AMERICAN JOURNAL OF PHYSICS VOLUME 37, NUMBER 3 MARCH 1969

Use of Grating to Find Interferometer White Light Fringes

GRAYDON D. BELL AND ELDRED F. TUBBS
Harvey Mudd College, Claremont, California 91711

(Received 1 August 1968; revision received 24 October 1968)

A procedure for using a transmission grating to aid in the adjustment of a Michelson interferometer for white light fringes is described. A theoretical analysis of the fringe formation seen in the grating spectrum is given and some ways in which the phenomenon can be used in a student laboratory are discussed.

INTRODUCTION

It is well known that the adjustment of a Michelson interferometer for observation of white light fringes can be a tedious process. Several procedures for locating the zero path difference necessary for bringing white light fringes into view have been described in textbooks on optics[1-3] and in journal articles.[4] Most of these employ a monochromatic light source to locate approximately the zero path difference condition and then a *very* slow motion of the interferometer mirror to bring the white light fringes into view. Two difficulties arise in this procedure: (1) great care must be taken in moving the mirror to avoid missing the fringes as they traverse the field of view, and (2) the direction in which the mirror should be moved is not easily determined. These difficulties often cause much wasted time in finding the proper setting.

A less tedious method for locating white light fringes, suggested to one of the authors (Tubbs) a number of years ago by Robert Rowe,[5] eliminates the two difficulties discussed above. This method utilizes a transmission grating for locating the white light fringes when they do not appear in the field of the interferometer. While viewing the fringes in the spectrum of the grating, one can quickly center the fringe pattern in the interferometer field, thus making the final adjustment for zero path difference a relatively simple and rapid process.

An article by Kahl and Sleator[6] describes this method and gives a thorough analysis of the fringe formation. To understand the theoretical analysis given by Kahl and Sleater, however, one needs a more extensive background in optical theory than that possessed by most teachers. Thus, it seems worthwhile to present here a simplified analysis developed independently by one of the authors of this paper (Bell) and to point out the usefulness of both the method and the theory to teachers employing Michelson interferometers in undergraduate student laboratories.

First we will describe a procedure for using the grating to adjust an interferometer, and then we will present the simplified theoretical analysis of white light fringe formation in the grating spectrum. Finally we will discuss ways in which this interesting interference phenomenon can be brought to the attention of students in undergraduate optics laboratories.

I. PROCEDURE

A fairly course transmission grating (e.g., 7500 lines per inch) is most suitable for this application. The procedure for finding white light fringes with the aid of the grating is as follows. First, the mirrors are set for approximately equal paths by measuring with a millimeter scale and adjusted to be perpendicular by observing the images of a common pin, as described by Jenkins and White.[1] One mirror is then rotated very slightly about a vertical axis so that vertical localized fringes will be produced. If a monochromatic source is available, it can be used at this point to adjust the mirror for well aligned vertical fringes, but a satisfactory adjustment can be made with only white light by slightly displacing one image of the pin in a horizontal

---

[1] F. A. Jenkins and H. E. White, *Fundamentals of Optics* (McGraw-Hill Book Co., New York, 1957), pp. 246–250.

[2] R. W. Ditchburn, *Light* (Wiley–Interscience Publ., Inc., New York, 1963), pp. 105–106.

[3] R. W. Wood, *Physical Optics* (The Macmillan Co., New York, 1934), pp. 294–297.

[4] W. Primak, Appl. Opt. **3**, 432 (1964).

[5] R. L. Rowe credits Dr. C. W. Chamberlain, deceased, of Michigan State University, with first using this method for adjusting interferometers.

[6] G. D. Kahl and D. B. Sleator, Rev. Sci. Instr. **36**, 993 (1965).

direction. A monochromatic light source can also be employed to make the path lengths approximately equal by adjusting the movable mirror for minimum curvature of the monochromatic fringes as described by Jenkins and White.[3]

The interferometer field, illuminated with white light, is now viewed through the grating held before the eye with the rulings in the vertical direction. A continuous spectrum is observed in various orders on either side of the zero order, and as adjustments of the movable mirror are made, a set of dark fringes will come into view in one of the outer orders. Further adjustment of the movable mirror is made in such a direction as to move the fringes, which appear on only one side, toward the zero order. When the fringes have been moved into zero order, the grating is removed and the white light fringes are seen in the field of the interferometer.

II. THEORY

The very obvious fringes which appear in one of the grating orders are not the same as the dark bands, Edser–Butler bands, which can be seen through a prism spectroscope. Such bands can be seen in all orders of the grating spectrum, though much more faintly, and are due to destructive interference for only one color, as discussed in Jenkins and White.[3] The fringes used for adjusting the interferometer, however, are "white light" fringes produced in the following way.

When the two path lengths of an interferometer differ by more than a few wavelengths of visible light, white light fringes will not be seen in the field of the interferometer because the overlapping of many colors washes out the fringes. When the exit beams of the interferometer pass through the grating, however, they are diffracted and, because of their angular separation, traverse different paths for essentially the same angle of observation. For some particular order on one side of the central image, the angle of viewing can produce a path difference beyond the grating which equalizes the total paths for the two light beams traversing different legs of the interferometer.

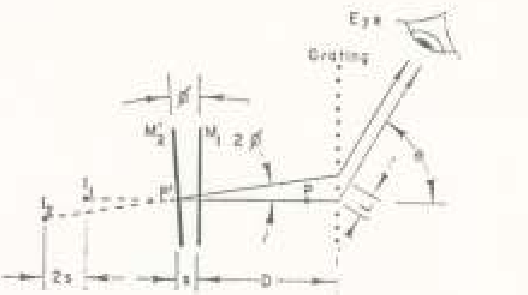

Fig. 1. Production of white light fringes by Michelson interferometer and diffraction grating.

This is best understood by referring to Fig. 1. In this figure the real mirror M_2 has been replaced by its virtual image, M_2', formed by reflection in the beam splitter (not shown). A point P on the extended white light source produces two virtual images I_1 and I_2 behind the two mirrors. If the mirrors are separated at the points of reflection by a distance s (i.e., the path lengths in the two legs of the interferometer differ by a distance s for the rays shown), then the virtual images will be separated in the longitudinal direction by a distance $2s$. If the mirrors are not perpendicular, the images will also be separated laterally and the reflected beams will have an angular separation of 2ϕ, where ϕ is the angle between M_1 and M_2'. For the special case shown in Fig. 1, where the ray from the source P is perpendicular to M_1, the two reflected rays will appear to come from a common point P' which lies on M_2', and the wave fronts will be out of phase for most wavelengths because of a path difference of approximately $2s$, assuming ϕ is small. Ditchburn[7] shows that, at a fixed location on the grating, the reflected ray pair from any point on the extended source will have the same path difference as the ray pair from any other point on the source. If s is greater than a few wavelengths, no white light fringes will be seen when the field of the interferometer is viewed directly. However, if L, the path difference created at the grating, just compensates for the original path difference, $2s$, then the two waves as seen through the grating will be in phase and will interfere over a wide range of wavelengths. It is this interference which produces the fringe pattern at only one value of θ and hence in only one order of the grating.

---

[7] R. W. Ditchburn, *Light* (Wiley-Interscience Publ., Inc., New York, 1963), pp. 137–138.

The quantitative condition which must be satisfied in order to produce the "white light" fringes seen with the grating can easily be derived. To equalize the total path lengths, it is first necessary that

$$L=2s. \tag{1}$$

The separation of the two rays at the grating is $D\cdot 2\phi$, where ϕ is the small angle, measured in radians, between M_1 and M_2', and D is the distance from the mirrors of the interferometer to the grating. Thus, the path difference L is given by

$$L=(2D\phi)\sin\theta=2s \tag{2}$$

where θ is the angle at which the light is viewed after being diffracted by the grating. Finally, the angle θ is related to the wavelength of the light, λ, and the grating spacing, a, by the usual grating formula

$$a\sin\theta=m\lambda \tag{3}$$

where m is the order number. Combining Eqs. (2) and (3) yields

$$s=D\phi m\lambda/a \tag{4}$$

or

$$m\lambda=as/D\phi. \tag{5}$$

This formula predicts that the *center* of the "white light" fringe pattern will be seen in the mth order centered on the color given by λ when a, s, D, and ϕ have values which satisfy Eq. (5). The angle ϕ can be measured by counting the number of monochromatic fringes across a measured portion of the field, and the other parameters can be measured directly. When measured values for the parameters are substituted into Eq. (5), it correctly predicts the location of the localized fringes.

III. APPLICATIONS

The use of a grating with the Michelson interferometer not only provides a practical method for finding the white light fringes but also introduces students to an interesting phenomenon which they can understand with only an elementary background in physical optics. In our optics laboratory at Harvey Mudd College we provide the students with an inexpensive transmission grating (Welch 3815B) when they first begin to use the Michelson interferometer, and we outline for them the way in which it can be used to adjust the interferometer for zero path difference. The students then have very little difficulty in making the proper setting, and some become quite intrigued with the phenomenon of seeing fringes in the spectrum of the grating. Because they have only an introductory understanding of interferometers at this point, they cannot develop an original explanation of the grating fringes, but they do often find for themselves some of the factors which determine the location of the fringe pattern as it is seen through the grating. For example, they find that changing the mirror angle not only spreads the fringes but also causes the pattern to shift to a different order.

After they have gone as far as they can in making experimental observations of white light fringes, we give those who are interested an explanation based on the theory presented in Sec. II of this paper. They have no trouble in following the analysis and are usually quite pleased to find that their basic understanding of the interferometer and of the diffraction grating are sufficient for explaining the fringes. Some also enjoy seeing how the fringe-location variables which they discovered enter into the equations of the theory. By this time they are familiar with adjustments of the interferometer and are well prepared to use the instrument for wavelength determinations, precise distance measurements, small wavelength difference measurements, and index of refraction studies.

ACKNOWLEDGMENT

The authors wish to thank a former Harvey Mudd College student, Jon Wunderlich, who searched the literature concerning techniques for finding white light fringes and also carried out some of the quantitative measurements to test the theory presented here.