# NSLS II: THE FUTURE OF THE NSLS*

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*Abstract*

The National Synchrotron Light Source at BNL was the first dedicated light source facility and it has now operated for more than 20 years. During this time the user community has grown to more than 2400 users annually. To insure that this vibrant user community has access to the highest quality photon beams, the NSLS is pursuing the design of a new ultra-high brightness ($\sim 10^{21}$) electron storage ring, tailored to the 0.3-20 KeV photon energy range. We present our preliminary design and review the critical accelerator physics design issues.

## INTRODUCTION

The NSLS VUV and X-ray rings have operated for more than 20 years for a user community which exceeds 2400 user per year. Numerous improvements to these rings have been carried out over the years but now to continue to advance and to open new scientific vistas a new photon source is required. After close consultation with the NSLS user community and the DOE/BES a preliminary design of a 3 GeV ultra-high brightness ($\sim 10^{21}$) electron storage ring tailored to the 0.3-20 KeV photon energy range has been developed. A conceptual rendering of the proposed NSLS-II complex is given in Figure 1.

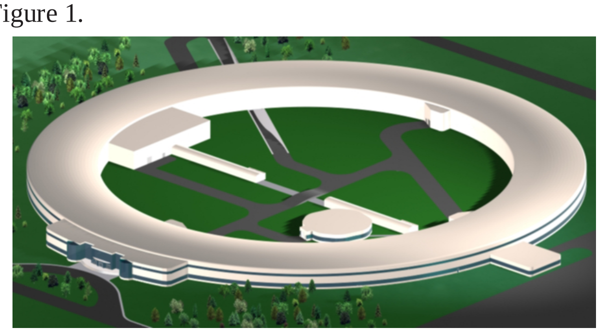

Figure 1: Conceptual layout of the NSLS II complex.

## NSLS II MACHINE

### *Machine Overview*

The goal of the machine design was to achieve a brightness $\sim 10^{21}$ ph/sec-mrad$^2$-mm$^2$-0.1%BW in the 0.3-20 KeV photon energy range with ~ 20 insertion devices. To minimize the construction and operating cost of the machine, an energy of 3 GeV was adopted which together with a 24 cell triple bend achromat (TBA) lattice results in a nominal emittance of ~1.5 nm. The main parameters of the preliminary storage ring design are listed in table 1.

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Table 1: NSLS II storage ring parameters.

| | |
|---|---|
| Nominal Energy [GeV] | 3 |
| Circumference [m] | 630 |
| Superperiods / Type | 24 / TBA |
| Straight Section Length [m] | 7 |
| Natural Emittance [nm] | 1.4 |
| Betatron Coupling [%] | 0.5 |
| Momentum Compaction | 0.000166 |
| Bend Radius [m] | 8.4 |
| Betatron Tunes H/V | 37.45/13.44 |
| Energy Spread [%] | 0.09 |
| RF Frequency [MHz] | 500 |
| RF Acceptance [%] | 3-4 |
| Natural Bunch Length [ps] | 12 |
| Current [Amp] | 0.5 |

A comparative estimate of the brightness of the existing NSLS-I rings and the proposed NSLS-II ring is given in Figure 2 below.

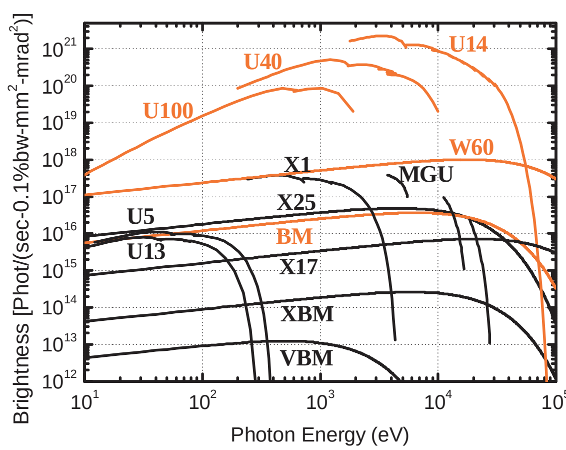


Figure 2: Brightness comparison of the existing NSLS-I (black) and the proposed NSLS-II (red).

### *Storage Ring Lattice*

The baseline lattice design is a 24 cell triple bend achromat (TBA) lattice with 7 meter straight sections. Reduced periodicity lattices (4 or 6) are also being explored to accommodate longer straight sections for injection and extended insertion devices. The Twiss parameters for one superperiod of this lattice are shown in Figure 3. Work is ongoing to optimize the sextupole arrangements to maximize the dynamic aperture for a large energy acceptance of $\delta$ = 3-4% to provide a good Touschek lifetime [1].



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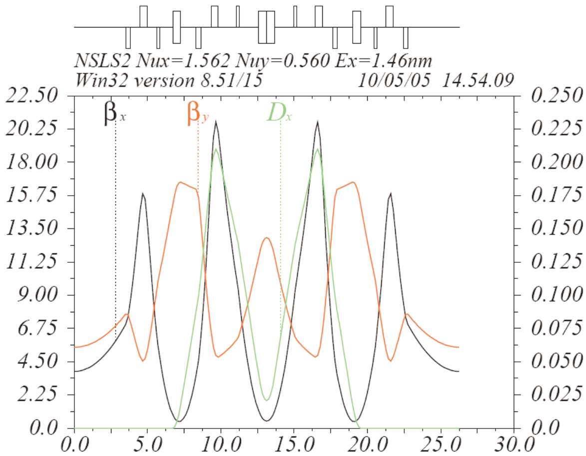


Figure 3: TBA cell for NSLS II ring.

### *Radiofrequency (RF) Systems*

Our plan is to use superconducting 500 MHz single cell cavities, but improved over existing designs to include two antenna type couplers per cavity to increase the power/cavity to reduce the number of cavities. As can be seen from Table 2 the radiation loss from the insertion devices has a strong effect on the required RF voltage [2].

Table 2: NSLS II RF parameters including IDs.

| | No IDs | All IDs |
|---|---|---|
| Synchrotron losses, kW | 426 | 1127 |
| Energy loss per turn, MeV | 0.85 | 2.25 |
| Total RF voltage, MV | 1.87 | 3.49 |
| RMS bunch length, mm | 3.8 | 3.3 |

Incorporating a third harmonic bunch lengthening RF system is planned to improve the Touschek lifetime, reduce resistive heating to insertion devices and to help combat collective instabilities. The electron bunch train will include a gap (~ 85% filled) to allow for ion clearing and the effects of this gap on the lifetime gain and bunch shapes has been studied [2].

### *Injection System*

Two alternate top off injection systems are being explored to determine the best option in terms of cost, performance and future development; 1) a 60 Hz, 3 GeV S-band linac operating in SLED mode with a pair of linac sections fed by a single klystron or 2) a low energy linac combined with a 3 GeV low emittance booster synchrotron cycling at 3-10 Hz [3]. Presently the linac is the preferred option as is provides for future development.

## INSERTION DEVICES

For a medium energy ring one desires as short of an undulator period as possible while maintaining K ~ 2.2 to provide good tuning between harmonics in the 2-20 keV range. To achieve this with a reasonable gap (4-5 mm) we are exploring superconducting undulators (SCU) with $\lambda_u$ ~ 14 mm. Both planar and variable polarization helical devices are being explored [4]. The designs are based on "APC-type" NbTi superconductor and they incorporate a novel cryogenic thermal management system.

Efforts toward the development of an SCU for NSLS-II advanced with the design and construction of a state-of-the-art cryogenic Vertical Test Facility (VTF), now completed and undergoing testing (Figure 4) [5]. This device will allow precise magnetic field mapping of SCU models up to 0.4 m long, using a motorized Hall probe array which has been calibrated at both room temperature and in liquid nitrogen against a NMR standard. An in-situ superconducting Helmholz coil will provide a calibration check in liquid helium. The apparatus also incorporates three channels of liquid He calorimetric instrumentation to measure thermal performance and quench behavior for a realistic operating scenario, including simulated beam heating. A pulsed-wire insert, interchangeable with the Hall probe mapper is also being developed to provide a complementary magnetic measurement technique.

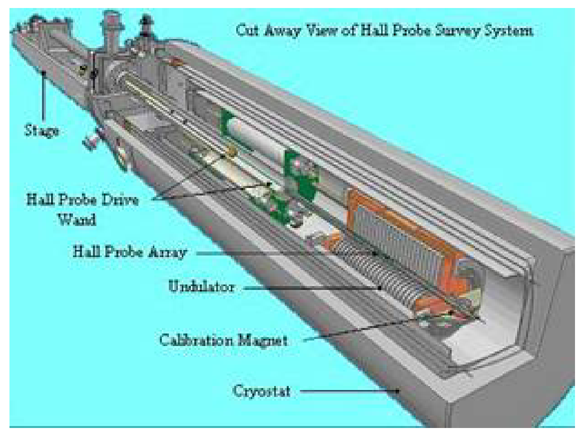


Figure 4: SCU VTF measurement apparatus.

## COLLECTIVE EFFECTS

Since we anticipate ~ 20 small gap insertion devices for NSLS-II, they will likely dominate the vertical impedance which governs single bunch transverse instabilities. In general both the geometric part, due to the tapers, as well as the resistive wall, contributes to this impedance. We are presently planning for fairly shallow tapers (L = 0.5 m on each side, θ = 20 mrad) so that $\sigma_z/\theta$ >> beam pipe radius (see Figure 5).

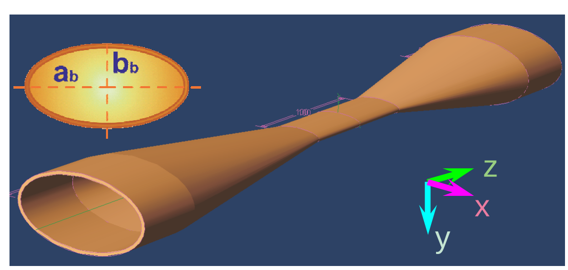


Figure 5: Tapered vacuum chamber for small gap IDs.

Calculations using the GdfidL code to quantify the geometric impedance have been made and estimates of the transverse mode coupling instability thresholds have been performed [6, 7].

For the resistive part, the TMCI threshold was estimated by comparing the resistive wall tune shift to the synchrotron tune. This results in comfortably large thresholds in the case of cold bore SCUs where the extreme anomalous skin effect regime applies to the inner bore pipe.

The CSR instability has been analyzed and was found to be harmless for the NSLS-II parameters due to the vacuum chamber shielding of the CSR impedance.

Multi-bunch instabilities due to the RF cavities, as well as due to the long range resistive wall wake, have been studied analytically and with the ZAP code. Assuming SC RF cavities, the longitudinal coupled bunch instability thresholds exceed the NSLS-II design currents. In the vertical plane a feedback system may be needed mostly due to the resistive wall contribution of the small gap SCUs. While conceptually straightforward this feedback system has some unresolved technical issues, for example stabilizing the motion to a small fraction of the already small vertical beam size.

Another area of concern in case of SCUs is beam driven heat loads. Assuming that the synchrotron radiation from the upstream dipole is well collimated our estimates show that the resistive wall generated heat (~ 5 W/m) dominates the heat load budget for SCUs shorter than ~ 4 m. For longer IDS the heat due to the undulator's own synchrotron radiation takes over. These estimates have prompted the exploration of cryogenic heat removal designs that go beyond the single cryo-cooler which are currently being pursued at the NSLS.

## VUV & INFRA-RED

To continue to serve our vibrant infra-red & VUV user communities we propose to move the existing VUV/IR ring to the new NSLS-II complex and operate it in top-off mode using the NSLS-II injection system. We are presently investigating the possibility of replacing the existing 53 MHz RF system with a 500 MHz SC system to enable an operation mode of the ring as a "coherent IR source" [8].

## PROJECT STATUS

In March 2004 a report detailing the scientific case and mission need for the NSLS II facility was submitted to the DOE for review (see Figure 6) [9]. The preliminary technical design of the NSLS-II complex is continuing as the DOE review process takes its course.

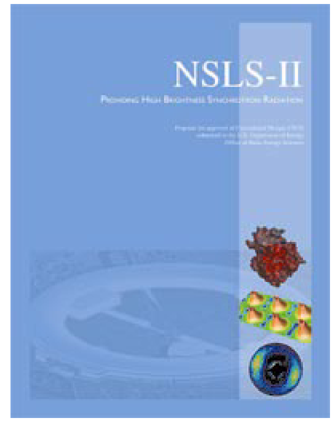


Figure 6: NSLS II Science Case and Mission Need report.

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