INSERTION DEVICES FOR NSLS-II BASELINE AND FUTURE

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Abstract

NSLS-II is going to employ Damping Wigglers (DWs) not only for emittance reduction but also as broad band hard X-ray source. In-Vacuum Undulators (IVUs) with the minimum RMS phase error (< 2 degree) and possible cryo-capability are planned for X-ray planar device. Elliptically Polarized Undulators (EPUs) are envisioned for polarization controls. Due to the lack of hard X-ray flux from weak dipole magnet field (0.4 Tesla), three pole wigglers (3PWs) of the peak field over 1 Tesla will be mainly used by NSLS bending magnet beam line users. Magnetic designs and kick maps for dynamic aperture surveys were created using the latest version of Radia [1] for Mathematica 6 which we supported the development. There are other devices planned for the later stage of the project, such as quasi-periodic EPU, superconducting wiggler/undulator, and Cryo-Permanent Magnet Undulator (CPMU) with Praseodymium Iron Boron (PrFeB) magnets and textured Dysprosium poles. For R&D, Hybrid PrFeB arrays were planned to be assembled and field-measured at room temperature, liquid nitrogen and liquid helium temperature using our vertical test facility. We have also developed a specialized power supply for pulsed wire measurement.

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 2015. Four types of insertion devices are planned at the initial stage of the operation. DWs have peak field of 1.8T and two units of a length of 3.5m will be installed in a long straight (LS) section. Some DWs will be used as canted configuration to increase the number of available beam lines. 3PW will be installed at the end of a dispersive section to accommodate NSLS BM users at the expense of small amount (~10%) of beam emittance increase. Gradient 3PW is under consideration to mitigate this effect. The main hard X-ray undulator source will be IVUs, and out-of-vacuum EPUs (APPLE-II type) will cover soft X-ray regions. Most of IVUs and EPUs will be in a short straight (SS) section. Table 1 shows the list of baseline insertion devices planned for the first phase of the operation of the ring as of June 2008.

Table : NSLS-II Baseline Insertion Devices

Insertion Device	IVU	EPU	DW	3 PW
Magnetic Flux Density B_{peak}[T]	1.0	0.89 (lin) 0.55(heli)	1.8	1.1
Total Length [m] in SS	3	2 x 2	3.5 x 2	0.3
Minimum Magnetic Gap [mm]	5.0	11.5	12.5	28.0
Period Length, λu [mm]	19	50	90	-
Wiggler Characteristic Energy, Ec [KeV]	-	-	10.8	6.8
Photon Energy Range [KeV]	1.8 - 20	0.18 - 7	>0.01 100	>0.01 40
Maximum K	1.8 (eff)	4.2 (lin) 2.6 (heli)	15.2 (eff)	-
Max Total Power [kW]	8.0	11.2	64.4	0.34

IVU

Our baseline design for 3m IVU device will be based on the MGU-X25 which was installed on NSLS X-ray ring in 2005 [2]. Final design will be completed by 2011. Future upgrade to CPMU is contemplated. Development of accurate cold measurement system to characterize the device in operating temperature is essential for the upgrade. For further improvement of the performance, it is mandatory that new magnet and pole materials must be developed.

Cold Measurement System

International efforts are aimed to establish a reliable cold insertion device measurement system [3]. BNL has completed preliminary design for cold measurement system. A short (~1.2m) prototype will be built in FY09 for test purpose. We plan to use ceramic motor and drive (NanoMotion), HV rated non-magnetic stages, Laser interferometer (Ranishaw) and HV rated cable (CiCoil). The figure 1 shows a preliminary design of the stages and drive.

New Materials

Praseodymium iron boron (PrFeB) magnet continuously increases its remanent field as the temperature is decreased. Proto type arrays have been

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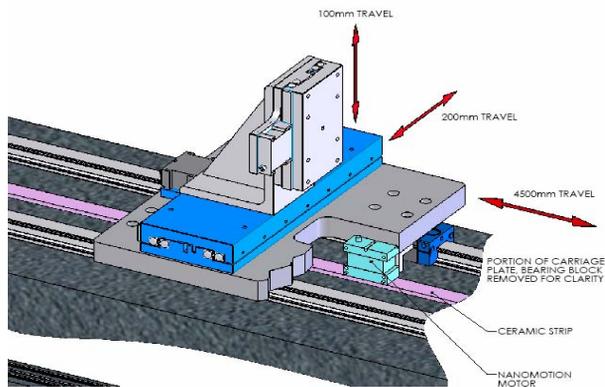
Figure 1: 3D rendering of NSLS-II in-vacuum cold measurement stages and drive.

built using NEOMAX 35CR. Unfortunately, the change in safety regulation (DOE 10CFR851 Worker Safety and Health Program)[3] in February 2008 prevented us from using a newly acquired dewar since it is not compliant with ASME code. Modification of the VTF is under way to satisfy the new safety requirement.

We also investigate the development of textured dysprosium poles for hybrid magnet structures in collaboration with SigmaBeam Technologies, LLC. It could potentially have a saturation level of over three Tesla and it may significantly increase a CPMU performance over the device with the currently used materials such as vanadium-permendur.

Low Temperature B-H curve of Vanadium Permendur (49Co-2V-Fe)

Unless a new cold temperature material is developed, vanadium permendur is the most likely material used for poles in CPMU. Therefore, it is important to know the accurate B-H curve for the material at the operating temperature. The material used for the measurement is taken from an actual pole piece used for X29 undulator. A vibrating sample magnetometer (VSM-5, Toei Kohgyo) with a sample container immersed in liquid nitrogen was used for the measurement. Figure 1 shows the image/volume adjusted data of its B-H curve.
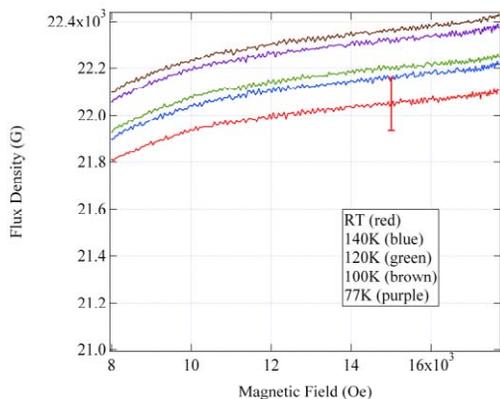
Figure 2 : Vanadium Permendur B-H Curves for various temperature in the range for saturated region.

The error bar is shown at the highest magnetic field setting for guaranteed performance spec of the measurement device. Statistically significant but small (1.5%) increase of permeability with lowering temperature from RT to 77K was observed.

EPU

Advanced Planar Polarized Light Emitter II (APPLE-II) type [4] was compared to SPring-8 type EPU [5] in tracking study using Radia kickmaps . It is concluded that improvement of DA with SP8 type EPU over Apple-II is not significant. Therefore Apple-II EPU is selected as baseline design for NSLS-II EPU. The baseline switching design utilizes a small angle (0.25mrad) static canting scheme with choppers at the beamline similar to what was used at BESSY [6]. Use of dynamic switching with kickers [7] has not been excluded in the future. Another concern for NSLS-II EPU is use of fixed gap vacuum chamber, which may create neutron shower to demagnetize the magnets [8]. NEG coating currently requires the minimum vertical aperture of 8mm. It determined the minimum magnetic gap of 11.5mm for the device. Careful design of vacuum chamber extremities is required due to space constraint.

DW

NSLS-II DW conceptual engineering design was being conducted. Two types of end structures are examined. One is for a standard straight configuration and the other is to include the bends for canting at the extremities. Figure 3 (a) and (b) show the magnetic design and horizontal trajectory, respectively.
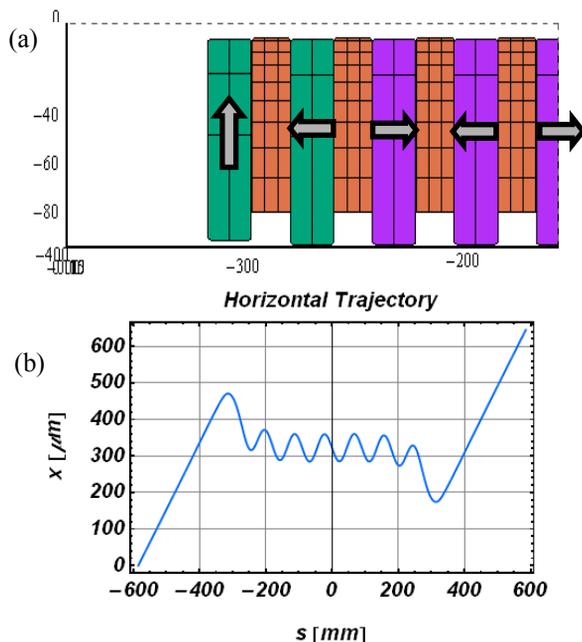
Figure 3: (a) Magnetic design. Green and magenta pieces represent magnets with the direction of magnetization indicated by arrows. Orange elements is vanadium permendur poles; (b) Horizontal trajectory of electron.

calculated by Radia. The entrance angle was chosen to be 1.8 mrad.

   In both cases, placement of a small horizontally focusing/defocusing unit at each end is preferred for linear optics correction. DA studies will determine the minimum pole width which is crucial parameter to reduce the cost of the device. One period unit using the concept of edge focusing wiggler [9] was examined. An isometric rendering of such an unit is shown in Fig. 4.
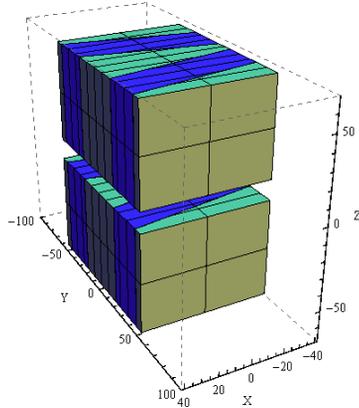
Figure 4: A horizontally focusing unit with the edge angle of 10 degree.

GRADIENT 3PW

   Space was provided in the dispersion region for up to 15-TPWs to be installed. By introduction of a gradient into the TPW field, the increased quantum excitation can be countered by an increase in the damping partition number, an idea proposed by A. Hofmann [10]. The change in J_x for a wiggler of bend radius, ρ_w , length, L_w, and gradient, K_w, in a lattice with dipole bend radius, ρ_o is given by ($\rho_w < 0$ this case):
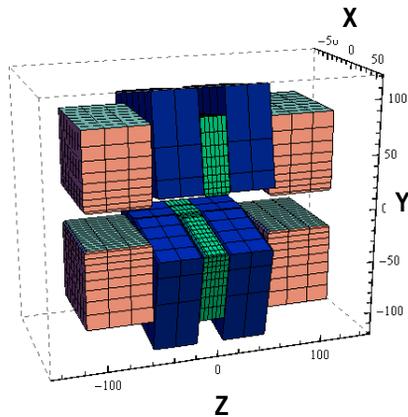
Figure 5: Gradient 3PW magnetic design.

$$J_x = 1 - \frac{K_w L_w \eta_x \rho_0}{\pi \rho_w} \qquad (1)$$

Estimating these values for the NSLS-II TPW, gives for ρ_w =9.1m, ρ_o =25.02m and dispersion η_x =0.168m at the TPW. Then, $K_w \sim 1.65$ m^{-2} for 15-TPW with L_w = 2.7cm length of the center pole only. More careful simulation

indicates the optimum value for Kw is found out to be 1.4 m^{-2}.

PHASE-II DEVICES

   Table 2 shows a list of candidates for insertion devices in phase-II which is planned after 2015. IVU may be upgraded to CPMU if the technology matures. Superconducting wiggler will be installed for high-energy-photon applications. Quasi-periodic elliptically polarized undulator (QEPU) is considered for low photon energy users.

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	100	100
Ec [KeV]	-	35.9	-
Photon[KeV]	1.8 - 30	0.01 - 200	0.008 - 4
K	2.2	56.0	14 (lin) 10.7 (heli)
Power [kW]	33-98	410	32

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