Acta Cryst. (1963). **16**, 1070

Primary extinction of X-rays. By R. Steadman, *Department of Physics, Bradford Institute of Technology, Bradford 7, England*

(*Received* 10 *April* 1963)

The purpose of this note is to suggest that the simple explanation usually put forward to account for primary extinction of X-rays in a perfect crystal appears to be fallacious, and to put forward a possible alternative.

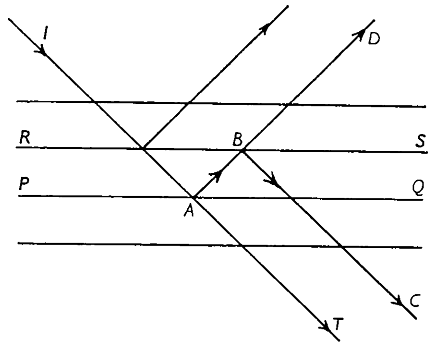

Fig. 1. Explanation of primary extinction according to James (1948).

The explanation in question is that given most clearly by James (1948), which is a re-exposition of the work of Darwin (1914). According to this, the direct beam IAT in Fig. 1, which is incident at such an angle as to satisfy the Bragg condition for the planes shown, suffers extinction because of its interaction with twice-reflected beams such as BC. The beam ABC suffers a phase retardation of $\pi/2$ on reflexion, both at A and at B, and differs in phase by π, therefore, from the direct beam. Provided that the crystal is larger than a certain minimum size, and that absorption is small, the amplitude of the direct beam may be reduced to zero by the effect of many beams such as BC, and the whole of the energy then appears in a beam travelling in the direction AD.

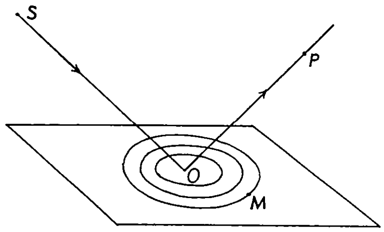

Fig. 2. Half-period zones on a reflecting lattice plane.

The fallacy lies in the explanation given for the phase retardation of $\pi/2$ at each reflexion. This phase change is arrived at by considering the amplitude of the wave reflected by a lattice plane as shown in Fig. 2. At the point P, the resultant wave is the sum of the contributions from all the half-period zones of the reflecting plane. These zones are defined by elliptical boundaries drawn so that, for any point such as M on the outer edge of the nth zone, the distance SMP is greater than SOP by $n\pi/2$.

The sum is shown in Fig. 3, in which the direction OX would represent the phase of the wave arriving at P if this were to be calculated simply from the distance SOP and the wavelength λ. The arc OA represents the contribution of the innermost zone, AB that of the second, and so on, the resultant of all the contributions being OZ, the phase of which differs by $\pi/2$ from that which would be expected. This is the phase change of $\pi/2$ upon which the extinction explanation depends.

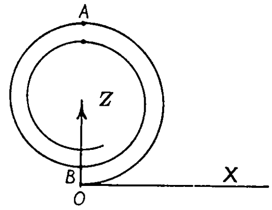

Fig. 3. Summation of the contributions from an infinite number of half-period zones.

That this phase difference does not in fact exist was known by Fresnel, upon whose method the above treatment is based. The difficulty may most easily be resolved by introducing the phenomenon predicted by Kirchhoff and observed experimentally by Gouy (1890), that any spherical wave, radiating from a source which is small compared with the wavelength, advances in phase by $\pi/2$ within a short distance of the source. In the case of the reflected waves in Fig. 2, these small sources are the lattice points in the reflecting plane.

It remains now to provide an alternative explanation, in simple terms, of the phase difference between waves AT and BC in Fig. 1, in order to account for primary extinction.

This may be done by rejecting completely the Fresnel treatment and the phase retardation it introduces, and retaining only the $\pi/2$ phase advance demonstrated by Gouy.

This rejection is not suggested simply as an expedient, but because Fig. 2 and its accompanying argument appear irrelevant to the case of reflexion of X-rays at successive lattice planes such as PQ and RS in Fig. 1. Darwin uses the Fresnel summation to obtain the amplitude of the reflected wave from a lattice plane PQ, and then assumes that a wave of this amplitude is incident on RS. But the construction in Fig. 2 requires, for several reasons, that the distance OP be large compared with the wavelength of the radiation, and this cannot hold for X-rays which are about to reach B, having been reflected from PQ.

The Gouy phase advance is likely to be complete well within the distance AB. Experiments with microwaves carried out by Carpenter (1959) have revealed that the phase change is complete within about one wavelength of the source.

References

Carpenter, C. R. (1959). *Amer. J. Phys.* **27**, 98.
Darwin, C. G. (1914). *Phil. Mag.* **27**, 315; 675.
Gouy, G. (1890). *C. R. Acad. Sci. Paris*, **110**, 1251.
James, R. W. (1948). *The Optical Principles of the Diffraction of X-Rays.* London: Bell.