# Spectral Measurements & Synchrotron Radiation Calculation Comparisons of the New X25 Mini-Gap Undulator (MGU)

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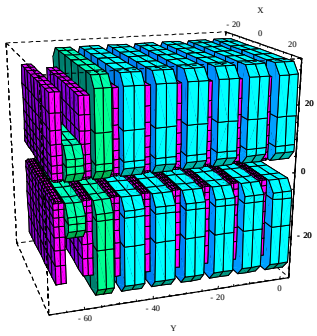
At the start of 2004, NSLS beamline X25's programmatic focus shifted completely to monochromatic macromolecular crystallography, following 14 years of operation as a mixed-use high-brightness beamline. During the winter 2006 shutdown, the original X25 hybrid wiggler, which served as the radiation source for beamline X25 since its inception in 1990, was replaced by a custom-designed in-vacuum miniature gap hybrid undulator. The new radiation source is 15 times brighter than the original one at 6.3 keV, and 6 times brighter at 10.5 keV. Its design consists of ~1 m long planar hybrid magnet arrays with a period length of 18 mm (56 periods total) and a minimum attainable gap of 5.6 mm, with corresponding maximum field of 0.95 T and maximum deflection parameter K of 1.59. It also incorporates provision for cryogenic operation (in order to attain an even higher field and higher K, by 13-14%), which may be implemented in the future.

**The X25 MGU in the magnetic measurement laboartory**

**First few periods of undulator magnet array.** Improved end design maximizes number of poles radiating in-phase, beginning with pole #3. The two special end magnets (green) are reduced in height and/or thickness.




Expected performance vs. Remanence:

| | | | |
|---|---|---|---|
| $B_{rem}$ (T) | 1.2(1) | 1.3(2) | 1.45(3) |
| $B_{peak}$ (T) | 0.83 | 0.90 | 1.00 |
| K 1.40 | 1.52 | 1.69 | |
| $E_1$ (keV) | 2.1 | 1.92 | 1.70 |
| $E_3$ (keV) | 6.3 | 5.76 | 5.1 |
| $E_5$ (keV) | 10.5 | 9.6 | 8.5 |

Notes:

(1) Same NdFeB grade as X13 & X29 MGU

(2) New "hybrid car motor" grade @ 20ºC (used at X25)

(3) New grade cryo-cooled @ -120ºC (X25 potentially)

**X25 MGU Measurements**

• Using a single-crystal x-ray spectrometer and a well-defined x-ray beam dimension (white-beam), the energy-dependent photon flux was measured as a function of magnetic gap opening.

• The magnetic fields and deflection parameters were determined by measuring the position of the undulator harmonics.

• The energy-dependent photon flux measurements were converted into brightness by using silicon reflectivity values, taking into consideration x-ray absorption through beamline windows & flight paths, and using measured source-size dimensions.

• The SPECTRA (version 8.0) synchrotron code was used, in association with previously measured source-size values, to determine the emittance of the NSLS x-ray ring by fitting the measured undulator spectra, which were found to be consistent with a horizontal emittance of 62 nm rad and a 0.4% coupling.

**X25 MGU Measured Values**

| | |
|---|---|
| Periodic Length | 1.8 cm |
| Total Length | 1.02 m |
| Number of Periods | 56 |
| Peak On-Axis Field, B | 0.948 T to 0.675 T (5.6 mm to 7.3 mm) |
| Deflection Parameter, K | 1.594 – 1.135 (5.6 mm to 7.3 mm) |

**Undulator Equations**

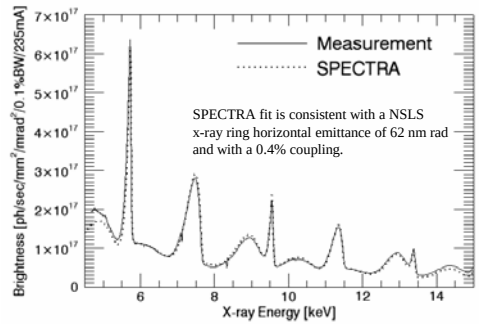
$$\lambda = \frac{\lambda_u}{2n\gamma^2}\left(1+\frac{K^2}{2}\right), \quad K = 0.934\,\lambda_u\,[\mathrm{cm}]\,B[\mathrm{Tesla}]$$

$\lambda$=x-ray wavelength, $\lambda_u$ =magnetic period

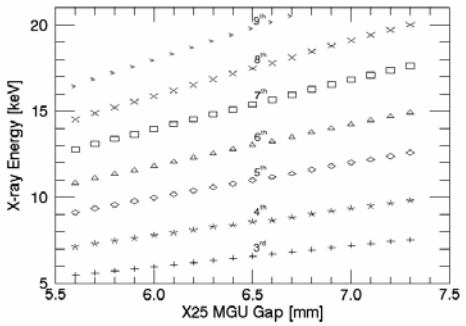
n=undulator harmonic

$\gamma$=relativistic factor, K=deflection parameter

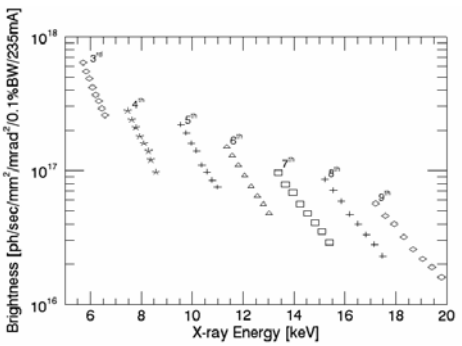
B=peak on-axis magnetic field




**Comparison of X25 Undulator Spectrum at a gap opening of 5.8 mm with a "best fit" from the SPECTRA synchrotron radiation code, which corresponds to a horizontal emittance of 62 nm rad and a coupling of 0.4 % for the NSLS x-ray ring.**




**Measured x-ray energy locations of the X25 MGU harmonics (3rd – 9th) as a function of magnetic gap openings of 5.6 to 7.3 mm.**




**X-ray energy dependent brightness measurements of the X25 MGU harmonics (3rd – 9th) at magnetic gap openings of 5.8, 5.9, 6.0, 6.1, 6.2, 6.3, 6.4 and 6.5 mm.**

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