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III. A FURTHER APPLICATION OF LOCALIZED WHITE-LIGHT FRINGES OF SUPERPOSITION

By S. TOLANSKY.

Introduction. — The principle of superposition of fringes has been long in use, since in fact their discovery early last century by Brewster. Two types can be used, either fringes of equal inclination or fringes of equal thickness, and they can be used either with two beams or with multiple beams. The Brewster and Jamin fringes are typical two beam arrangements and the classical superposition system of equal inclination fringes used by Fabry, Perot and Buisson in the metre determination was the first use of multiple-beams for such fringes. More recently Sears and Barrell determined the refractive index of air with a closely similar optical arrangement.

By far the larger number of studies using multiple-beam fringes of superposition have been made with the fringes of equal inclination, and apart from very brief mention by Fabry in his book "Les applications des interférences lumineuses" very little use of the system using fringes of equal thickness appears to have been made.

It is the purpose of this Note to describe such an application, highly specific it is true, yet none the less of much interest because of its great power and simplicity. The method is applied to studying "invisible" inclusions in mica sheets. The illustrations used were taken for me by my assistant, Miss Austin.

Experimental. — The arrangements are of the simplest possible. The mica is cleaved and silvered on both sides (reflectivity 90 → 95 per cent). The piece of mica is cut in two, and the pieces held close together, i.e. effectively parallel. This is illuminated with a parallel beam of white light from an arc or pointolite and following the mica is a lens of focal length 25 → 50 cm. On placing the eye at the principal focus localised white light fringes of superposition are seen.

The results are striking. If the mica had consisted of a truly parallel-sided sheet, then one would only have seen a uniformity of illumination. But in general, mica sheets have minute steps on them, cleavage steps, and it has already been established that these are integral multiples of the crystal lattice spacing 20 Å, often only a single lattice spacing (see M. B. I.) yet possibly extending over quite large areas. Thus in the field of view one sees beautifully tinted areas, separated by cleavage lines. Plate 5 is a photograph of such a region and gives only a very poor impression indeed of what the eye actually sees, for the different regions have great purity of colour and are also very brightly differently coloured, e.g. green, red, blue, etc.

It is immediately obvious from the superposition principle that that in effect one has white-light multiple-beam interference over the path lengths which are the minute differences in thickness between the two mica sheets, i.e. over the cleavage areas. It has been shown elsewhere by the author (see M. B. I.) that when using single parallel-sided stepped films (in the "crossed Fizeau fringe technique") a change of height of but one crystal lattice spacing in mica can make a 50 per cent change in the intensity of transmission. Indeed, it requires only the remarkably small alteration of 3.5 Å in optical path difference to produce a detectable 10 per cent change in intensity of illumination. Thus even with a single double-silvered film, and monochromatic light, a single lattice change is easily detected providing one adapts the angle of incidence to give correct transmission, as has been already fully discussed.

Now it is well known from the theory of the
compound Fabry-Perot interferometer (see Tolansky, *High Resolution Spectroscopy*, Methuen 1947) that the fringe width of a double interferometer, both identical, is \( \frac{1}{\sqrt{2}} \) times that of either alone. Hence the sensitivity of the fringes of superposition to small changes in path is \( \sqrt{2} \) times as great as in the case of a single mica film. Furthermore, one always finds a suitable colour available, and in addition, the eye is certainly far more sensitive to a slight *colour-tint* alteration than to a slight *intensity* alteration.

One recognises therefore that the sensitivity of the method is such that one should be able to detect optical path differences of only 2.5 \( \lambda \), i.e. \( \frac{1}{\sqrt{2}} \) 1/\(10^3\)th of a green light wave. This being so, even very slight variations in chemical composition of mica should show up. Any "invisible" inclusions should be revealed with very great contrast if they have a refractive index differing even slightly from that of mica. In plate 5 a mass of unsuspected secondary inclusions appear. These cannot be seen normally.

Plate 6 shows typical "invisible" inclusions. Two features may be remarked upon, namely, (a) the fringe sharpness, (b) the reproduction is only in monotone and gives a very inadequate picture of what is actually seen by the eye.

Plate 7 is another characteristic example. Here one sees that the inclusions have often a small crystalline nucleus, and one notices, too, the revealing secondary structure surrounding the nucleus. On other plates continuous variations appear in patchy areas, indicating secondary changes in chemical composition.

**Conclusion.** — The method has many obvious applications to the study of thick and thin films. For example, if films are put down in a selected piece of mica and then silvered, a means for studying film uniformity becomes available. This should find application in evaporated films, grown films, even crystalline deposits and probably organic monolayers.

It also becomes a means of matching thick optical specimens for exact equality (or equating two equal Fabry-Perot interferometers), for it is the differential effect which leads to the interference, but with thick specimens collimation will be critical. The fact that a special monochromatic source is not needed is a considerable attraction.

The rapidity and simplicity of the technique has much to commend it. White light sources (arcs) are so bright that one can tolerate quite heavy silverings and thus obtain maximum sensitivity. With thin specimens very crude collimation can be used with little loss in sensitivity.

It is re-emphasised that the monotone reproductions given here fail entirely to give an idea of the real sensitivity a colour reproduction reveals.

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**Intervention de M. O. S. Heavens.**

The limit to the sharpness of the fringes of equal chromatic order would appear to be set by the statistical fluctuations in thickness of the deposited silver film.

**Intervention de M. Kuhn.**

This will in turn set a limit to the magnification which may be used between the interferometer and the dispersing system.

This beautiful method of detecting local inclusions and variations in refractive index is, of course, closely related to the interference microscope. These fringes which are of the Brewster type are, however, entirely different from those used in the double interferometer. In the latter instrument, no interference takes place of any two rays which have suffered reflection in different etalons.