Crystal optics for 0.3 eV energy resolution

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A channel-cut silicon monochromator and bent germanium backscattering analyzer were tested using first harmonic radiation at 7.59 keV from the CHESS-ANL undulator.[1] A value of 0.30±0.07 eV was obtained for the FWHM of the elastic peak in the spectrum of radiation scattered from C_{60} crystals in powder form.

The optical arrangement of the experiment is shown schematically below. A Si(111) double-crystal monochromator with crystals cooled with liquid gallium was used to monochromate the white beam to a bandwidth of 1 eV. A channel-cut Si(620) monochromator was then inserted into the beam path to reduce the bandwidth. In order to obtain high efficiency, the acceptance angle of the channel-cut was matched to the vertical divergence from the undulator by cutting the crystal to have a 13° angle of incidence. We calculated the bandwidth to be 0.15 eV.

The analyzer was constructed by waxing a 0.25-mm-thick (111) oriented germanium wafer to a spherically concave glass form having a radius of 1 meter. A focal spot size of 5 mm diameter for x-rays was measured for the central 50-mm diameter area of this optic. The bandwidth of the analyzer was calculated by applying x-ray dynamical diffraction theory to a spherically bent crystal,[2] and we obtained a value of 0.14 eV.

We used a silicon avalanche photodiode (APD) as a detector. This device had a 9 mm square active area and a time response sufficiently fast to permit discrimination of background counts based on a time-of-flight (TOF) analysis. That is, using the pulsed nature of the photons produced by CESR, we arranged to count only those photons with a TOF corresponding to the travel time from the sample to the detector via the analyzer (≈6 ns).

The measured value for the resolution, 0.30±0.07 eV, is to be compared with the quadrature addition of the calculated resolutions of the Si(620) monochromator and the Ge(444) analyzer, 0.20 eV.

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