ACCELERATOR DIVISION REPORT

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Organization and Mission

The NSLS Accelerator Division (AD), headed by James B. Murphy, is organized into two sections: the Storage Ring & Insertion Device Section (SR&ID), headed by Boris Podobedov, and the Linear Accelerator (Linac) Section, headed by Xijie Wang. In addition to the NSLS accelerator complex, the AD staff operates the Magnetic Measurements Laboratory (MML) and the Source Development Laboratory (SDL), which are led by Toshiya Tanabe and Xijie Wang, respectively.

The NSLS Accelerator Division has a four-part mission:

- To ensure the quality of the electron beam in the existing NSLS booster, linear accelerator, and x-ray & vacuum ultraviolet storage rings
- To participate in the NSLS-II project, in particular the design of the storage ring and injection system
- To operate the MML and the SDL
- To perform fundamental research and development in accelerator and free-electron laser physics.

2006 Activities

NSLS Accelerator Complex

The AD staff performed studies to improve the efficiency and diagnostics of the NSLS injection system. The studies resulted in identifying a loss region near the extraction septum in the booster and led to a better understanding of the injection system performance. Improvements in the diagnostics and controls of the injection system provided for measurement of the electron beam position in the booster at anytime during the booster ramp. During the NSLS May shutdown, the AD staff assisted the Operations and Engineering Division (OED) staff in replacing a 40-year-old klystron with a rebuilt tube resulting in a significant improvement in the reliability of the NSLS linac system.

James Murphy

Close cooperation of all the NSLS divisions contributed to the successful commissioning of the new X25 mini-gap undulator (MGU) after its installation in the winter shutdown. The commissioning included establishing the correct undulator elevation, calculation of the proper trip points for the active interlock system, and assessing the impact of the new insertion device on the beam dynamics and lifetime of the X-ray ring.

The Task Force on Orbit Stability generated its final report and concluded that no major problems were identified. The feed forward system to compensate for the elliptically polarized wiggler (EPW) was significantly improved by the OED staff. A procedure to regularly check the performance of the beam position monitoring (BPM) receivers with an RF calibrator is being explored.

Development of the Middle Layer Toolkit for studying the properties of the VUV and X-ray storage rings continued to make progress. Automated scripts for the evaluation of accelerator parameters were deployed. The scripts provide for calibration of the correctors and BPMs, restoration of the lattice symmetry broken by gradient errors in the sextupoles, and estimation of the quadrupole gradients in the sextupoles due to closed orbit shifts. Studies to determine the minimum emittance coupling in the X-ray ring were very successful, and it was shown that the coupling ratio could be reduced to 0.3%. An improved characterization of the X-ray ring lattice at injection energy (750 MeV) will be launched in the near future.

NSLS-II Project

The accelerator physics staff of the AD provided the core team for the design of the NSLS-II accelerator complex, including the ultra-high brightness storage ring and the top-off booster injection system. A conceptual design report was prepared as part of the qualification process to achieve Critical Decision One (CD-1) approval from the Department of Energy for the NSLS-II project.

While the primary emphasis of the NSLS-II project is the production of ultra-high brightness x-rays, it is highly desirable to continue to provide for state-of-the-art capabilities in the VUV and IR as well. For the IR region in particular, several options were explored, including upgrading the existing VUV ring with a superconducting RF system to provide short bunches for a coherent mode of operation.

Magnet Measurement Laboratory (MML)

The AD staff worked in collaboration with the OED, the User Science Division and an outside vendor to design, construct, and measure the new X25 cryo-ready MGU. The team completed the iterative process of magnetic measurements, shimming, and optimization in time for the December 2005 installation. Magnetic measurements before and after baking at 90°C, as well as before cool down to –120°C and after warm-up to room temperature, confirmed that the high field quality and very low phase error (2.5° RMS) were preserved through the thermal cycling. Also proven were the mechanical design features for accommodating differential expansion and contraction during the extreme temperature excursions, as were the Keyence optical micrometers monitoring the actual magnet gap. Commissioning took place in February 2006. **Figure 1A** shows the measured brightness spectrum at the minimum gap of 5.6 mm, and the theoretical spectrum computed by the SPECTRA code (from SPRING-8) for an ideal undulator; there is excellent agreement between the two results. **Figure 1B** shows the measured tuning curves for the 3[rd] through 9[th] harmonics over the normal range of magnetic gap operation. (Figures courtesy of J. Ablett & L. Berman, NSLS)

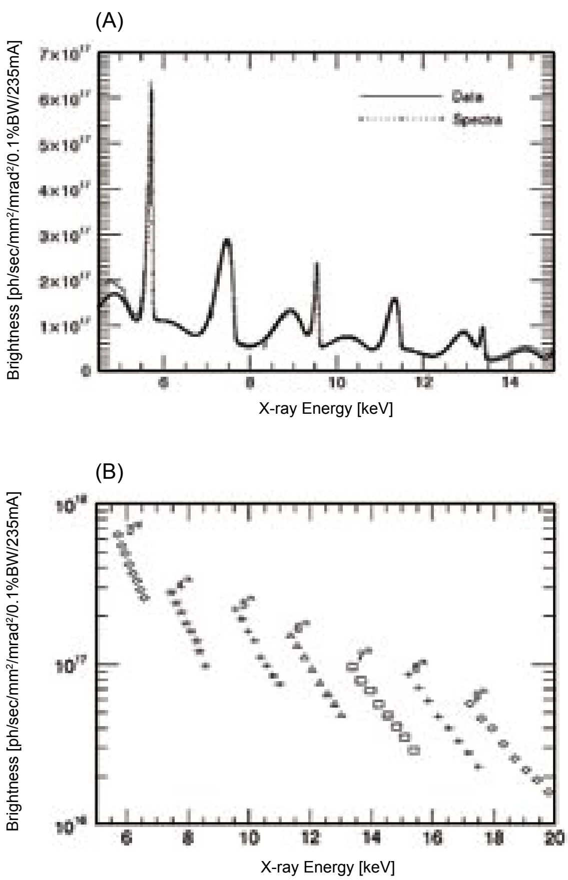

Figure 1. (A) Measured (solid curve) and predicted (dotted curve) brightness spectra of X25 MGU at minimum magnetic gap of 5.6 mm. (B) Measured tuning curves for the 3[rd] through 9[th] harmonics.

The X25 MGU is operating presently with water-cooling only. Cryogenic operation at 150K could extend the tuning range of each harmonic downward by about 10%. Potential benefits of the extended tuning are being weighed against the cost of the refrigeration system and the lack of magnetic measurements at cryogenic temperatures.

The BNL Cryogenic Safety Committee approved the Phase I configuration of the superconducting (SC) undulator Vertical Test Facility (VTF), permitting operation with liquid helium in the pool-boiling mode. For the commissioning test, a SC Helmholtz coil (for in-situ Hall probe calibration) and a refurbished pair of legacy SC mini-undulator sections with 8.8 mm period were used. Field scans were taken over a range of currents from 25 to 150 A. **Figure 2** shows the on-axis field map of the Helmholtz coil and the test SCU at a current of 150 A in both devices. The commissioning run successfully demonstrated the operation of the cryogenic Hall probe mapper and the in-situ calibrator.

In collaboration with BNL Superconducting Magnet Division and HTS110, Inc., the MML staff embarked on a technical study of using high-temperature superconductor (HTS) coils to replace the existing copper coils used in VUV dipoles. Three identifiable benefits from an HTS retrofit are: a significant reduction in electrical power requirements to run the dipoles, a simpler and cheaper current supply, and an increased aperture for beam extraction.

As an LDRD project, the development of cryo-coil packs for an X-ray ring sextupole magnet has been conducted. Fabrication of the cryo-coil packs has been undertaken and a prototype will be tested by the end of FY07.

The 2-meter long strong focusing VISA undulator magnet was completed and measured as part of the Office of Naval Research-funded Free Electron Laser program at the SDL.

Source Development Laboratory (SDL)

The SDL is an ideal platform to conduct R&D on high-brightness electron beams and laser-seeded free electron lasers (FEL). The SDL consists of a Titanium-Sapphire laser, a photoinjector, a 300-MeV linac and a 10-meter undulator. A second year of funding was obtained from the Joint Technology Office (JTO) and the Office of Naval Research (ONR) to pursue high-gain free electron laser amplifier experiments in the infrared wave-

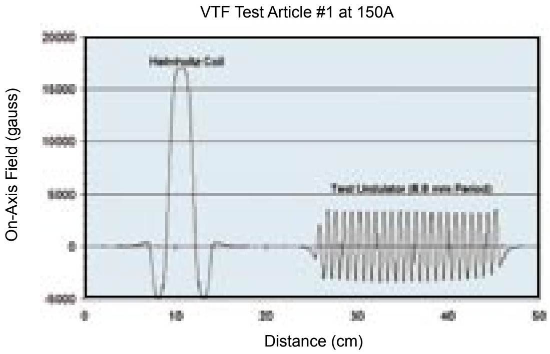

Figure 2. VTF commissioning run with Helmholtz coil and legacy 8.8 mm period SC undulator immersed in LHe. Helmholtz coil provides cold Hall probe calibration up to 1.7 Tesla at 150 A.

length regime. The JTO/ONR-sponsored program included experiments on optical guiding, efficiency enhancement and the first observation of super-radiance in an FEL.

In addition to the work in the infrared regime, new short-wavelength milestones in the ultraviolet region (UV) were also established. UV light at 190 nm was generated by operating the FEL in the Self Amplified Spontaneous Emission mode and the first lasing of the High Gain Harmonic Generation (HGHG) scheme in 4th harmonic mode at 199 nm was achieved. Preliminary results on operating the SDL FEL in the Enhanced Self Amplified Spontaneous Emission mode (E-SASE) were also obtained.

The SDL has the ability to generate very short electron pulses (1 ps FWHM) with high charge (~ 1 nC), which is ideal for the generation of copious quantities of coherent terahertz radiation (THz). The AD worked in collaboration with the NSLS User Science Division and the BNL Instrumentation Division to characterize the high intensity (~ 100 μJ/pulse) single cycle THz radiation. The high-intensity pulses allowed BNL researchers to explore new phenomena such as nonlinear cross-phase modulation (XPM) in electro-optic crystals and preliminary ideas on using the THz as a pump in pump-probe experiments on high-temperature superconductors. The development of an ultra-fast electron diffraction source based on the SDL photoinjector technology is also being considered.