6.5 FECO (Fringes of Equal Chromatic Order)

FECO (Fringes of Equal Chromatic Order)

Ref: Born & Wolf, p. 359.

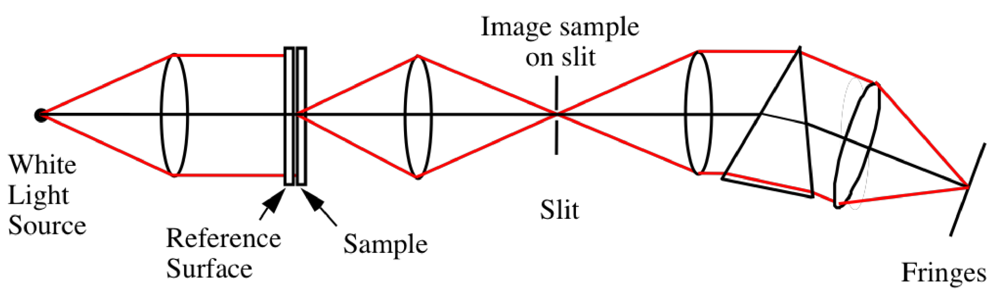
The FECO interferometer is a multiple-beam interferometer in which the test sample is focused onto the entrance slit of a spectrograph. A white light source is used in the interferometer. It can be shown that each fringe gives the profile of the distance between the test surface and the reference surface for the line portion of the surface focused onto the entrance slit.

For multiple-beam interference the transmission is given by

$$I_t = \frac{I_{max}}{1 + F \operatorname{Sin}[\delta / 2]^2} \quad \text{where} \quad \delta = \frac{2\pi}{\lambda_o} 2\, n\, d \operatorname{Cos}[\theta] + 2\phi$$

ϕ is the phase change on reflection at each surface.

A schematic diagram of a FECO interferometer is shown below. Both the sample and the reference surface must have high reflectivity so high finesse multiple beam interference fringes are obtained. The sample is imaged onto the entrance slit of a spectrometer



If n = 1 and $\theta = 0°$ for a bright fringe of order m

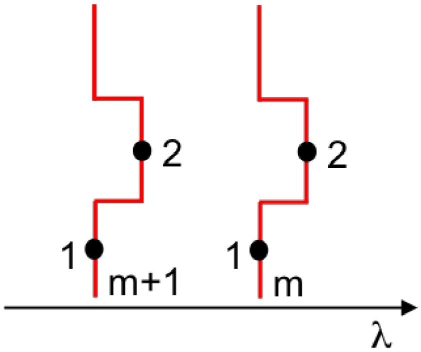
$$\frac{\phi}{\pi} + 2\frac{d}{\lambda} = m$$

It should be noted that for a given fringe $\frac{d}{\lambda}$= constant and

$$\lambda_m = \frac{2\, d}{m - \frac{\phi}{\pi}}$$

Solving for the height difference across a sample is complicated since $\phi = \phi[\lambda]$. However, with many coatings ϕ can be considered to be independent of λ over the small spectral region used for the analysis. (For more details see Born & Wolf or Jean Bennett, JOSA 54, p. 612 (1964).

The following drawing shows two fringes in the FECO output. The goal is to find the surface height difference between points 1 and 2.



$$d = \left(m - \frac{\phi}{\pi}\right) \frac{\lambda}{2} \quad \text{and} \quad d_2 - d_1 = \left(m - \frac{\phi}{\pi}\right) \left(\frac{\lambda_{2,m} - \lambda_{1,m}}{2}\right)$$

For point 1 and fringe orders m and m + 1

$$\left(m - \frac{\phi}{\pi}\right) \lambda_{1,m} = \left(m + 1 - \frac{\phi}{\pi}\right) \lambda_{1,m+1}$$

Thus,

$$\left(m - \frac{\phi}{\pi}\right) = \frac{\lambda_{1,m+1}}{\lambda_{1,m} - \lambda_{1,m+1}}$$

and

$$d_2 - d_1 = \frac{\lambda_{1,m+1}}{\lambda_{1,m} - \lambda_{1,m+1}} \left(\frac{\lambda_{2,m} - \lambda_{1,m}}{2}\right)$$

The following figure shows some actual FECO interference fringes (Ref: Born & Wolf).

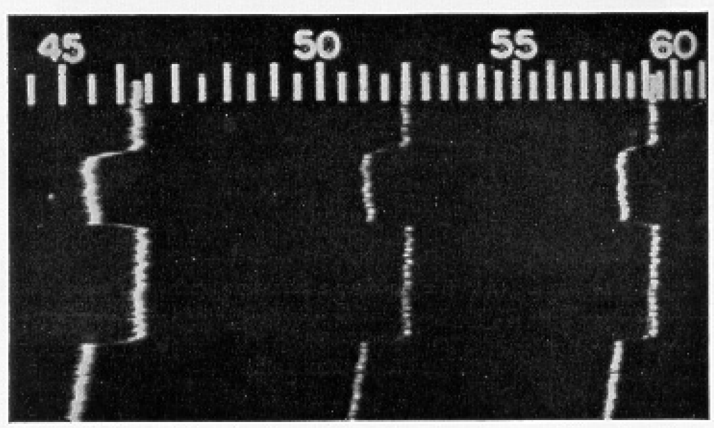


Fig. 7.79. Fringes of equal chromatic order given by a section of a diamond crystal surface. The scale is of wavelength in hundreds of Ångstroms.
(After S. Tolansky and W. L. Wilcock, *Proc. Roy. Soc.*, A, 191 (1947), 192.)

Since $d_2 - d_1$ is proportional to $\lambda_{2,m} - \lambda_{1,m}$, the profile of the cross-section of an unknown surface is obtained by plotting a single fringe on a scale proportional to the wavelength.

The spectroscopic slit is in effect selecting a narrow section of the interference system and each fringe is a profile of the variation of d in that section since there is exact point-to-point correspondence between the selected region and its image on the slit.

Small changes in d are determined by measuring small changes in λ. There are no ambiguities as to whether a region is a hill or a valley. There are no ambiguities at a discontinuity as we would have with monochromatic light where it is difficult to determine which order belongs to each fringe. Surface height variations in the Angstrom range can be determined.

Two disadvantages are

1) we are getting data only along a line and
2) the sample being measured must have a high reflectivity.