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Insertion Device Activities for NSLS-II

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Abstract

National Synchrotron Light Source –II (NSLS-II) will be a medium energy storage ring of 3GeV electron beam energy with sub-nm.rad horizontal emittance and top-off capability at 500mA. Damping wigglers will be used not only to reduce the beam emittance but also used as broadband sources for users. Cryo-Permanent Magnet Undulators (CPMUs) are considered for hard X-ray linear device, and permanent magnet based elliptically polarized undulators (EPUs) for variable polarization devices for soft X-ray. 6T superconducting wiggler with minimal fan angle will be installed in the second phase as well as quasi-periodic EPU for VUV and possibly high-temperature superconducting undulator. R&D plans have been established to pursue the performance enhancement of the baseline devices and to design new types of insertion devices. A new insertion device development laboratory will also be established.

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I. INTRODUCTION

National Synchrotron Light Source –II (NSLS-II) will provide the electron beam with sub-nm.rad horizontal emittance and 500mA of electron beam current with top-off capability by 2013. 1.8T damping wigglers will be used for both emittance reduction purpose and broadband user hard X-ray source albeit with large power density to be handled. The bending magnet field is chosen relatively weak (0.4T) compared to other light sources in order to minimize the dispersion. As a result, the critical energy of bending magnets is too low for NSLS-I bending-magnet hard X-ray users. Three pole wiggler will be installed at the end of dispersive section to accommodate those users at the expense of small beam emittance increase. The main hard X-ray undulator source will be cryogenic permanent magnet undulator (CPMU) [1], and out-of-vacuum elliptically polarized undulator (EPU) will cover soft X-ray regions. Table 1 shows the list of baseline insertion devices planned for the first phase of the operation of the ring.

Phase II insertion devices include, 6T superconducting wiggler (SCW), VUV quasi-period EPU, and possibly superconducting undulator (SCU). R&D plans are established to ensure the performance goals of various devices are achieved. In section II, we discuss the preliminary designs of the baseline devices as well as the phase-II devices. Issues of cold measurement for CPMUs is discussed in in section III . Section IV is devoted to the future R&D plans and establishment of new insertion device laboratory.

II. INSERTION DEVICES PLANNED FOR NSLS-II

2-1. Planar Hybrid Cryo-Permanent Magnet In-Vacuum Undulator

NdFeB type permanent magnet which is most commonly used in insertion devices has a negative thermal coefficient of remanent field (Br) and also of intrinsic coercivity (Hcj). Therefore, one can expect higher field and higher radiation resistance simply by cooling the magnet array to lower temperature. Typical value of the former is -0.1 %/ºK@20ºC and the latter -0.5%/ºK@20ºC. The latter fact is considered important for the medium energy ring with top-off capability due to the increased number of lost electrons. NdFeB exhibits a spin orientation below 150K and its Br starts decreasing as the temperature goes lower) [2]. Recent reports [3] show the peak performance of magnetic circuits was obtained in slightly lower temperature than that from single magnet. Therefore the cooling system should be able to handle at least 120K operation.

The baseline design of U19 CPMU is based on the X-25 MGU [4] which was installed in NSLS X-ray ring in December, 2005. Besides providing higher field than pure permanent magnet (PPM) device, another advantage of hybrid structure for CPMU configuration is that magnets have magnetization in the longitudinal direction. A NdFeB magnet can have negative thermal expension coefficients in the direction perpendicular to the easy axis, which results in greater mechanical stress with temperature gradient for PPM structure.

2-2. EPU design

The most popular design, based on PM technology, is the Advanced Planar Polarized Light Emitter (APPLE) type [5]. It has been popular because it can generate all the possible polarization states with the minimum number of magnets. However, it also has a few deficiencies. Strong multipole components inherent to the design would reduce the dynamic aperture of the machine. No separation of vertical and horizontal field components from different magnetic arrays would also complicate magnetic shimming. Heretofore, no shimming method valid for all the polarization states has been found. There is an alternative design proposed for HiSOR by SPring-8 [6]. It separates the magnets for horizontal and vertical field, for ease of tuning as well as more moderate skew multipoles, at the expense of weaker achievable horizontal field. Detailed tracking studies will be carried out to decide which type of device is appropriate for NSLS-II. Another concern for NSLS-II EPUs is the possible demagnetization of the permanent magnets by the use of the APS-style narrow gap vacuum chamber [7]. Improvements to the vacuum chamber design will be investigated in order to minimize the source of radiation at the extremities of the chamber.

2-3. Damping Wiggler

NSLS-II damping wiggler (DW) is used not only for electron beam emittance reduction but also for broad-band radiation source. Since there is a provision for canting of two devices, it is important to minimize the fan angle of the radiation for easy separation. The first vesion described in the CDR employs standard hybrid structure of the period length of 100mm with permendur poles and NdFeB magnets. Various new requirements have called for new design.

1) New requirements from absorber heatload demands further reduction of the fan angle from 2.8 mrad for CDR-DW.

2) Damping effect of the device which is proportional to the integral of B_y^2 of the CDR-DW has only 90% of that of the ideal device.

Therefore, a new 80mm period hybrid device with side magnets has been designed to supplement these deficiencies. The magnetic gap has been decreased from 15mm to 12mm to obtain 103% of the damping effect of the ideal device without increasing the peak field. The fan angle has been reduced from 2.8mrad to 2.3mrad.

The effect of longitudinal higher harmonics and transverse roll-off of the vertical field component on the dynamic aperture has been studied [8]. It shows that the vertical dynamic aperture will be reduced by approximately 50% if the harmonics up to the 7th are included in the analysis.

2-4. Three pole wiggler

NSLS-II DW will be an excellent source for broadband hard X-ray users. However, the number of available beam lines is limited and some users prefer to have radiation with lower angular power density for their optics. Three pole wiggler will be utilized to accommodate this type of user. It will be installed before the second bending magnet in the dispersive section in order not to modify the vacuum chamber shape to incorporate the device. Main design requirements are the followings:

1) More than 2 mrad of fan angle of the radiation from the field of at least 1 Tesla.
2) Minimize the emittance degradation by suppressing the peak field of side poles while maintaining the closed bump.

2-5. Phase II devices

Superconducting insertion devices with superior performance to PM devices are planned for the second phase of the development as well as unconventional PM devices. 60mm period / 6T SCW requires more than 1300 A / mm^2 for 15mm magnetic gap. Artificial Pinning Center (APC) NbTi may be used for this device if the result of R&D will satisfy the requirements. Due to the high field condition, the use of Nb^3Sn wire will be pursued simultaneously. Low temperature SCU has intrinsic difficulty due to the proximity of cold mass to various heat sources.

Medium temperature superconductor such as MgB2 (Tcr = 39K in self field) and a variety of high temperature conductors (YBCO, GdBCO, etc.) which are developing rapidly will be a promising candidate for realistic storage-ring SCU. As for other PM device, a long period QEPU has been proposed. However dynamic field integral effect is proportional to the period squared, and with combination of intrinsic multipole components of EPU device, careful design and trackings will be required.

III. DEVELOPMENT OF COLD MEASUREMENT SYSTEM

3-1. Field measurement requirement

Cryogenic insertion device, whether CPMU at 130K or SCU at 4K, has to be field-measured and corrected to satisfy beam dynamics conditions. It is preferable that the field measurement can be conducted in high vacuum with temperature controlled environment. For field mapping system, monitoring the precise location and temperature of Hall probes is essential. The variation of the integrating area due to temperature change must be compensated to obtain accurate integrated field measurement. International efforts are aimed to establish a reliable cold insertion device measurement system [3].

3-2. CPMU vacuum chamber design

Our current line of thinking is that the cold measurement should be able to be conducted without removing the vacuum chamber of the in-vacuum device. Therefore the vacuum chamber must have continuous opening on one side similar to MGU-X25 for NSLS. Detailed design efforts are being made for this subject.

IV. R&D ACTIVITIES AND NEW ID MEASUREMENT LAB

Vertical test facility is in operation with boiling LHe pool. It is planned to be connected to a closed circuit He gas refrigerator able to adjust the device temperature between 4K and 200K. Small prototype YBCO tape based SCU and MgB2 thick film conductor patterns will be tested in the near future.

Praseodymium iron boron (PrFeB) magnet continually increases its remanent field as the temperature is decreased. This technique will offer significantly higher magnetic field as well a lower temperature regime where distortion produced by thermal heat loads will be minimized. We also investigate the use of dysprosium poles for hybrid magnet structures which could potentially have a saturation level of over three Tesla which can dramatically increase CPMU performance over the currently used materials such as vanadium-permendur.

V. SUMMARY

Due to the strict beam stability requirement and sensitivity of medium energy low emittance electron beam, all the insertion devices for NSLS-II will have to comply higher standard than many existing devices. Rigorous R&D will ensure the success of this project.

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Table 1 Planned Insertion Devices for NSLS-II (Phase-I)

Insertion Device	**CPMU**	**EPU**	**DW**	**3 Pole Wiggler**
Magnetic Flux Density, Bpeak[T]	1.2	1.03 (lin) 0.64/0.64 (helical)	1.8	1.1
Total Length [m]	3	2 x 2	3.5 x 2	0.3
Minimum Magnetic Gap [mm]	5.0	10.0	12.0	32.0
Period Length, lu [mm]	19	45	80	-
Wiggler Characteristic Energy, Ec [KeV]	-	-	10.8	6.8
Photon Energy Range [KeV]	1.5 - 20	0.18 - 7	>0.01 - 100	>0.01 - 40
Maximum K	2.03 (eff)	4.33 (lin) 2.69 (heli)	13.6 (eff)	-
Max Total Power [kW]	11.2	12.09	64.6	0.34