A QUASI-PERIODIC ELLIPTICALLY POLARIZED UNDULATOR AT NSLS-II

M. Musardo, T. Tanabe, O. Chubar, Y. Hidaka, D. Harder, J. Rank, P. Cappadoro and T. Corwin,
Energy Sciences Directorate, Brookhaven National Laboratory, 11973 Upton, NY, USA
C. A. Kitegi, Synchrotron-SOLEIL, Saint-Aubin, France

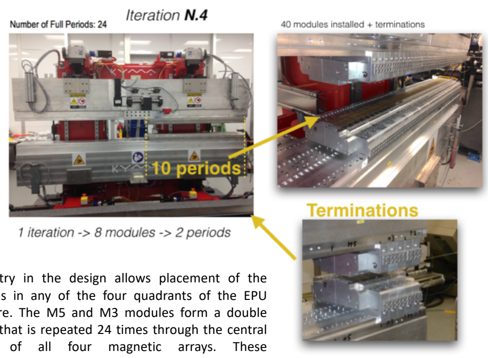
A 2.8 m long quasi-periodic APPLE II type undulator has been commissioned at the National Synchrotron Light Source II (NSLS-II) for the Electron Spectro-Microscopy (ESM) beamline in the framework of the NEXT (NSLS-II Experimental Tools) project [1]. It provides high brilliance photon beams in circularly and linearly polarized radiation from VUV to soft X-Rays. The mechanical structure implemented to achieve the quasi-periodicity in the magnetic field profile is described together with the optimization techniques utilized to correct the undesirable phase-de- pendent errors. The final magnetic results are presented as well as the spectral performance of the device. Although this EPU (Elliptically Polarizing Undulator) was procured as a turn-key device, the vendor was only responsible for the mechanical frame and the control system. Sorting and assembly of the magnet modules and the magnetic field tuning - Virtual Shimming and Magic Finger - were per- formed at the NSLS-II Magnetic Measurement Lab.

MEDSI PARIS 2018

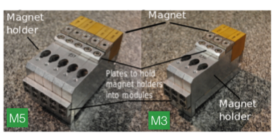
MAGNETIC AND MECHANICAL STRUCTURE

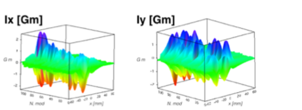
SORTING and ASSEMBLY

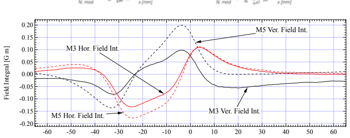
The magnetic structure of the device is modularized. The magnets are grouped in small compensated modules. They are clamped on individual holders and arranged in modules containing either three (**M3**) or five (**M5**) magnets by means of small aluminum bars as shown in figure.



Symmetry in the design allows placement of the modules in any of the four quadrants of the EPU structure. The M5 and M3 modules form a double period that is repeated 24 times through the central region of all four magnetic arrays. These compensated modules are accurately characterized by measuring their field integral.





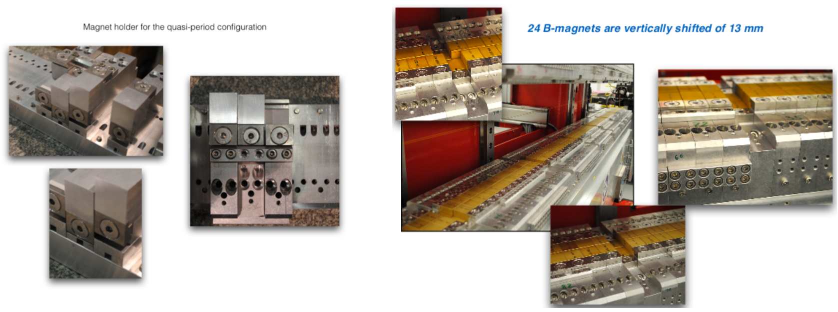


Horizontal (red) and vertical (black) average field integral of M3 (continuous line) and M5 (dashed line) module populations.

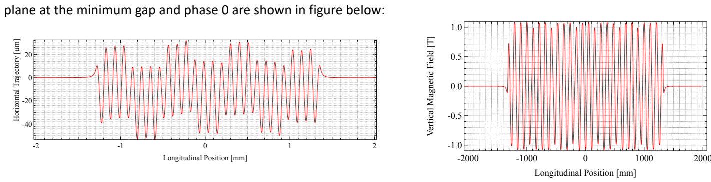
The magnetic field integral measurements of the modules are used to optimize the arrangement of the modules within the undulator in order to minimize the unwanted field integrals and multipole errors, and to ensure a straight electron beam trajectory through the device. The optimization is iterative and provides a good control of the field integral errors. The assembly process consists of successive and repetitive installation of M3 and M5 magnet modules onto the mechanical frame in order to build up the 24 periods of the EPU. The measured data of the current configuration and the previously measured field integrals of each module are used as inputs to IDBuilder. The software then optimizes the selection of the next two sets of M3/M5 modules to be installed. Following that process for each successive installation of two magnet modules, permits IDBuilder to minimize the first and second field integral for the fully assembled EPU.

QUASI-PERIODIC CONFIGURATION

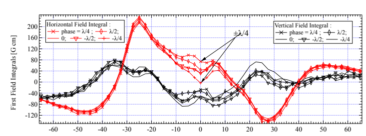
The Quasi-Periodicity (Q-P) is obtained by modulating the magnetic field amplitude along the length of the device. This is achieved by vertical displacement of B- magnets (blocks magnetized longitudinally) at six specific locations.



In order to reduce the magnetic field strength at those locations the standard magnet holders were replaced with special holders that displace the magnets vertically by 13 mm with respect to the mid-plane. The measured magnetic field on-axis and the 3 GeV electron trajectory in the horizontal plane at the minimum gap and phase 0 are shown in figure below:



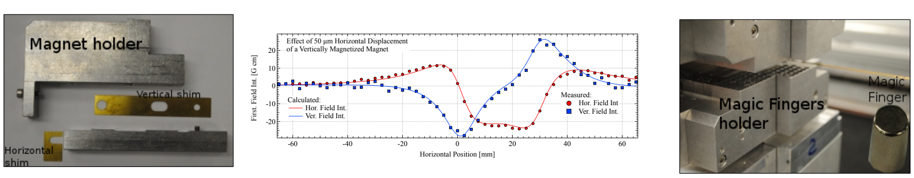
The first field integrals after sorting at a gap of 16 mm and five phases (±λ/2, ±λ/4 and 0) are shown in figure below. A maximum variation in phase of the horizontal field integral on-axis of about 1 G m occurs at ± λ/4. These results demonstrate that the assembly/sorting process has been very effective: the peak to peak field integral of the fully assembled device is comparable to the field integral of the individual modules.

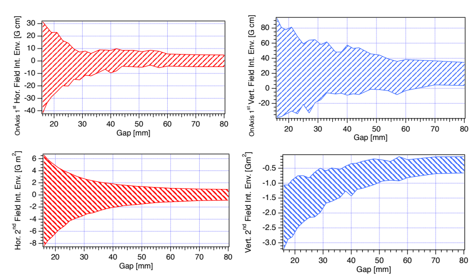


In order to meet the requirements for installation in the NSLS-II storage ring a virtual shimming of the device followed by Magic Finger correction has been performed after assembly to further reduce the field integral distribution and to minimize the multipole variation in phase.

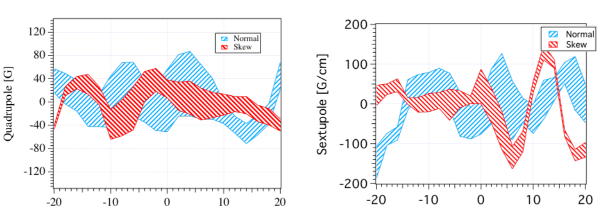
VIRTUAL SHIMMING & MAGIC FINGER CORRECTION

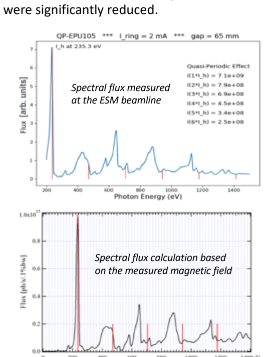
Virtual Shimming is a well-established magnetic optimization technique for post-assembly tuning of an insertion device. Virtual shimming is accomplished by making small horizontal and vertical displacements of a limited number of magnets. The horizontal and vertical displacement of magnets is an efficient way to compensate the magnetic field errors of the device and thus reduce the phase error of the emitted radiation. The shimming procedure is performed based on magnetic measurement data and pre-calculated shim signatures. The shim signatures are defined as the variations of given components of the magnetic field and/or the field integral with displacements of specific types of magnets along a given direction and at a given gap and phase.





Four successive iterations of virtual shimming were performed in the Q-P configuration and seven Magic Finger (MF) iterations were necessary to achieve the NSLS-II specification. MF is another corrective technique used for magnetic tuning of undulators. The MF optimization was carried out using cylindrical permanent magnets inserted into appropriate holders located at both ends of the upper and lower magnetic arrays. An optimal arrangement of these small cylindrical magnets further reduces the residual field integral and the multipole variations. After five successive MF iterations the magnetic field errors were significantly reduced.





The spectral flux measured at the ESM beamline reveals the quasi-periodic performance of the device. The two Q-P effects, reduction in intensity and a shift in energy of the higher harmonics with respect to multiples of the fundamental, are clearly visible in the spectrum. The spectral flux was measured with a ring current of 2 mA at a gap of 65 mm. This result is in a good agreement with the flux calculation based on the measured magnetic field.

CONCLUSION

Introduction of the Q-P in the device resulted in a large variation of the second field integral as a function of phase. This unwanted variation cannot be corrected using MF, but rather requires additional virtual shimming or, most efficiently, the use of external correction coils. The coils were installed and energized to quantify their correction. The maximum variation was successfully corrected by setting a current of 6.6 A.

* Work supported by DOE under contract DE-SC0012704
† musardo@bnl.gov