High Heat Load Crystal Optics Experiments
at the NSLS X25 X-Ray Wiggler Beam Line

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The X25 hybrid wiggler beam line¹ at the National Synchrotron Light Source (NSLS) offers a unique environment for testing x-ray optics under high-power and high-power-density loadings. Conditions that are encountered at existing insertion device beam lines, and those that are expected at third-generation beam lines, can be simulated at X25. Tests can be performed with the direct, unfocussed wiggler white beam, in which 300 W of total power in a 60 mm wide by 5 mm high cross-section are available in the experimental hut; this is representative of present insertion device beam lines. A portion of the wiggler white beam can be focussed via reflection from a toroidal platinum-coated silicon mirror, resulting in 75 W of total power in a 0.8 mm wide by 0.4 mm high cross-section. This will be a typical power density at third-generation insertion device beam lines when they become fully developed. The test apparatus includes analyzer crystal, filter, and scanning pinhole diagnostics which allow spatial and angular mapping of both fundamental₂₋₄ and harmonic Bragg reflections within the beam footprint to be undertaken. Thus both mechanical and thermal strain fields within the crystal optic under study can be quantified.

Crystal optics designed for use in the unfocussed wiggler beam were studied initially. Tests of directly² and indirectly-water-cooled^{1,5} thin silicon crystals revealed relatively small Bragg angle variations, resulting in near-perfect performance for fundamental Bragg reflections. These designs were later improved to include provision for adaptive compensation of the strain fields, and test results using harmonic_{4,6} Bragg reflections showed nearly complete cancellation of the strains. Thus passive water-cooling methods for silicon monochromators employing fundamental Bragg reflections are sufficient for present high-power beam lines.

When subjected to the focussed wiggler beam, uncompensated silicon crystals suffer severe thermal strains which render them unsuitable even as fundamental reflection monochromators. Two general approaches that can be used to minimize such strains were studied. In one, the crystal design includes provision for adaptive compensation as noted above.³ The second approach involves avoiding thermal strains to begin with, using various techniques. In one, the surface power density⁷ is lowered by tilting the crystal about an axis in the scattering plane. In another, a very thin crystal can be designed to allow most of the incident power to be transmitted.⁸ Thirdly, a crystal can be cooled to cryogenic temperatures to enlarge its thermal conductivity and minimize its thermal expansion coefficient.⁹ Finally, an alternate crystal material with superior room-temperature mechanical and thermal properties, such as diamond, can be substituted for silicon.^{10,11} Test results at X25 for each of these cases will be presented. Mosaic crystals whose x-ray diffraction properties are less sensitive to thermal strains can also be used when preserving the high source brightness isn't necessary; relevant test results will also be discussed.^{12,13}

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