attain such high precision, the optical parts must be of a very fine quality and the experimenter must be quite skilful, especially in matching light intensities. In fact, the experimental difficulties are so great that the half-shade interferometer has not been generally used regardless of its many important possible applications. Where the precision of the instrument is considerably reduced, the experimental difficulties are of course very much lessened, but the demand for fine optical parts still remains. In many experiments, where the light need not be completely plane-polarized in both arms of the instrument, almost any ordinary interferometer as, for example, the Jamin type, can be used by merely polarizing the incident light.

We have had occasion to construct an instrument by which a change in the optical path of completely plane-polarized light could be measured with a precision of approximately one one-hundreth of a wave length. The instrument turned out to be so simply adjusted and easily operated, in addition to being nearly independent of the eye of the observer, that it was thought worth while to describe it here.

Light from a mercury arc H, passed through a filter F which transmits only a single line, was made almost parallel by the lens L_1 and plane-polarized by the Nicol prism N. The light then entered a crystal of Iceland spar (or a double image prism) which is so oriented with respect to N that two beams of equal intensity polarized in perpendicular planes emerged. Each of these beams is reflected back practically on its path by plane mirrors M_1 and M_2 and recombined at A, forming

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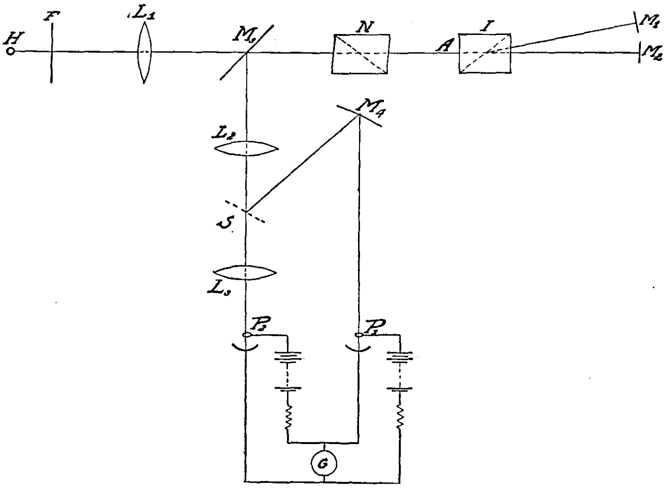
[1] Cotton: Comptes Rendus, *152*, pp. 131–33; 1911.

[2] Skinner and Tuckerman, Phys. ZS., *12*, p. 620; 1911.

elliptically polarized light. It then continues through N and is reflected by the half silvered mirror M_3 into the lens L_2. In the position S a system of light and dark bands is formed. Then if M_1 is moved with respect to M_2 or the optical path AM_1 changed with respect to AM_2, these bands or "fringes" shift their position. The exact shape of these fringes depends somewhat upon the optical surfaces. If the optical path AM_2 differs from the optical path AM_1 by an integral multiple of one fourth of a wave length, the two beams recombine at A to form plane polarized light.



Since now the two beams are reflected not quite, but almost, back on their original paths, the theory of the ordinary interferometer is applicable. It can be shown that the ellipticity of the light is constant over certain loci of the same type as the fringe systems of the Michelson interferometer. The ellipticities in adjacent loci, however, vary by all stages from light polarized in one plane to that polarized in another perpendicular to it. Therefore, when this light passes back through N, dark bands are formed where the light is polarized in a plane perpendicular to its plane of transmission. A change in the optical path AM_2 by half a wave length, while AM_1 remains constant, shifts one dark fringe into the position of the next. If white light is to be used, a crystal of Iceland spar of proper thickness must be placed in the shorter optical path to make the two paths equal. We have, however, used only monochromatic light in our experiments, rendering the plate unnecessary.

In order to measure small shifts of these fringes, a system of slits whose dimensions were nearly identical with those of the fringes themselves, was made by scraping off the silver from a mirrored surface. It was then placed so that the center of each reflecting portion received the edge of a fringe. About half of the light, therefore, was reflected and half transmitted. The reflected light (coming off at a small angle) fell upon the concave mirror M_4 and was focused on a photoelectric cell P_1; while the transmitted portion was focused on a second similar photoelectric cell P_2 by the lens L_3. The circuits of P_1 and P_2 are arranged to send their currents through a high sensitivity galvanometer in opposite directions. If now the fringes move, the light received by one cell is increased and that received by the other is decreased. The result is a change in the deflection of the galvanometer. The relation between the galvanometer readings and the fringe shifts, provided the latter are small, can be easily obtained by placing tubes containing a gas of known index of refraction in the two arms AM_1 and AM_2 respectively and then determining the galvanometer deflections as a function of the pressure of the gas in one tube. Other methods could be used but the above proved to be quite satisfactory.

The advantage of this arrangement of two photoelectric cells instead of one lies in the fact that fluctuations of intensity in the source of light are, to a first order of approximation, compensated out. The instrument is comparatively free from troubles due to small temperature variations but, for the highest sensitivity, the whole apparatus, except the light source, should be placed in a constant temperature box with a water cell placed between the arc and the first lens. In our experiments the interferometer and slits were placed on a Julius suspension in order to avoid troublesome small vibrations.

It is of course possible to use the photoelectric cell arrangement to detect the fringe displacement in any kind of interferometer provided the fringes are comparatively sharp. The precision obtainable depends upon the distribution of light in the fringes, the strength of the light source and the sensitivity of the photoelectric cell and circuit. We could easily measure a displacement of one one-hundreth of a fringe and we believe the sensitivity can be considerably increased, if desired, by taking a few further precautions.

UNIVERSITY OF VIRGINIA.