Notes and News

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APS Stores and Extracts Beam!

At 7:13 am on Sunday morning, 26 March 1995, X-rays were extracted from the Advanced Photon Source storage ring and delivered to 1-BM-A, the first optics enclosure on the experiment floor at Sector 1's (SRI-CAT's) bending-magnet beamline.

Commissioning of the APS storage ring began officially on Saturday 18 March 1995, with two complete turns of the beam. Excellent progress continued during the week, with several hundred turns achieved by mid-week. Very early Saturday morning, 25 March 1995, the first r.f. capture occurred, and a beam lifetime of 15 min (more than 10^8 turns) was achieved. At 7:13 am on 26 March 1995, with all of the APS systems functioning satisfactorily, the beamline shutters were opened on beamline 1-BM and the X-rays produced at the bending magnet were allowed to enter the first optics enclosure. A fluorescent screen in the first optics enclosure (1-BM-A) recorded the X-rays.

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Perfect Crystals in the Asymmetric Bragg Geometry as Optical Elements for Coherent X-ray Beams

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Perfect crystals in the asymmetric Bragg geometry are evaluated as optical elements for manipulating coherent X-ray beams. Such optics can be used to modify the transverse coherence length of a synchrotron X-ray beam, with the intention of increasing the usable coherent flux. The wavelength range, angular divergence and flux of X-rays passing through a pinhole aperture are examined in detail, as functions of source and pinhole size, crystal-to-pinhole separation and the asymmetry factor. In developing this analysis, the behavior of asymmetrically cut crystals is explained in reciprocal space, with reference to the crystal truncation rod associated with the reflection. The results show that, for synchrotron beams that are collimated to a small fraction of the incident Darwin width, the wavelength range accepted by the crystal is typically dispersed into an angular spread in the exit beam. This chromatic aberration greatly reduces the transverse coherence length in a manner that does not conserve the coherent flux. The calculations are in agreement with measurements of the divergence and flux through a micrometer-sized pinhole using a synchrotron wiggler X-ray source.

Keywords: perfect-crystal optics; coherent X-ray beams; coherent flux; dynamical diffraction; crystal truncation rod.

1. Introduction

Understanding the behavior of perfect crystals as X-ray optical elements is becoming increasingly important as the collimation of synchrotron X-ray sources increases. In the past, the angular divergence of the source was generally significantly larger than the angular acceptance (Darwin width) of a crystal monochromator. In contrast, the divergence of the beam emitted by an X-ray undulator at a third-generation synchrotron ($\sim$20 µrad) is smaller than the Darwin width of a typical monochromator crystal. Under these new conditions, it is necessary to understand the detailed optical behavior of diffracting crystals, such as the exact angles the exit beam makes with respect to the incident beam, on a scale finer than the Darwin width. These properties are especially important for the manipulation of *coherent* X-ray beams, which have typically been collimated to a small fraction of the total source divergence.

The use of coherent X-ray beams is a new area of research in X-ray science, made feasible by recent large increases in the brilliance of X-ray sources. This development is exciting because many powerful experimental techniques that rely on coherent illumination have previously been limited to visible wavelengths, where high-brilliance sources (*e.g.* lasers) are available. Such techniques can now be considered at hard-X-ray wavelengths. With advantage taken of the small wavelength and relatively large penetration depth, X-ray speckle patterns from antiphase domains in a binary metal alloy have already been observed (Sutton *et al.*, 1991). Techniques such as X-ray intensity-fluctuation spectroscopy (XIFS) and Fourier imaging of atomic sized structures with coherent X-rays are currently under development (Dufresne *et al.*, 1992; Brauer, Stephenson, Sutton, Brüning *et al.*, 1995). For each of these techniques it is essential to obtain the maximum coherent flux, and to control the spatial and angular size and the wavelength content of the coherent beam. In this paper, we will focus on the use of asymmetrically cut perfect crystals to influence these properties of the X-ray beam.

Although synchrotron sources emit incoherent radiation, coherent X-ray illumination may be obtained by selecting a sufficiently collimated and monochromatic portion of the light. The longitudinal coherence length d_l is determined by the range of wavelengths $\Delta\lambda$ through the relation $d_l = \lambda^2/2\Delta\lambda$. A typical symmetrically cut Si(111) monochromator gives $\Delta\lambda/\lambda \simeq 1.3\times10^{-4}$, so that the longitudinal coherence length is about 0.3 µm for $\lambda = 0.10$ nm. The transverse coherence length d_t is determined by the divergence D through the relation $d_t = \lambda/2D$. In the absence of optical elements which affect the collimation, the divergence at a point is equal to the angle subtended by the source. At a distance $L = 30$ m from a source of size $A = 300$ µm one obtains $D = A/L \simeq 10$ µrad, which gives $d_t \simeq 5$ µm. A pinhole aperture several micrometers

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