CLASSICS OF SCIENCE: Michelson on Interference

Physics

Light Waves and Their Uses, *by Professor A. A. Michelson of the department of physics, University of Chicago. The Decennial Publications, second series, vol. III, University of Chicago Press,* 1903.

Before the properties of lenses were known, linear measurements were made by the unaided eye, as they are at present in the greater part of the everyday work of the carpenter or the machinist; though in many cases this is supplemented by the "touch" or "contact" method, which is, in fact, susceptible of a very high degree of accuracy. For angular measurements, or the determination of direction, the sight-tube was employed, which is used today in the alidade and, in modified form, in the gun-sight—a fact which shows that even this comparatively rough means, when properly employed, will give fairly accurate results.

The question then arises whether this accuracy can be increased by sufficiently reducing the size of the apertures.

The answer is: Yes, it can, but only up to a certain limit, beyond which, apart from the diminution in brightness, the diffraction phenomena just described intervene. This limit occurs practically when the diameter of two openings a meter apart has been reduced to about two millimeters, so that the order of accuracy is about 1/5 × 1/500 or 1/2500 for measurements of angle. Calling ten inches the limit of distinct vision, this means that about 1/250 of an inch is the limit for linear measurement. An enormous improvement in accuracy is effected by the introduction of the microscope and telescope, the former for linear, the latter for angular measurements. Both depend upon the property of the objective lens of gathering together waves from a point, so that they meet again in a point, thus producing an image.

It can readily be shown that the luminous point and its image are in the same line with the center of the lens—sufficiently near for the first approximation. Accordingly, if we take separate points of an object, we can construct its image by drawing straight lines from these through the center of the lens, as shown in Fig. 21. The size of the image will be greater the greater the distance from the lens, so that the magnification is proportional to the ratio of the distances from object and image respectively to the center of the lens; hence in the microscope an error in determining the position of the image means a much smaller error in the determination of the position of the point source. This error could be diminished indefinitely by increasing the magnifying power, were it not for the attendant loss of light and the fact that the light waves, though very minute, are not infinitesimally small. In fact, the same diffraction effects again limit the possibility of indefinite accuracy of measurement.

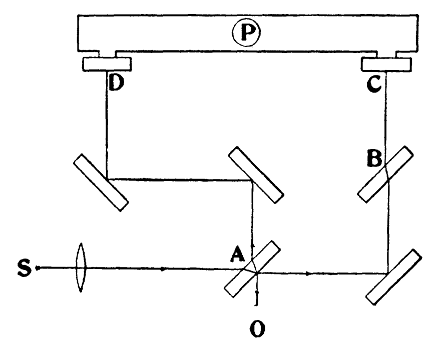

DIAGRAM illustrating the Principles Governing the Michelson Interferometer

In most cases these diffraction rings are so small that they escape notice, unless the air is unusually quiet and the lens exceptionally good. If these conditions are satisfied, and the instrument is focused on a very small or distant bright object (a star or a pinhole in front of an electric arc), the rings are readily visible with a sufficiently high-power eyepiece. They may be much more readily observed, however, if the ratio of diameter to focal length be diminished by placing a circular aperture before the lens. The smaller the aperture, the larger will be the diffraction rings.

In the case of a telescope, the angular magnitude of the diffraction rings, and with this the accuracy of measurement of the position of the luminous point, depends only on the diameter of the objective. . . . The utilization of the two portions of a lens, at opposite ends of a diameter, converts the telescope or microscope into an *interferometer.*

This term is used to denote any arrangement which separates a beam of light into two parts and allows them to reunite under conditions to produce interference. The path of the separated pencils may be varied in every possible way; for instance, by interposing prisms or mirrors, provided the optical paths are nearly equal and the angle between the two final directions very small. The first condition is essential only when the light is not homogeneous. The reason will be apparent when it is remembered that the width of the interference bands depends on the wave-length of the light employed. If the light is composite, as in the case of white light, each component will form interference bands whose width is proportional to the wave-length.

It is important to note that the path of the two pencils after their separation by the first plate is entirely immaterial; for example, either or both pencils may suffer any number of reflections or refractions before they are reunited by the second plate, without affecting in any essential point the efficiency of the interferometer, provided that the difference in the path of the two pencils is not too great, and provided that the two pencils are reunited at a sufficiently small angle.

One type of interferometer has been arranged in such a way as to show the extreme delicacy of the interferometer in measuring exceedingly small angles. For this purpose two of the mirrors, *C* and *D,* have been mounted on a piece of steel shafting *P* two inches in diameter and six inches long. When the length of the paths of the two pencils is the same to within a few hundred thousandths of an inch, the interference fringes in white light are readily observed, or may be projected on the screen. If, now, the steel shafting be twisted, one of the paths is lengthened and the other diminished, and for every movement of one two-hundred-thousandth of an inch there would be a motion of the fringes equal to the width of a fringe. Now, taking the end of the steel shafting between thumb and forefinger, the exceedingly small force which may thus be applied in this way is sufficient to twist the solid steel shafting through an angle which is very readily observed by the movement of the fringes across the field.

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