Optics for Macromolecular Crystallography (MX) Beamlines Being Planned for NSLS-II

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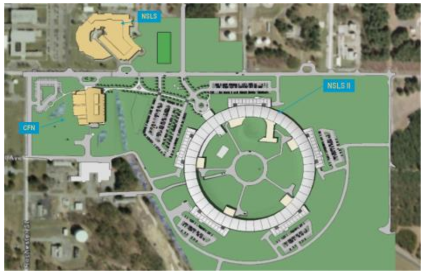
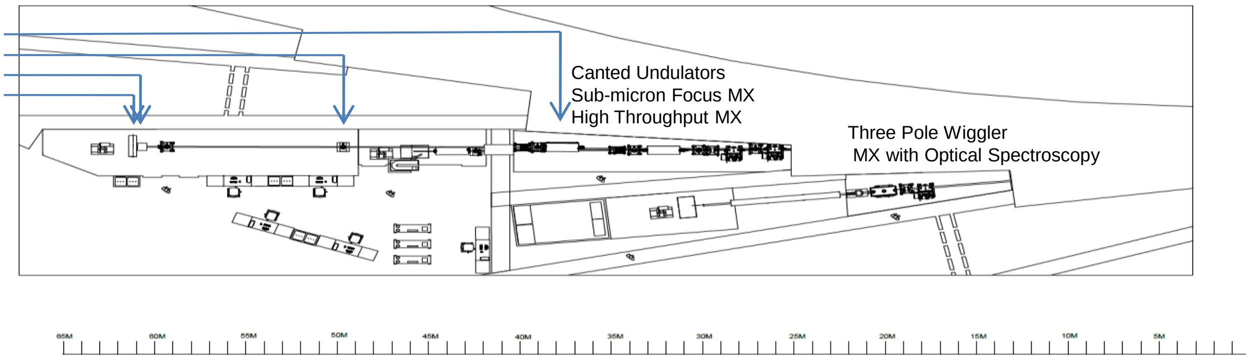


A new, highly-optimized 3rd-generation synchrotron radiation source, the National Synchrotron Light Source -II (NSLS-II), is being constructed as a replacement of the existing 2nd-generation SR source NSLS at Brookhaven National Laboratory (BNL). When NSLS-II becomes operational in 2015, it will deliver unprecedented brightness in the soft and hard x-ray spectral regions, about 10 times higher (at 8 keV) than the brightest SR sources now available.

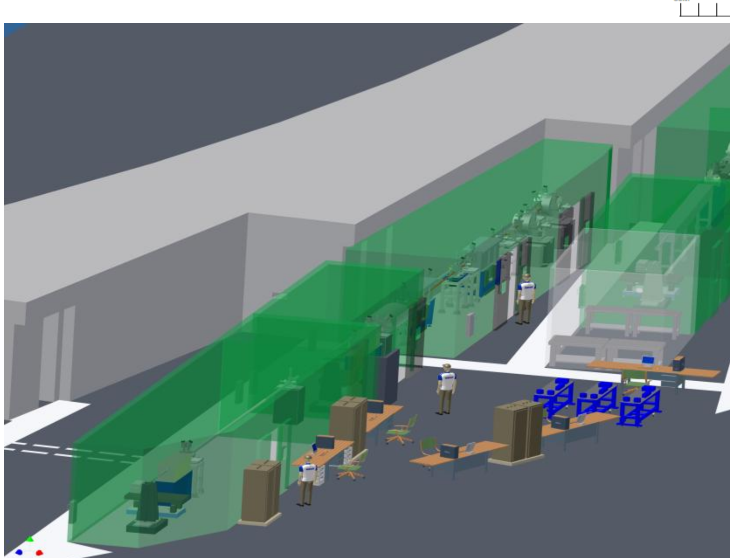
The NSLS-II short straight section insertion device source dimensions and opening angles are 66 µm (h) x 6 µm (v) and 45 µrad (h) x 7.5 µrad (v) respectively (all values FWHM).

Achieving a 1 µm beam dimension in the vertical direction in the experimental hutch should not pose a great difficulty for the beamline optical system. Focusing optics employing a modest demagnification factor of 6:1 (for perfect optics) would suffice in the vertical direction. However, because the residual slope error of the final focusing element may predominate in determining the beam size in the vertical direction at the focal position, the focusing element might be located rather close to the focal position, 1 m or less. The resulting demagnification factor, 50:1 or greater, would still be tolerable as far as impact on the vertical beam divergence is concerned.

Achieving a 1 um beam dimension in the horizontal direction in the experimental hutch poses a greater challenge, due to the required demagnification factor of 66:1. This would give rise to a horizontal beam divergence, at the focal position, of 3 mrad, too high for state-of-the-art macromolecular crystallography. Thus, the first order of business in the beamline optical system would involve trimming down the horizontal source divergence by, say, a factor of 3, and this would most likely be carried out using an aperture in the beamline front end. In this case, the horizontal beam divergence at the focal position becomes 1 mrad.



Following each double crystal monochromator in the canted undulator beamlines will be a tandem pair of deflecting mirrors deflecting the beam in opposite directions, with each tandem pair imparting a net angular deflection of 12-16 mrad (depending on whether the incident angle on each mirror is 3 mrad or 4 mrad). For the one micron beamline, one of these mirrors will actually be curved, not flat, as it will serve as the first demagnifying horizontal focusing mirror. The result of these deflections, plus the intrinsic 2 mrad canting angle between the undulator beams, will allow a separation of up to about 0.4 m between the two beams at the location of the focal position in the upstream (high throughput) experimental hutch.



We've chosen to investigate an approach involving two-stage demagnification in the horizontal direction instead of one-stage, to afford the opportunity to control the effective source dimension. This is the approach which the NSLS-II SRX beamline is pursuing in its beamline optical design, although its goals are different. The following table summarizes the horizontal beam size and divergence at particular locations along the beamline (mirror slope errors are assumed to be 0.25 µrad).

Location (m from source)	Horizontal size (µm)	Horizontal divergence (µrad)
source, 0 m	66	45
234 µm wide front end slit, 20 m	234	15
3.17:1 demag horizontal focus mirror, 38 m	504	15 (incident)
secondary source aperture, 50 m	27	47
2nd 22:1 demag horiz focus mirror or lens, 61 m	490	47 (incident)
final focal position, 61.5 m	1.5	1045

The above arrangement is what is sketched out in the beamline layout. The long experimental hutch, where the 2nd demagnifying horizontal focusing mirror and secondary source aperture are located, permits significant flexibility in positioning these components for best performance. Note that a final focal position beam width of smaller than 1.5 µm is easily realized, in this two-stage optical scheme, by reducing the width of the secondary source aperture to be less than 27 µm. In a single-stage demagnification scheme, this sort of approach is possible only by reducing the width of an aperture along the beamline to define a new secondary source, discarding significant intensity in so doing since there is no secondary focal point at which this can be done.

We calculate that flux through a 100 micron square aperture at 12 keV at the high-throughput beamline will be 1x10^{13} ph/sec with 0.1 mrad horizontal and vertical divergence, and at the three pole wiggler will be 1x10^{11} ph/sec with 1 mrad divergence. For a 1 micron beam (FWHM) at the sub-micron beamline, we calculate that the flux will be 1x10^{12} ph/sec with divergence of 1 mrad horizontal.

For more information about NSLS-II, visit http://www.nsls2.bnl.gov. For more information about macromolecular crystallography at NSLS, visit http://www.px.nsls.bnl.gov.

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