Increased Resolution with Oblique Illumination

According to Abbe's theory, the direct ray and *one* of the diffracted rays should be sufficient to resolve a grating. By the use of an oblique illuminating beam, these two rays may both be grasped by the objective when otherwise only the direct ray would enter (Fig. 4).

With axial illumination, a grating of 25,000 lines/in. is barely resolved by an 8-mm, 0.50-NA objective (or one of 14,000 lines per inch by a 16-mm, 0.25-NA objective).

Rendering the illumination oblique in an aximuth *crosswise* of the rulings of the grating markedly improves resolution. This may be done by decentering the diaphragm used to make the original illumination unidirectional. Initially, the diffraction spectra are only partially included, with axial light. As the obliquity of illumination is increased, the undiffracted (direct) ray is seen to shift and the diffracted ray to enter at one edge of the aperture of the objective. As soon as the direct ray and one diffracted ray are included, resolution is accomplished. Oblique illumination from an azimuth *endwise* of the rulings of the grating does not give this effect or improve resolution.

It is possible, with illumination of the proper degree of obliquity, nearly to *double* the resolving power of an objective. Obviously, if the oblique illumination is from one side only, the structural details in different orientations will not be equally resolved, and coarser outlines will be unsymmetrically shaded. For these reasons, light is generally made to converge upon the object from all azimuths, as a cone of rays, by means of a condenser. The proper use of a suitable condenser is essential if objectives of high numerical aperture are to function at their fullest efficiency (page 40).

The regulation of the relative intensity of the axial and oblique rays, as supplied in illumination and as produced by diffraction at the object, is very important in governing the contrast between light and dark in the image.

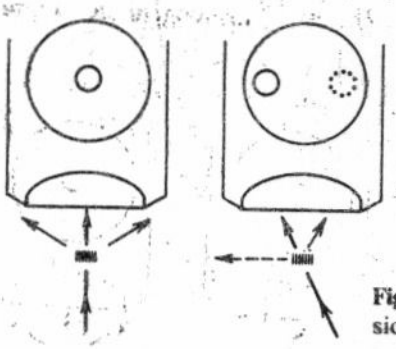

Fig. 4 Effect of oblique illumination on the inclusion of diffracted rays by an objective.