A New Method of Obtaining Focused Images with X-Rays

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ATTEMPTS at constructing an x-ray microscope have been made utilizing the total reflection of x-rays at glancing angles less than about 30 minutes of arc.[1-3] Since the images are highly astigmatic, a combination of two concave mirrors with their planes of reflection at right angles is necessary. Magnifications of 15 to 30 have been reported with an object of dimensions of approximately 0.4 mm square.

It occurred to the author that under certain conditions, focused images could be obtained using crystal reflections. The use of Bragg reflection in various types of cameras for focusing a particular wavelength to a linear focus is familiar to the x-ray crystallographer. In the method to be described below, the wavelength of the x-rays may vary, but rays diverging from a particular point are again brought to a focus at another point.

Crystal reflection has the property that the angle of incidence is equal to the angle of reflection for a particular set of lattice planes, but for a given value of this angle θ only a narrow range of wavelengths on either side of a wavelength λ satisfying the Bragg relation $\lambda = 2d \sin\theta$ is reflected. Thus those rays which are reflected, are reflected according to the same law as ordinary light, incident at the same angle on a plane mirror placed in the same orientation as the lattice plane of the crystal under consideration.

Now in the optical case, a concave mirror would give a focused image (either reduced or magnified) of an object placed in front of it at a suitable distance. If the mirror were now replaced by a thin cleavage plate of the crystal, curved to the same surface as the mirror, and if white x-rays were allowed to illuminate the object, then according to the argument of the preceding paragraph one should get a focused image with x-rays of the same size and at the same place as that produced in the optical case. It is important to realize that of all the rays which originate from a point on the object, those which are reflected must converge to the corresponding point of the image, if the mirror has no aberrations. The others are just transmitted. Thus the only background would be that resulting from x-rays incoherently scattered by the mirror.

This very simple possibility does not appear to have been pointed out before. Experiments have been undertaken by the author in collaboration with Mr. Y. T. Thathachari in this laboratory to test the preceding ideas, and it is found that they are workable. Although details of the experiment will be published elsewhere, the possible methods of constructing such an x-ray focusing arrangement may be mentioned here. One method would be to fix a cleavage flake of mica on a flange attached to a circular tube and to partially evacuate the inside of the tube, thereby obtaining a concave surface. Another method would be to bend a circular plate of quartz, cut perpendicular to the *c*-axis, by means of two concentric rings, where the region inside the smaller ring should have nearly constant curvature.[4] A third method would be to deform a plastic crystal like rocksalt to take the shape of a truly spherical surface. In all these cases, one would expect the lattice planes to take up the requisite curvature (at least on a macroscopic scale).

The geometry of the arrangement would be as follows. The object, kept inside an aperture on a lead screen, is placed close to the window of an x-ray tube and the diverging beam of x-rays is allowed to fall on the "mirror" situated at a suitable distance from it. The mirror is slightly tilted so as to throw the reflected beam on one side of the object, and a photographic plate is kept at the correct distance from the mirror, judged optically. The x-ray image also would occur at the same place and could thus be recorded.

This technique has interesting possibilities in connection with constructing an x-ray microscope. Although the image would be astigmatic in the aforementioned arrangement, it would be possible to get an axial arrangement by combining two mirrors (with central holes) similar to the arrangement in an optical reflection microscope. But, unlike the optical case, the wavelength of a ray reflected by the first mirror is dependent on its angle of incidence, and very special conditions have to be satisfied by the second mirror if each ray is again to be incident at the Bragg angle on it. These conditions have been worked out, and the results of the theory will be published elsewhere. It is found that the accuracy in setting of the two mirrors is of the same order as that required in a double crystal spectrometer.

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