*musardo@bnl.gov

Phasing Magnet for CSX-2 beamline at NSLS-II

27th International Conference on MAGNET TECHNOLOGY
November 15-19, 2021, Fukuoka, Japan
Hybrid Conference: On-site and On-line

M. Musardo*, T. Tanabe, J. Rank, D. Harder, T. Corwin and C. Rhein,
Photon Science Directorate, Brookhaven National Laboratory, Upton, NY, 11973 U.S.A.

Abstract

A phasing magnet has been developed at National Synchrotron Light Source II (NSLS-II) for the Coherent Soft X-ray Scattering (CSX) beamline. The phasing magnet will be located at the center of the straight section in between two identical and independent variably polarized APPLE-II devices. Based on Permanent Magnet technology, the phasing magnet has been designed to achieve the required electron beam delay in order to properly adjust the phase matching of these two consecutive EPUs (Elliptically Polarizing Undulators) and ensure a positive interference between the photon beam emitted in each device. This paper will describe the mechanical and magnetic design together with the final field measurements and magnetic tuning results. Also, the spectral performance of the two EPUs and the method used to properly set the field strength of the phasing magnet for any given radiation wavelength and polarization mode will be presented as well.

Historically the National Synchrotron Light Source II Coherent Soft X-ray Scattering canted beamlines (NSLS-II **CSX** and **IOS**, formerly CSX-1&2) were independently sourced via two identical variably polarized APPLE-II EPU49 devices. Limited phasing could only be crudely achieved by shift of the four independent longitudinal axes of each EPU. This Phaser now installed in the very narrow space downstream of the existing Canting Magnet shares its stanchion and a channel from its motor driver and controls as shown in Figure 2

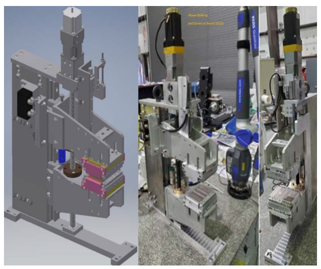

Fig. 1 NSLS-II C23 Phasing Magnet 3D model

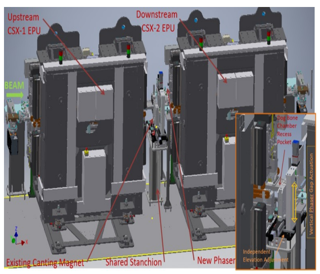

Fig. 2 Phaser integrated into canted straight

1. Mechanical Design of the Phaser Core

Four types of custom permanent magnets (PM) of varying length and magnetization construct the Phaser Magnet Core depicted in Figure 3. Neodymium-Iron-Boron rare earth magnet having 25 kOe intrinsic coercivity and are oven-aged and nickel plated. Each underwent magnetic characterization for PM sorting in our Helmholtz coil. Custom 3D-printed measurement fixture (inset, Figure 4) are used for the measurements.

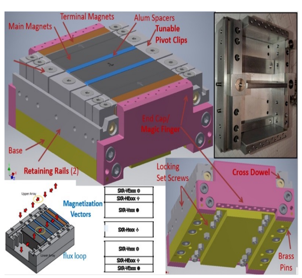

Fig. 3. Phaser half core assembly; Inset: Core structure and magnetic flux loop.

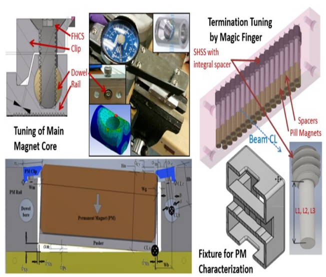

Fig. 4. Tool for coil measurement of each PM

The PM array has design features which allow for expanded tuning capacity (Fig. 4).

1) pivoting PM retaining clips fastened by a system of cross-threaded cylinders, or dowels (two per PM);
2) side and bottom set screw adjustors
3) MF pill-capturing set screws with integral spacer of varying lengths .

2. Mechanical and Structural Assembly of Phaser

The Phaser mechanics is single axis consisting of right-hand left-hand lead screw. The screw is non-lubricated and acts on two opposing nuts. These actuate the gap through a flexible-coupled step motor with 1.21 N-m peak torque output rating driving a 20:1 gearhead. The full-speed ramp up takes 1 second. The nuts which are nearest to both gap and electron beam have low relative magnetic permeability (< 1.3). The lead screw, however, is from high permeability hardened steel. The calculated fringe field at 115 mm is acceptable 15 G. The drive axis is self-locking to inhibit overhaul without a brake. A single sub-assembly serves both as spring compensation system and as a finely adjustable hard stop. Gravitational force acting on the RH/LH screw self-cancels. A heavy die spring opposes magnetic force at small gaps. Critically, at all gaps the design assures a positive net load to inhibit backlash with smooth axis motion. The radiation sensitive electronic absolute encoder/scale providing positional feedback is shielded by lead.

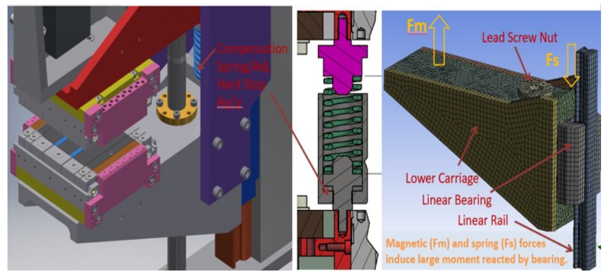

Fig. 5. Hard Stop/ Force Compensation System; Compound moment at fixed linear rail and bearing assembly.

3. Magnetic Design

The device's magnetic length is 99 mm, and the block height/width is 25mm and 66mm, respectively. The magnet thickness is 18mm and 4.5mm spacings on the both sides of the center magnet. All magnets have 2 mm chamfer at four corners. Figure 6 shows the magnetic model's rendering by Mathematica.

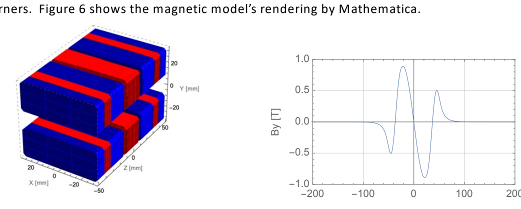

Fig. 6. 3D Magnetic Model and vertical magnetic field profile at 15 mm of gap

4. Magnetic Field Optimization

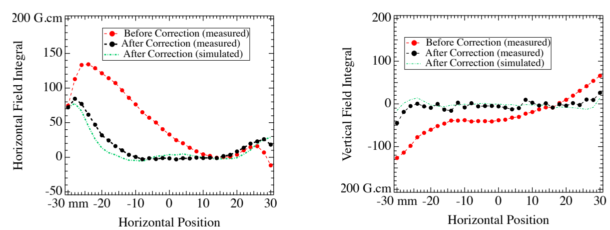

Fig. 7. Magic Finger Optimization Results

5. Magnetic Field Measurements

The Phaser has been characterized by Hall probe and Flip-Coil measurements to determine the magnetic field (Fig.8.1), field integrals (Fig. 8.2), integrated multipole (Fig.8.3) and phase integral PI (Fig.9.2) along the device for different gaps.

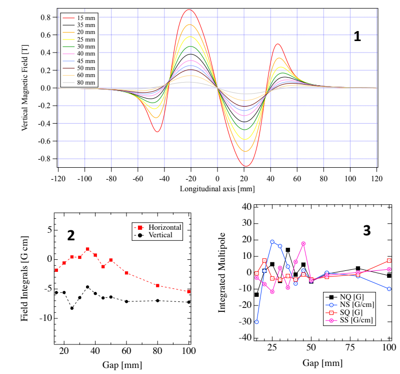

Fig. 8. 1. Magnetic field profile at different gaps; 2 First field integral as a function of gap; 3. Integrated Multipole Vs gaps

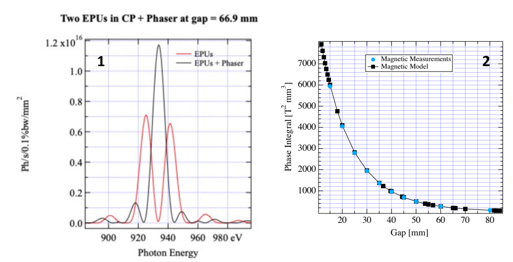

Fig. 9. 1. Comparison between the flux density on-axis of two EPUs in circular polarization with and without Phaser. 2. Phase Integral (measured/estimated) along the device for different gaps.

5. Conclusion

The restrictive physical constraints of the interstitial space between two tandem canted EPU49 at the C23 straight section of the NSLS-II ring have been overcome by design of a unique Phaser magnet core and structure. The magnet core design is highly bench-tunable and the mechanics employ a versatile compensation system to permit use of our most common and interchangeable NSLS-II ID components. Magnetic measurements by Hall Probe and Flip-Coil were performed and met specification with minimal tuning. The Phaser now in service provides efficient phasing control for an effective 4.0-meter source to the CSX-2 beamline users