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PRELIMINARY EVALUATION OF A SPHERICAL BRAGG X-RAY CRYSTAL

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Preliminary Evaluation Of A Spherical Bragg X-ray Crystal

Louis N. Koppel and Lawrence V. Knight

Curved diffraction crystals have been chosen as one of several classes of advanced x-ray optic components that could be used in x-ray back-lighting and target imaging diagnostics.

Recently, preliminary measurements were taken to demonstrate the quality of narrow spectral band, two-dimensional imaging of a specially-shaped quartz x-ray diffracting crystal. The sample crystal, built by Hewlett-Packard Corporation originally as an x-ray concentrator for ESCA instruments, is elastically-bent into a concave spherical shape with a 38.0 cm radius. The evaluation consisted of back-illuminating a fine wire mesh, located off the focal circle of the crystal, with a monochrome of aluminum K radiation and observing the quality of the grid-shadowed pattern diffracted by the crystal. The experiment was performed in a vacuum diffractometer located in the L-Division x-ray calibration facility in Building 255. While the actual spatial resolution limit of the crystal was not measured, we did demonstrate that this limit is significantly less than 50 microns.

Consider in Figure 1, a crystal that is elastically-bent so that its diffracting planes conform to a circular arc of radius r_1 . This is called the Johann crystal geometry, for which a focusing circle exists with a radius half that of the radius of curvature. The focusing of a source point on the circle to a corresponding image point is nearly perfect in the plane of

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dispersion. For any single angle of incidence θ of source point rays on the crystal, astigmatism is eliminated by imposing a second curvature normal to the plane of dispersion of radius $r_2 = r_1 \sin^2 \theta$. When the crystal is used to diffract x-rays near its long wavelength limit; that is, at large values of θ ; then r_2 approaches r_1 and a spherical crystal can produce a satisfactory two-dimensional image of the source point. In the present experiment, the wavelength of the aluminum monochrome was $8.337 \text{ \AA}$, the 2d spacing of the (10·0) planes of quartz was $8.512 \text{ \AA}$, and the angle of incidence was thus 78.35° .

Due to equipment restraints, we were not able to obtain the data that would best characterize the spatial resolution of the crystal, the point spread profile of a small source point on the focusing circle. We did, however, place a fine mesh across the fan of radiation passing through an aperture on the circle and photograph the crystal-diffracted image of the mesh. The layout of the experiment is shown in Figure 2. The spherical crystal was mounted at the center of the diffractometer chamber on a rotating, externally-controlled table. The aperture, a pinhole $62 \text{ }\mu\text{m}$ in diameter, was placed 37.2 cm forward of the crystal, which is the calculated chord length for $\theta = 78.35^\circ$ and $r_1 = 38.0 \text{ cm}$. The pinhole was back-illuminated by a aluminum anode in a Henke x-ray tube. The peak applied high voltage was 8 kilovolts , which produced a strong aluminum line over a low energy continuum.

A thin-window proportional counter in the diffractometer was used to align the crystal at the required value of θ . With the counter locked at the proper 2θ position, the crystal was carefully rocked until a maximum diffracted signal was obtained. A 500 wire/inch grid was then placed across the incident

beam, 19.25 cm forward of the crystal, and a piece of type AA film was located in front of the proportional counter, an equal distance from the crystal. The radiograph shown in Figure 3 resulted from a 8400 second exposure. Since the wire-to-wire spacing of the grid is 50 μm and the grid pattern is discernible in Figure 3, the resolution limit of the crystal in this experiment must be significantly less than 50 μm .

Having demonstrated the ability of the spherical crystal to transfer a monochromatic x-ray image with a resolution high enough to maintain our interest, we plan to return to the laboratory in late July to perform the point spread profile measurement and investigate the crystal's imaging properties at shorter wavelengths.

Figure 1

Figure 2