MAGNETIC OPTIMIZATION OF LONG EPUS AT NSLS-II

C. Kitegi.†, P. Cappadoro, O Chubar, T. Corwin, H. Fernandes, D. Harder, D. Hidas, M. Musardo, W. Licciardi, J. Rank, C. Rhein and T. Tanabe
Energy Sciences Directorate, Brookhaven National Laboratory, Upton, NY 11973, USA

Abstract

The Soft Inelastic X-ray scattering (SIX) and the Electron-Spectro-Microscopy (ESM) are two beamlines under construction at National Synchrotron Light Source-II (NSLS-II). The specifics of these two beamlines required the use of two long Advanced Planar Polarized Light Emitter-II (APPLE-II) undulators, as a source that provides both circularly and vertically polarized radiation. Thus, we designed 3.5 m and 2.7m long APPLE-II type undulators for SIX and ESM. The NSLS-II ID group is responsible for the magnetic optimization of these two long undulators. In this paper, we first summarize the APPLE-II magnetic and mechanical design. Then, we discuss the magnetic performance of the first APPLE-II achieved with the shimming performed at BNL.

INTRODUCTION

NSLS-II is in operation since February 2015. With 17 beamlines already in operation and at least 6 more scheduled for next year, the NSLS-II beamline development timeline is very aggressive [1]. To support this ambitious planning, the Insertion Devices procurement strategy is quite diverse. During the NSLS-II construction, all the insertion devices were ordered as turnkey devices. Now simple devices such as 3 Poles Wigglers are fully constructed, assembled and shimmed in-house. In a few cases, devices previously installed in other facilities are refurbished before being installed at NSLS-II [2]. For the construction of more complex devices, we rely on our industrial suppliers. However when the magnetic correction is a clearly identified risk, it can trigger the decision of performing the magnetic assembly and the shimming in-house.

We currently use this strategy for the delivery of two APPLE-II type undulators to the NEXT project [3]. Because of their length and their period, these devices are challenging to shim within the NSLS-II specifications. Thus, the two devices were procured as turnkey devices similarly to the other NSLS-II devices but the magnetic optimization was excluded from the scope of the contract. In this approach, the selected vendor is responsible for the delivery of the mechanical frame, the control system and sorting and mounting magnets in M3 and M5 modules. Still in order to demonstrate that the devices are properly functioning under magnetic load and the required field is achieved at minimum gap, the magnetic assemblies have to be temporally installed on the mechanical frames for the Factory Acceptance Test. The contract for the two devices was awarded to Kyma in October 2014.

At NSLS-II we use "IDBuilder", a genetic algorithm based computer code for the assembly and the magnetic tuning of undulators [4]. This versatile software was developed at SOLEIL and has been used for the assembly and the tuning of most of the APPLE-II type undulators and In-Vacuum Undulators installed at SOLEIL. In the next section, the magnetic and mechanical design of the 2 APPLE-II is discussed. We first received the SIX EPU, on March 1. Its large number of periods, almost 60, makes its assembling and disassembling a long and tedious process. Therefore it was agreed that for SIX only, the supplier would perform a best effort assembly using their software [5] and ship the device as is. The magnetic performance of the SIX EPU, achieved after magnetic correction was done at NSLS-II, is reviewed in this paper.

LONG EPUS DESIGN

Magnetic Design

The NSLS-II ID group provided to the supplier a magnetic reference design for the SIX EPU57 and ESM EPU105. While most of the parameters were fixed, the supplier was able to further improve the magnetic end section design, by adding an air gap between the last magnet of the end section and the first main magnet of the periodic structure. The main parameters of the two long EPUS are listed in Table 1. The name of the end section magnets uses the convention defined in [6]. The air gaps s1, s2 refer to the spaces between end section magnets as detailed in [6] and s3 is the added air space proposed by the supplier.

Table 1: Magnetic Design Main Parameters

	ESM EPU105	**SIX EPU57**
Period	105 mm	57
Nb of Periods	24	59
Minimum Gap	16mm	16mm
Length	2.7m	3.5m
Vert. and Hor. Peak Field	1.14T 0.7T	0.83T 0.57T
Main Mag. Geom.	34mm x 34mm x 26.2mm	34mm x 34mm x 14.2mm
HW/W/HL Thickness	7.9mm/13mm /17mm	4.3mm/7.1mm /8.7mm
Air gaps s1/s2/s3	5.5mm/7.6mm /3mm	5.6mm/4.1mm /3.1mm
Remanence	1.25T	1.25T
Intrinsic Coercive field	2.5T	2.5T

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

Mechanical Frame

This supplier previously delivered two 8 axis APPLE-II type undulators for the Coherent Soft X-ray beamline (CSX) at NSLS-II [7]. As we found the mechanical behaviour of these two devices satisfactory, the mechanical design of the long EPUs is based on a similar concept. The so-called double frame originally developed for the CSX EPUS is used for the 2 long EPUs. The 3D rendering of the SIX EPU57 is shown in Figure 1.

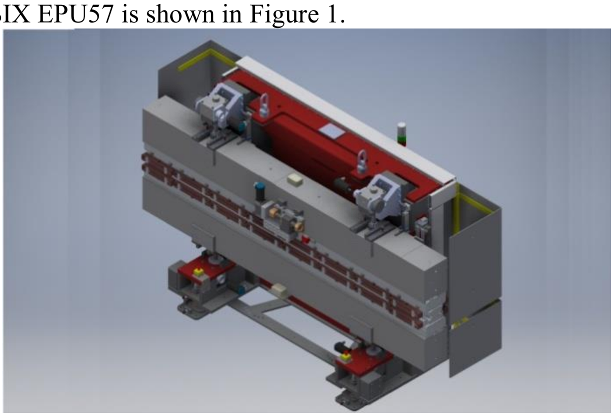

Figure 1: 3D rendering of the SIX EPU57.

Magnet Holders

The horizontal and vertical displacement of magnets is an efficient way to compensate for magnetic field errors in the undulator. As a result, the implementation of this functionality, without departing too much from Kyma's conventional design, was an important focus during the design phase. In the supplier's design, inspired by Elettra, two plates hold together three (resp. five) magnet holders into an M3 (resp. M5) module as shown in Figure 2.

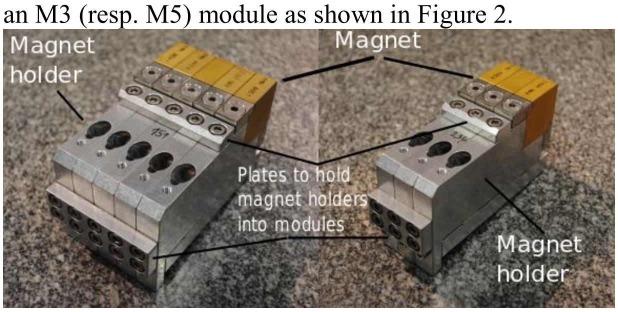

Figure 2: M3 (left) and M5 (right) modules for the SIX EPU.

We suggested the addition of a base to the magnet holder. The horizontal or the vertical translation of each individual magnet is then easily achieved by installing nonmagnetic shims between the magnet holder and its base. A magnet holder and its base are shown in Figure 3. We prefer this approach of a single base for each magnet holder over adding a common base to the magnet holders in a module. Indeed the single base concept allows for pre-shimming of all the magnets holders prior to assembling magnet holders into M3 and M5 modules. In practice during the assembly of the modules, the supplier pre-shimmed each magnet holder with 0.25 mm thick horizontal and 0.25 mm thick vertical shims. Foremost during the shimming of the undulator, one can easily extract the magnet holder whose magnet needs to be displaced, change and secure the shims on a table, away from the undulator, and then easily install the magnet holder back into the undulator.

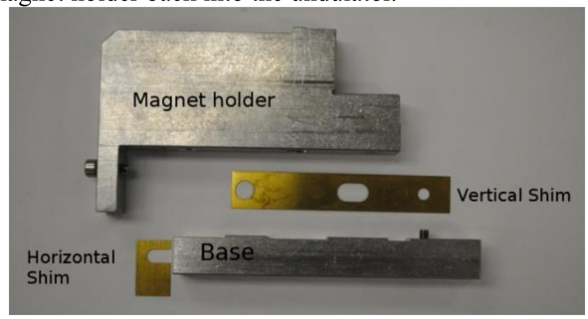

Figure 3: Single magnet holder and its base for the SIX EPU.

SIX EPU SHIMMING

Although IDBuilder has proven to be very efficient and reliable and has become the cornerstone of the ID assembling and shimming at SOLEIL, it was the first time this software was used at BNL to shim an EPU. Therefore upon the installation of SIX on the magnetic bench, we performed simple magnetic measurements to benchmark IDBuilder computations to the magnetic measurements. Figure 4 compares the measurement of the field integral variation caused by a 0.25mm magnet displacement and the addition of a magic finger to the IDBuilder computations. In both cases a good agreement has been achieved.

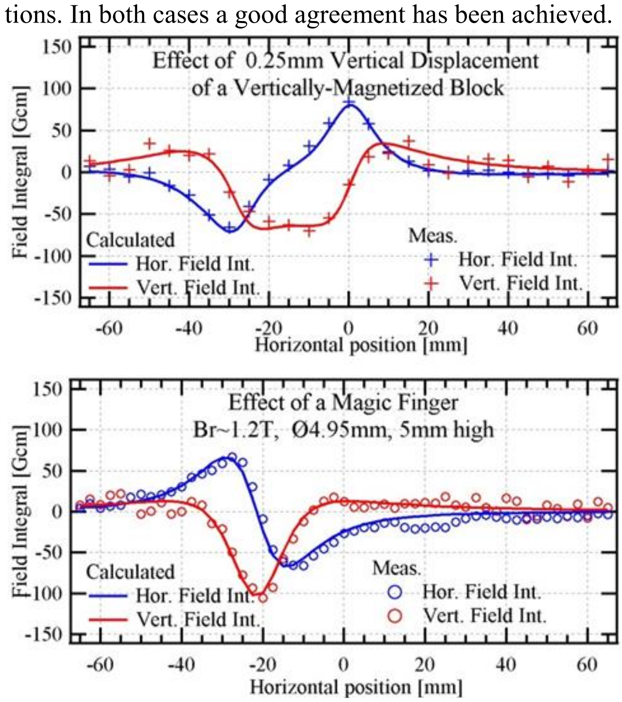

Figure 4: Comparison of the measured and computed field integral variation achieved by virtual shimming (Top) and magic finger (bottom).

The initial magnetic performance magnetic achieved with the best effort assembly was good enough to avoid disassembling the device. The SIX EPU was the first APPLE-II to be installed in a long straight section, where the amplitude of the horizontal beta function is five times larger than the one in a short straight section. Therefore a great care was given to the reduction of the integrated multipoles and their variation with respect to the phase.

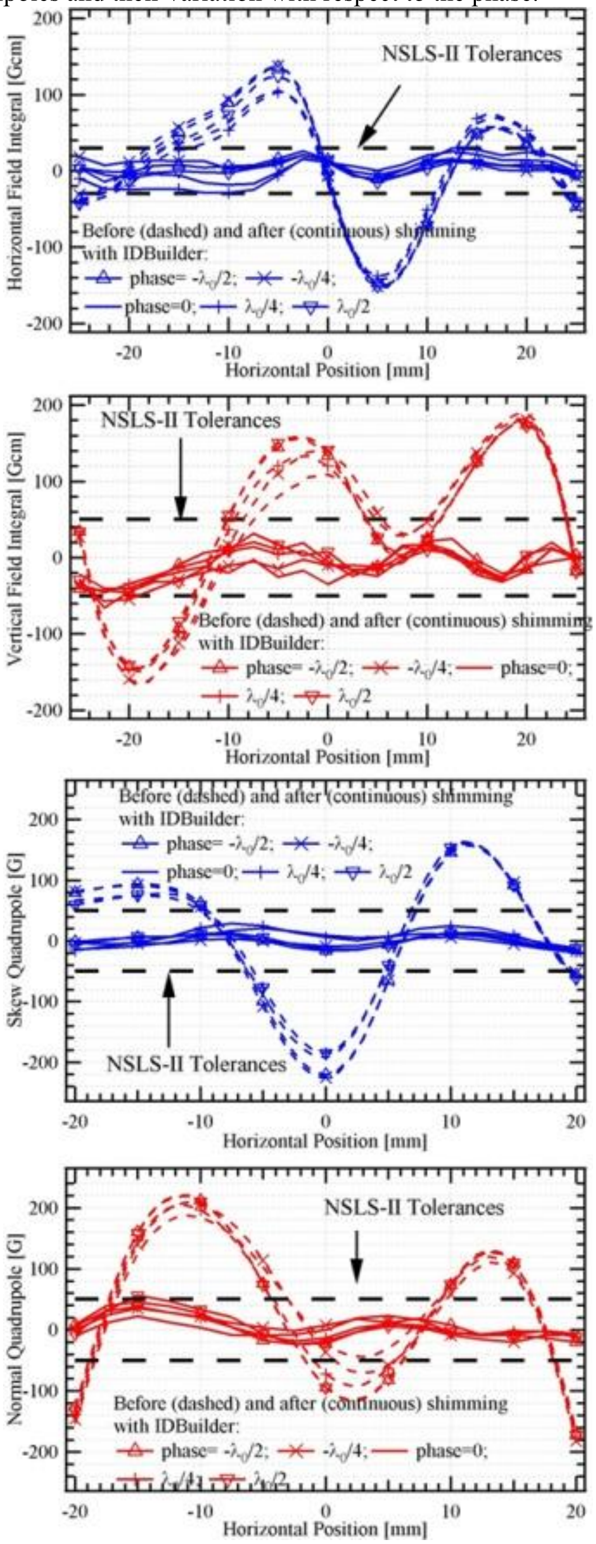

Figure 5: Horizontal and vertical field integrals and the normal and skew integrated multipoles before and after shimming.

4 Virtual shimming and 7 Magic fingers iterations were necessary to shim the device within the NSLS-II specification. Figure 5 compares the field integrals and integrated quadrupoles before and after shimming. Both field integrals and integrated quadrupoles are well kept within the NSLS-II specified tolerances over a large horizontal range. Furthermore the vertical field integral variation with respect to the phase is kept around ±20Gcm over a large horizontal range (±20mm); the on-axis horizontal field integral variation with respect to the phase is about ±2.5Gcm. Off-axis, this variation increases but stays within ±20Gcm over a large horizontal range (±20mm). This is significantly smaller than the variation measured on the two CSX APPLE-II type undulators which were delivered as turnkey devices. The SIX field integrals achieved after IDBuilder aided shimming compare well with the ones achieved with the innovative EPU61 for MAX-IV [8]. This work demonstrates the ability of the NSLS-II ID group to successfully perform IDBuilder aided shimming and to deliver well-tuned devices, even challenging ones, to NSLS-II

CONCLUSION

The two long EPUSs for the NEXT project were delivered during spring 2016. The NSLS-II ID group is responsible for the magnetic performance of these two devices. Using IDBuilder we successfully completed the magnetic correction of the first device in two months. The SIX EPU was installed in the storage ring in September 2016 and will be commissioned in October 2016. The second device is now in the NSLS-II magnetic measurement lab and the assembly of the M3 and M5 modules on the girders has begun.

REFERENCES

[1] NSLS-II Beamline Development Timeline, `https://www.bnl.gov/ps/nsls2/beamlines/time-line.php`

[2] M. Musardo *et al.*, "Recent Magnetic Measurement Activities at NSLS-II Insertion Device Laboratory" in *Proc. IPAC'16*, Busan, Korea, May 2016.

[3] NEXT project, `https://www.bnl.gov/nsls2/project/next/`

[4] O. Rudenko and O. Chubar, "An Evolutionary Approach to Shimming Undulator Magnets for Synchrotron Radiation Sources", in *Proc. PPSN IX,* Reykjavik, Iceland, September 2006.

[5] M. Kokole *et al.*, "Magnetic Characterization of the FEL-1 undulators for the FERMI@Elettra free electron laser" " in *Proc. IPAC'16*, Busan, Korea, May 2016.

[6] J. Chavanne, P. Elleaume, and P. Van Vaerenbergh, "End field structures for linear/helical insertion devices" in *Proc. PAC'99*, New York, USA, April 1999.

[7] C. Kitegi *et al.*, "Progress of the Coherent Soft X Ray Straight Section at NSLS-II" in *Proc. IPAC'11*, San Sebastian, Spain, September 2011.

[8] E. Wallén, I. Blomqvist, J. Bahrdt and F.-J. Boergermann., "Novel magnet production technique used for an elliptically polarizing undulator" in *Proc. IPAC'14*, Dresden Germany, May 2014.