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Insertion Devices R&Ds for NSLS-II

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DISCLAIMER

INSERTION DEVICES R&DS FOR NSLS-II

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Abstract

NSLS-II is 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 for 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) are for polarization control. Rigorous R&D plans have been established to pursue the performance enhancement of the above devices as well as building new types of insertion devices such as high temperature superconducting wiggler/undulators. This paper describes the details of these activities and discuss technical issues.

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 2014. Damping wigglers with peak field of 1.8T will be used for both emittance reduction purpose and broadband user hard X-ray source. The bending magnet field is chosen relatively weak 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 (3PW) 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 [1], and out-of-vacuum elliptically polarized undulator 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.

Table 1: NSLS-II Phase-I Insertion Devices

Insertion Device	CPMU	EPU	DW	3 PW
Magnetic Flux Density B_{peak}[T]	1.2	1.03 (lin) 0.64(heli)	1.8	1.1
Total Length [m]	3	2 x 2	3.5 x 2	0.3
Minimum Magneti Gap [mm]	5.0	10.0	12.0	32.0
Period Length, λu [mm	19	45	80	-
Wiggler Characteristi Energy, Ec [KeV]	-	-	10.8	6.8
Photon Energy Rang [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

CPMU

Our baseline design for 3m CPMU device will be based on the MGU-X25 installed on NSLS X-ray ring in 2005 [2]. Two remaining subjects must be resolved in order to assure reliable operation of the device. The first is to develop accurate cold measurement system to characterize the device in cold temperature. The second is development of a reliable closed-circuit gas refrigerator system.

Cold Measurement System

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].

Vacuum chamber design is an integral part of cold measurement system. 4.5m long square UHV chamber will be constructed to ensure the vacuum integrity and test detachable measurement system now being designed.

Proto type closed circuit He gas refrigerator has been developed. Two cryocoolers (Cryomech AL300 and Sumitomo ***) have been employed to achieve around 70K with 100W of cooling capacity. Improved version with larger capacity with more than 300W will be built.

New Materials

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.

EPU

Most popular permanent magnet based EPU design is

Advanced Planar Polarized Light Emitter (APPLE) type [4]. 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. Alternative design [5] has been investigated and tracking studies are conducted.

Another concern for NSLS-II EPU is use of fixed gap vacuum chamber, which may create neutron shower to demagnetize the magnets [6]. Careful design of vacuum chamber extremities is required.

DW

NSLS-II DW is not just for beam emittance control, but also for broadband user source. Therefore, there are additional requirement such as canting use, reduction of fan angle while maintaining the damping requirement. Preliminary dynamic aperture (DA) study reveals that high harmonics components of longitudinal field profile would reduce the DA by 50% compared to bare lattice case. Further investigation is being conducted.

3PW

3PW will be conventional PM based magnetic circuit and no technical obstacle appears to exist. However, the proximity of 3PW to adjacent magnets would raise the issue of magnetic interaction. 3D simulations have been conducted to estimate the effect.

Table 2: Phase-II Device Candidates

	SCU	SCW	QEPU
B_{peak}[T]	1.68	6.0	1.5
Length [m]	2	1	4
Gap [mm]	6.5 *	15	15
λu [mm]	14	60	100
Ec [KeV]	-	35.9	-
Photon[KeV]	1.8 - 30	0.01 - 200	0.008 - 4
K	2.2	33.6	14 (lin) 10.7 (heli)
Power [kW]	33-98	3.3-	32

Table 2 shows a list of candidates for insertion devices in phase-II which is after planned after 2014. CPMU may be upgraded to superconducting undulator (SCU) if this type of device becomes dependable. Superconducting wiggler will be installed for high energy photon applications. Quasi-periodic elliptically polarized undulator (QEPU) is considered for low photon energy users.

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SCU

Low temperature SCU has intrinsic difficulty due to the proximity of cold mass to various heat sources. Medium temperature superconductor such as MgB2 (Tc = 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.

LTS APC-NbTi Wire

Our LTS undulator effort focuses on the development of artificial pinning center (APC) NbTi wire which promises to give a few times higher critical current compared to the normal NbTi wire under the same operating condition. The wire development has not been finalized yet.

HTS Tape Conductors

The first generation HTS tape, so-called BISCCO ($Bi_2Sr_2Ca_2Cu_3O_{10}$), was used to test the performance in the form of cold coil pack for a sextupole. Quench limit for individual coil was measured in LN pool boiling. Special winding machine was developed to wind two pancake coils at a time in order to have splices on the outer side of the coils. Figure 1 shows two coil packs installed in the yoke of existing sextupole used in X-ray ring at NSLS.

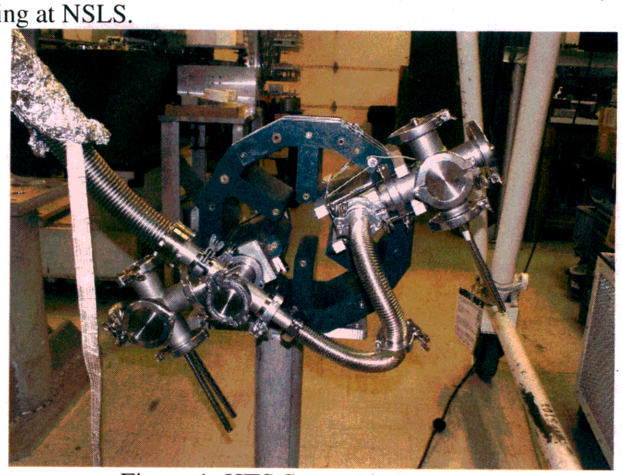


Figure 1: HTS Sextupole Prototype

Some of limitations for BSCCO tape are the minimum bending radius, brittleness and high price due to the complexity of manufacturing process. The second generation material, $Y_1Ba_2Cu_3O_7$ (YBCO) can be used to make coated conductor. Unlike BSCCO tape which is made from compressed multi strand tube, YBCO tape can be made 5-10cm wide. This wide tape can be cut to make an arbitrary shaped conductor path.

Figure 2(a) shows a preliminary YBCO tape based undulator tested in LN and the measurement result is given in Fig. 2(b).

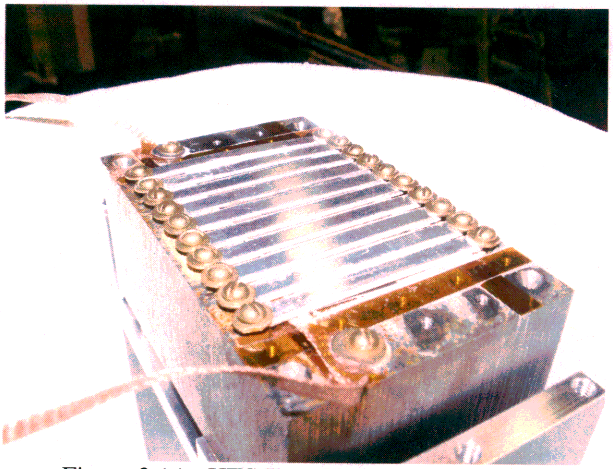


Figure 2 (a) : HTS Tape Undulator Prototype

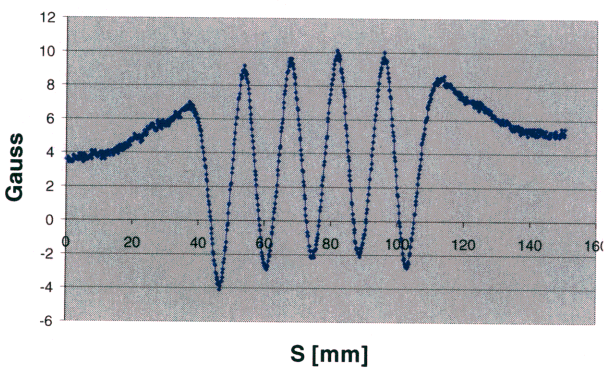
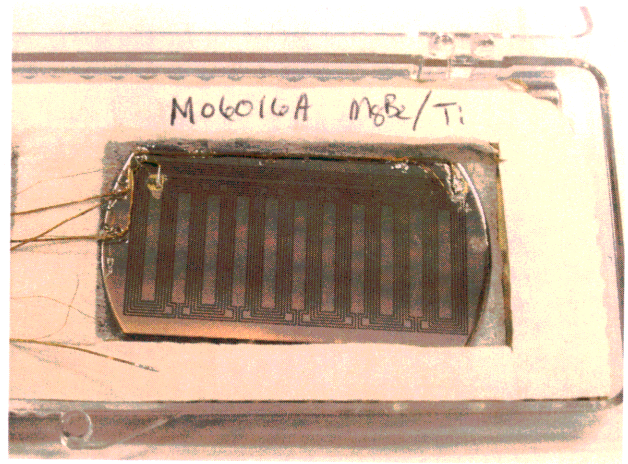


Figure 2 (b) : HTS Tape Undulator Measurement. One layer, one array. Hall probe is 2mm away from the poles and the current is 10A.

The reason that the field amplitude is not much enhanced by the yoke is that the thickness of plate appears to be too great for return flux to come back to the poles effectively with given field level. Simulation result indicates that thinner yoke could enhance the field by 50% more.

MgB2 Etched Pattern Undulator

Medium temperature (T_c=39K) superconductor, MgB_2 can be made as a thin film using chemical vapor deposition technique. Once the film is created, the pattern can be etched like semiconductor circuit. Figure 3 shows one of our prototype MgB2 etched film undualtor on Ti substrate. The second identical pattern was created on Tungsten substrate.



SCW

NSLS-II SCW specification requested by the users is found to require approximately 1300A/mm^2 which is beyond capability of conventional NbTi wire. Nb_3Sn wire could be used if reaction process of high temperature baking can be tolerated. APC-NbTi wire is another option. Re-optimizing the period length (60mm) might be necessary if the tracking result shows excessive DA reduction.

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