PROGRESS ON INSERTION DEVICE RELATED ACTIVITIES AT THE NSLS-II AND ITS FUTURE PLANS

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Abstract

National Synchrotron Light Source-II (NSLS-II) project is now in the construction stage. A new insertion device (ID) magnetic measurement facility (MMF) is being set up at Brookhaven National Laboratory in order to satisfy the stringent requirement on the magnetic field measurement of IDs. ISO-Class7 temperature stabilized clean room is being constructed for this purpose. A state-of-the-art Hall probe bench and integrated field measurement system will be installed therein. IDs in the project baseline scope include six damping wigglers, two elliptically polarizing undulators (EPUs), three 3.0m long in-vacuum undulators (IVUs) and one 1.5m long IVU. Three-pole wigglers with peak field over 1 Tesla will be utilized to accommodate the users of bending magnet radiation at the NSLS. Future plans includes: 1) an in-vacuum magnetic measurement system, 2) use of PrFeB magnet for improved cryo undulator, 3) development of advanced optimization program for sorting and shimming of IDs, 4) development of a closed loop He gas refrigerator, 5) switchable quasi-periodic EPU. Design features of the baseline devices, IDMMF and the future plans for NSLS-II ID activities are described.

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. All the types of IDs planned to be installed in the project baseline are shown in the Table. 1.

Table 1: NSLS-II Baseline Insertion Devices

Insertion Device	IVU	EPU	DW	3 PW
Magnetic Flux Density B_{peak}[T]	1.0	0.94 (lin) 0.57(heli)	1.8	1.1
Total Length [m]	3 or 1.5	2 x 2	3.5 x 2	0.3
Minimum Magnetic Ga[p] [mm]	5.0	11.5	15.0	28.0
Period Length, λu [mm]	20 or 21	49	100	-
Wiggler Characteristi[c] Energy, Ec [KeV]	-	-	10.8	6.8
Photon Energy Rang[e] [KeV]	1.6 - 20	0.18 - 7	>0.01 100	>0.01 40
Maximum K	1.8 (eff)	4.3 (lin) 2.6 (heli)	16.8 (eff	-
Max Total Power [kW]	8.0 or 3.6	11.2	64.4	0.34

Unprecedented small emittance of the electron beam requires very demanding beam stability, which imposes tight field error specifications, especially the allowed second integral wandering inside device. This quantity is difficult to measure accurately with conventional measurement methods such as Hall probe scan and stretched wire scheme.

ID-MMF

It is essential to have the capability to measure magnetic field (induction) more accurately than currently possible in order to advance the quality of IDs. Our state of the arts ID-MMF is composed of the following equipment:

- ISO-Class 7 Temperature stabilized (+/- 0.2 C°) clean room.
- Kugler Hall probe bench with air bearing carriage with 6.5m measurement range. Straightness spec is +/- 7microns.
- Flip coil, moving coil, and stretched wire bench with 0.5 G.cm repeatability in terms of the 1st integral measurement.
- Calibration dipole with NMR probes.

DW SPECIFICATION CHANGE

The specifications of a DW have been changed from 90mm period with 12.5mm gap to 100mm period with 15mm gap due to heat load concerns. It has been found that the electron beam with a miss steering condition; +/-0.25mrad in angle, +/-2mm in combined displacement by the beam and mechanical tolerance would create excessive heating on the vertical surface of the chamber (9.5mm inner vertical aperture). Calculation shows that 2.8 kW of power will be deposited to the chamber wall with the maximum power density of 0.22 W/mm^2. The maximum temperature for Al chamber even with water cooling channels turned out to be higher than 600 °C.

The intercepted power can be reduced to 500W when the vacuum aperture is increased from 9.5mm to 11.5mm. The resulting maximum temperature of the chamber is calculated to be 75 C° and the adjacent NdFeB magnets will will be exposed to a maximum temperature of 45 C°. The heat distribution can be seen in the Figure 1. In this simulation, assumed thermal conductivity, specific heat, density for aluminium is 150W/m/K, 875J/kg.°C and 2770 kg/m^3. Those for air is 0.03W/m/K, 1000J/Kg.°C and 1 kg/ m^3. Those for NdFeB magnet is 7W/m/K, 500 J/kg.°C and 7870 kg/m^3.

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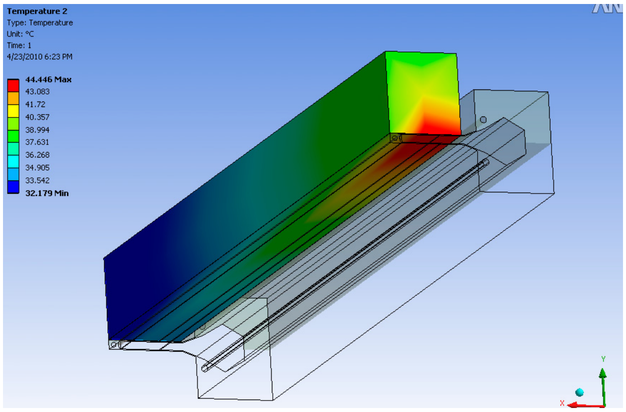

Figure 1: Steady state magnet temperature distribution when the electron beam's overall angle error of ±0.25 mrad and displacement of ±2mm.

EPU DYNAMIC SHIMMING

It is well-known that the Apple-2 type EPU [1] has strong non-linear effect on the electron beam due to its small good field region especially in the horizontal plane. Static shimming using L shaped shims can alleviate this effect only for a given polarization. Then, a dynamic compensation scheme using current carrying strips has been proposed and implemented [2].

The principle is that the effect of the ID's second order kicks [3] can be compensated by the counteracting 1st order correction with the current strips at given electron beam energy. Figure 2 shows the Radia [4] model of the EPU in 45 degree inclined linear polarization mode. The number of current strips is 20 per array. Strip size is 3mm(X) x 0.3mm (Y) x 2.1m (Z) and the spacing between strips is 1mm. The gap between upper and lower strips is 10.7mm. Figure 3-(a) and 3-(b) delineate both uncorrected (blue) and corrected (red) trajectories with horizontal trajectory offset of +5mm and -5mm, respectively.

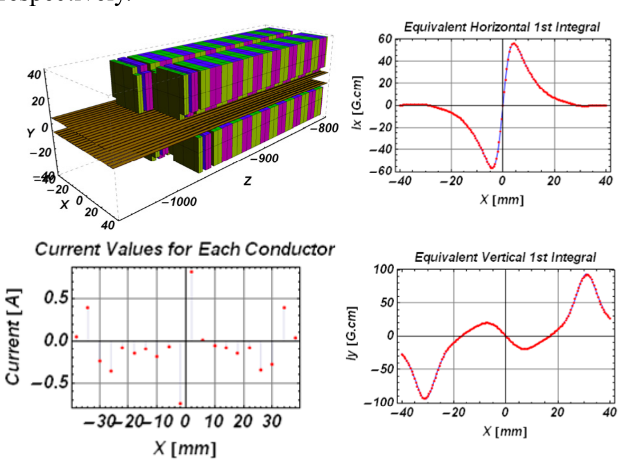

Figure 2: Radia model of NSLS-II EPU in 45 degree inclined linear polarization mode (upper left). Necessary current value for each conductor (lower left). The amount of 2nd order kick translated to the equivalent 1st integral in blue line and corresponding 1st integral created by current strips are plotted in red dots in the horizontal field (upper right) and the same for the vertical field (lower right).

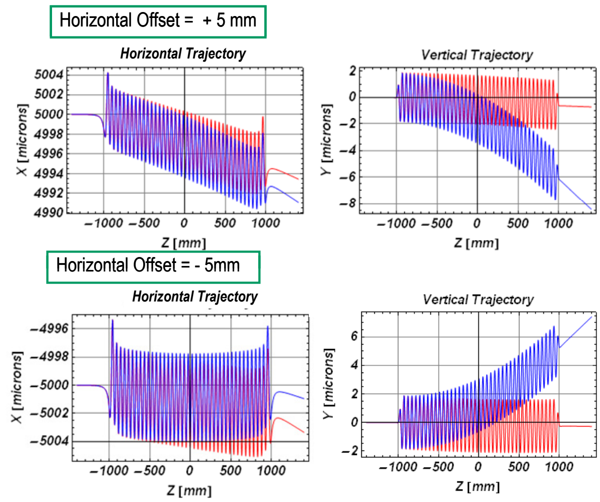

Figure 3: Trajectories with horizontal offset of ±5mm. Blue curves are uncompensated ones and red ones are corrected with current strips.

The same principle can be applied to different polarization states. Figure 4 shows the current values and equivalent vertical integral in the case for vertical linear polarization and Fig. 5 for helical polarization. In both cases, the correction is needed only on the horizontal trajectory.

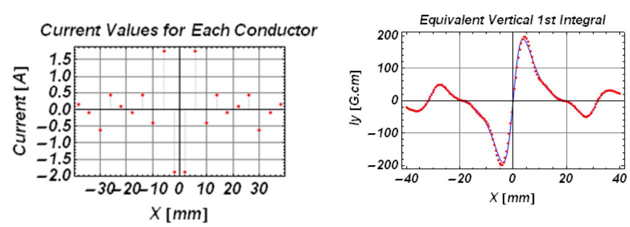

Figure 4: Necessary current value for each conductor and produced equivalent 1st integral distribution for the correction of NSLS-II EPU in vertical linear polarization mode.

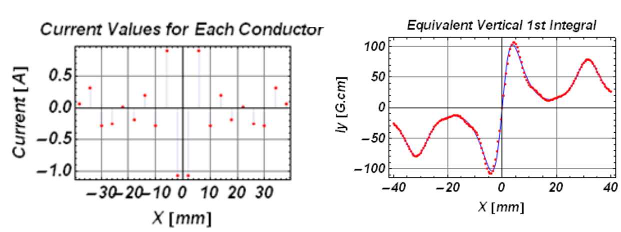

Figure 5: Necessary current value for each conductor and produced equivalent 1st integral distribution for the correction of NSLS-II EPU in helical polarization mode.

IVU WITH CRYO OPTION

The baseline IVUs are planned to be operated in the room temperature. Cryo Permanent Magnet Undulator (CPMU) option which was originally in the baseline scope was dropped in 2007 due to technical uncertainty and cost concern. However, recent successful test of PrFeB undulator in the liquid nitrogen temperature [5] may alleviate various technical issues compared to CPMU using NdFeB magnets. Figure 6 shows a preliminary mechanical design of 1.5m SRX undulator. The cooling circuits have been designed suitable both for regular copper cooling water and, in the case of CPMU, liquid nitrogen.

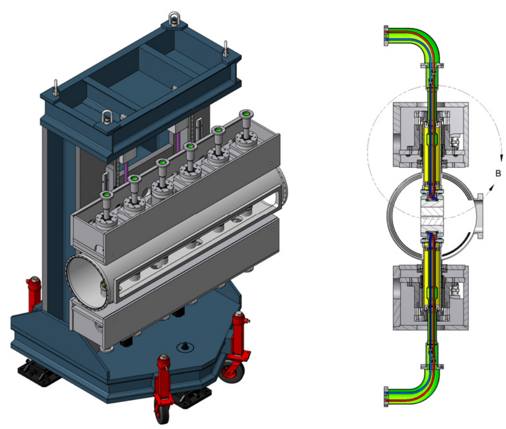

Figure 6: Preliminary CAD design of SRX-IVU with cryo capability.

Figure 7 shows photographs of 1m long Cu platen with integrated cooling channel inside. All the welding are done with friction stir welding technique which minimize the distortion of the structure with temperature cycles.

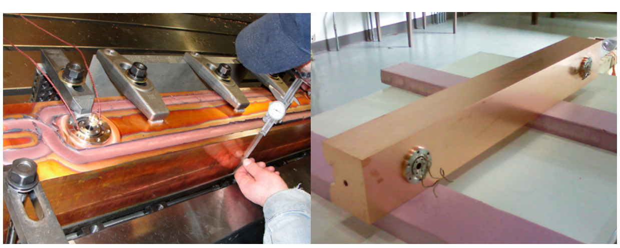

Figure 7: A proto-type 1m long Cu friction-stir-welded platen.

SCW AND SCU

A super conducting wiggler (SCW) is planned to be installed in one of the short straights in the NSLS-II ring. We are currently in the process of optimizing the specifications. Tracking studies have been carried out for two cases: 3.5T SCW with 60mm period and 6T SCW with 100mm period. The assumed magnet gap for both cases is 15mm and the device length is 1.0m. Figure 8 shows a Radia model of the SCW and the calculated vertical flux density and trajectory are also shown. A preliminary tracking result shows that the 3.5T version is comfortably integrated to the ring. However, the 6T version requires further adjustment to find an optimized operating point within our tune foot print. Assuming to use 1006 steel for yokes, the estimated engineering current density for 6T wiggler is less than 900A/mm^2. This value is achievable with conventional NbTi wire but there is not much safety margin. However, if the recent successful production of NbTi wire with artificial pinning centers (APC) [6] can be used, there is possibility to even reduce the period length further. SCW parameters are planned to be further optimized to meet the requirements of hard X-ray beam lines while satisfying the machine physics constraints.

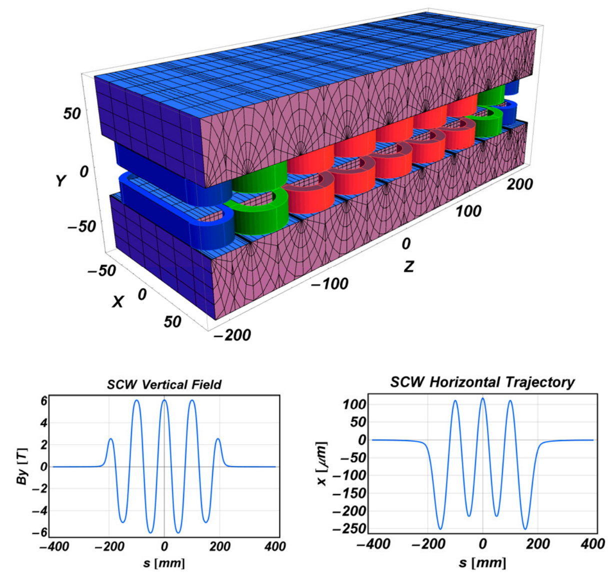

Figure 8: Radia model of 6T SCW. The period is 100mm and yoke gap is 15mm. Calculated vertical flux density in Tesla and trajectory in μm are also shown.

A super conducting undulator (SCU) has been considered technically immature as long as conventional wires such as NbTi or Nb_3Sn are utilized. APC-NbTi wire will also open up the possibility to increase the magnetic gap of SCU arrays, which enables us to create enough insulation space to prevent the cold mass from quenching. However, other obstacles such as difficulty in shimming still remain.

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