14-Diffraction Physics and Optics

14.01 – X-ray Optics for Synchrotron Radiation

MS-14.01.01 X-RAY OPTICS FOR THIRD GENERATION SYNCHROTRON SOURCES: NEW DEVELOPMENTS AND FIRST EXPERIENCE AT THE ESRF. Andreas K. Freund, European Synchrotron Radiation Facility Grenoble , France

The low emittance and high brilliance of third generation synchrotron sources require a substantial research and development effort in the domain of x-ray optics in order to be capable of preserving the beam quality from the source along the beamline until the sample under study.

At the ESRF we have developed new techniques for cooling, focusing, polarization, etc. During the past seven months the performances of several optical elements under full load have been studied on four different beamlines fed by undulators and high powder wigglers.

Results of these test experiments will be presented for various devices and techniques such as microfocusing by Bragg–Fresnel optics and by glass capillaries, focusing by bent crystals, progress in adaptive mirror optics, cryogenic cooling, diamond coated optics, thin crystal monochromators.

This presentation will be followed by an outlook on ongoing projects and on the most likely performances of future devices.

MS-14.01.02 HIGH HEAT LOAD OPTICS AT THE ADVANCED PHOTON SOURCE. By W. K. Lee* and D. M. Mills, Advanced Photon Source, Argonne National Laboratory, Argonne, IL 60439, USA.

At 100 ma ring current, the 2.5 m insertion devices at the Advanced Photon Source (APS) are capable of producing up to 5 kW total power and up to 150 W/mm^2 peak power density. Optical elements placed in such a beam will suffer considerable thermal distortions unless they are properly cooled. These distortions will dilute the brilliance of the synchrotron radiation. The APS has embarked on an aggressive program designed to develop solutions for this problem. The techniques being developed include liquid metal cooling, novel crystal geometries, cryogenic cooling and novel materials. One of the more promising approaches to this problem is the inclined crystal, which has been pioneered and developed by the APS staff. Recent experimental and computer modeling results of the inclined crystal performance indicate that this may provide an acceptable solution to the high heat load problem for the APS. Details of this will be presented along with a brief overview of the APS high heat load program.

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PRODUCTION OF 0.1 TO 5 MICRON DIAMETER X-RAY BEAMS AND THEIR APPLICATION TO X-RAY CRYSTALLOGRAPHY. By D. H. Bilderback*, S. A. Hoffman, & D. J. Thiel, CHESS and Applied Physics, Cornell University, USA.

We have produced x-ray beams of 0.1 to 5 micron dimension by passing larger diameter x-ray beams through a hollow tapered glass tube. The x-rays are squeezed to a smaller cross section as they undergo successive total reflections from the smooth inner wall of this 'x-ray funnel'. The capillaries we have pulled are made from leaded glass (density=5.2 g/cm^3) tubing with an inside bore of either 20 or 40 microns. Typical lengths for these tapered needles are 10 to 20 cm. Samples are placed within a few microns of the tip to minimize the effect of a slightly diverging x-ray beam. There are many uses for these miniature hard x-ray beams including diffraction, imaging, spectroscopy, etc., from a small part of a sample.

We are just beginning to investigate the x-ray crystallography impact of this technology on the study of tiny crystals. The kind of information that can be obtained from crystallography includes not only the orientation, 3-d structure, mosaicity, but also information on the local stress of a crystallite in a larger polycrystalline matrix of material.

One of the first questions to answer is how small of a sample can be studied? This is a question of the combined strength of the x-ray source, the gain of the x-ray optics, the scattering power of the sample, and the efficiency of the detector. Since the observed diffracted intensities are generally proportional to the volume of sample illuminated, the smallest samples will always demand a very powerful x-ray source and efficient optics. To date with our optics, we have observed intensity gains of up to 1000 and have made beam sizes down to 0.1 microns.

We have recently made Laue diffraction images with a 5 micron diameter beam, utilizing white bending magnet radiation from CHESS on a biological single crystal, lysozyme. Well-exposed and spatially-resolved Laue patterns were obtained on film with a 120 second exposure time, but currently the main problem is radiation damage. The sample had to be translated every 25 seconds during the exposure period in order to keep exposing fresh volumes to a damaging x-ray beam. With cryogenic cooling added, we hope that stationary exposures from even much smaller diameter beams will be possible. If so this method may lead to the study of the 3-d structure of medically important crystals that refuse to grow to a size big enough to handle by more standard methods.

With materials science type of samples (silicon and gold single crystals), we have been able to obtain Laue patterns in 300 seconds of exposure for beam sizes 0.3 micron diameter or smaller. Well shaped round Laue spots from a (100) silicon wafer showed the divergence of our small beam to be less than 8 mr. We observed Laue streaks from a somewhat stressed or slightly disordered 500 Angstrom thick gold crystal foil. The volume illuminated was 0.3 micron diameter by 0.05 microns, or 3.5 x 10^{-3} μ^3. The Laue spots were radially streaked, consistent with a mosaic spread of several degrees.

These and other experiments that are underway with this microbeam technology will be discussed.

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PERFECT-CRYSTAL X-RAY-OPTICS FOR PRODUCING AND CHARACTERIZING CIRCULAR POLARIZATION WITH SYNCHROTRON RADIATION. By T. Ishikawa*, K. Hirano and S.Kikuta, Department of Applied Physics, University of Tokyo, Japan.

Dynamic x-ray diffraction leads to different dispersion relations between σ and π states which is well known as *diffractive birefringence*. Perfect crystal x-ray phase retarders based on this effect are, in principle, attainable for all conceivable diffraction geometries, i.e. reflection and transmission in both Bragg and Laue geometries. Properties of the phase retarders in each geometry are discussed.

