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XVI. *Note on the Diffraction Theory of the Microscope as applied to the case when the Object is in Motion.* By R. T. GLAZEBROOK, D.Sc., F.R.S.*

ACCORDING to the Abbe theory of Microscopic Vision, when a grating is placed on the stage of a microscope and illuminated by plane waves, diffraction images are formed in the focal plane of the object-glass and the images in the view-plane result from these, and this is undoubtedly true.

The following difficulty has, however, been raised: if the grating be moved in its own plane in a direction perpendicular to the ruling the positions of the diffraction images do not change, those seen in the view-plane move. How, then, can the latter images be due to the former?

The answer lies in the fact that in the above argument, the effect of the differences of phase among the diffracted images has been neglected.

The diffracted images are not all in the same phase, their relative phases are altered by shifting the grating and the image pattern in the view-field is altered in consequence.

Thus, if A, B be two diffraction images in the same phase,

Fig. 1.

and P any point in a line bisecting A, B at right angles, then P is a point of maximum illumination. If, however, the phases at A and B are opposite, the illumination at P is zero, the point of maximum illumination has shifted. Now it is easy to prove that as the grating is shifted the relative phases at A and B do alter.

For let L_1, L_2, L_3, L_4 be a series of consecutive bright spaces of the grating, A and B the central and first diffracted

* Read April 22, 1904.

image, E, F the lens, and C, D a line at right angles to the direction of the parallel rays which go to form the first image B. And let L_1M_1 , $L_2M_2 \dots$ etc. these rays meet CD in $M_1, M_2 \dots$. Then the time to B from any point in CD is the same, and the series of differences $L_1M_1 - L_2M_2$, $L_2M_2 - L_3M_3$ etc., are each equal to one wave-length.

Fig. 2.

Let us assume that in this position A and B have the same phase. Now, suppose the grating shifted to the right through half a grating interval so that the bright spaces are now $L'_1L'_2 \dots$ midway between their former positions. This produces no change in the light coming to A but in that to B the phase is altered.

The length of path for the light from the first space has been increased by the amount $L'_1M'_1 - L_1M_1$, that from the next space by $L'_2M'_2 - L_2M_2$, and these increments are all equal and each is half a wave-length. For as we have seen $L_1M_1 - L_2M_2 = \lambda$, and since L'_1 is midway between L_1 and L_2 , $L'_1M'_1 - L_2M_2 = \frac{1}{2}(L_1M_1 - L_2M_2) = \frac{1}{2}\lambda$.

Thus the length of path for each component of the light

coming to B has been increased by half a wave, and the resultant phase at B is therefore altered by half a period.

Hence A and B are now in opposite phase.

But if the image in the view-plane be due to A and B only, it is clear that the dark lines in the image are by this change converted into bright lines and *vice versa*, the image shifts in a corresponding manner to the object. If we take into account the second diffraction image, it can be shown similarly that its phase is not altered by the assumed shift, while the third is changed, and so on; and the result is that in all cases the change in the image corresponds with that in the object.

The fact that there will be an alteration in phase of half a period at B when the grating is shifted can be seen readily thus.

With the grating in the first position light from $L_1L_2\dots L_n$ reaches B, and the waves from these points are all in the same phase; the respective paths differ by a wave-length. When the grating is moved to its second position, $L'_1L'_2\dots$ become the sources of the light; the waves from these points being again in the same phase, the respective path differences being again a wave-length. If the grating is moved entirely away so that both series of points $L_1L_2\dots L'_1L'_2\dots$ are effective, no light reaches B because the resultant phase of the disturbance from $L_1L_2\dots$ is exactly opposite to that from $L'_1L'_2\dots$ i. e., the effect of shifting the grating is to alter the phase at B by half a period.

Thus it is seen in this simple case how it comes about that the image in the view-plane may change without an alteration in the *position* of the diffraction images, the change in phase of these images suffices to explain it.