DESIGN AND DEVELOPMENT OF AN ELLIPTICALLY POLARIZED UNDULATOR OF LENGTH 3.5 M FOR TPS

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Abstract

An elliptically polarized undulator of length 3.5 m and period length 48 mm (EPU48) is designed to fulfil experiments on spin-polarized PES and inelastic scattering at the Taiwan Photon Source (TPS). EPU48 would be used to produce variously polarized light in the soft X-ray spectral domain 0.4-1.5 keV. To achieve efficient mechanical performance and a high quality of photon source, a new manufacturing method by casting is adopted to fabricate a key component of the carriage of the undulator at National Synchrotron Radiation Research Center (NSRRC). We expect this approach to bestow advantages of decreased assembly error, increased rigidity and highly precise properties. Here we describe details of the design of the magnetic circuit and the mechanical design of the EPU48 based on this new concept of engineering construction.

INTRODUCTION

With electron energy 3 GeV and beam current 500 mA, Taiwan Photon Source (TPS) is a third-generation experimental facility for synchrotron radiation that is undergoing civil-engineering construction. Various insertion devices, including in vacuum undulators (IU), cryogenic permanent magnet undulators (CPMU), elliptically polarized undulators (EPU) and superconducting undulators (SU) that are being considered for installation into the new storage ring in the TPS commission stage, are being discussed and planned so as to equip the machine to produce great brilliance and intense light to fulfil multidisciplinary experimental requirements. For the undulators adopted at TPS, table 1 and figure 1 show the key parameters and spectral performance estimated with Spectra code [1]. Two EPU of Apple-II type providing all polarized modes for radiation in the soft X-ray spectral range will be built internally [2]. To achieve a high quality and a brilliant light source, the demands of a robust and highly precise mechanical carriage become the most significant subject. For the implementation of this device, various aspects include magnetic-force behaviour, the layout of the structural configuration, the assembly and component selection that require thorough consideration. The entire control instrumentation must otherwise be compatible with the EPCIS system. Here we discuss the recent development and design status of two sets of EPU48.

Table 1: Specification of Insertion Devices Adopted at TPS First Stage

Ee /GeV 3		EPU48	IU22	IU22	U50
photon energy /keV	HP	0.4-1.5	5-20	5-20	0.08-1.5
	VP	0.4-1.5			
current /A		0.5	0.5	0.5	0.5
λ/mm		48	22	22	50
N_{period}		73	95	137	76
B_y /T		0.85	0.79	0.79	0.64
B_x /T		0.59			
Ky_{max}		3.81	1.54	1.54	3
Kx_{max}		2.65			
L /m		3.5	2	3	3.9
gap /mm		13	6.5	6.5	18
number of devices		2	2	3	1

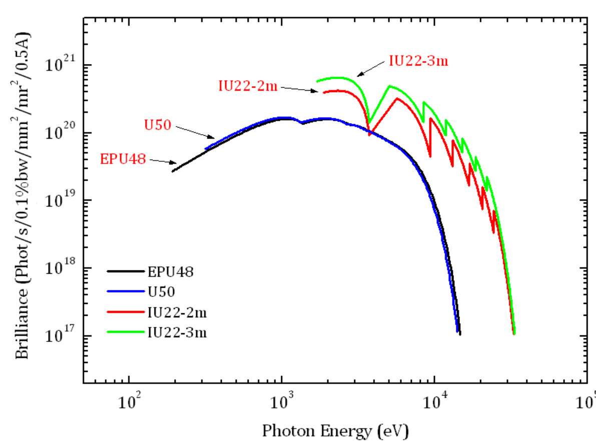

Figure 1: Spectral performance of insertion devices adopted at TPS

DESIGN OF THE MAGNETIC CIRCUIT

To realize the soft X-ray spectral range 0.4-1.5 keV in TPS, the EPU48 of Apple-II type shown schematically in figure 2 is considered to serve the facility in the future. The physical parameters of the undulator in table 2 are results optimized with Radia code [3]. In accordance with the magnetic circuit design, figure 3 shows the magnetic field at minimum gap 13 mm along the longitudinal direction that induces polarized modes vertical, horizontal and circular.

Table 2: Physical Parameters of the Undulator

magnet remanent field /T	1.24
intrinsic coercivity /kOe	≧25
material of the magnet block	NdFeB
height of the magnet block, H /mm	40
width of the magnet block, W /mm	35
thickness of the magnet block, L /mm	12
gap between adjacent arrays, g_x /mm	0.7

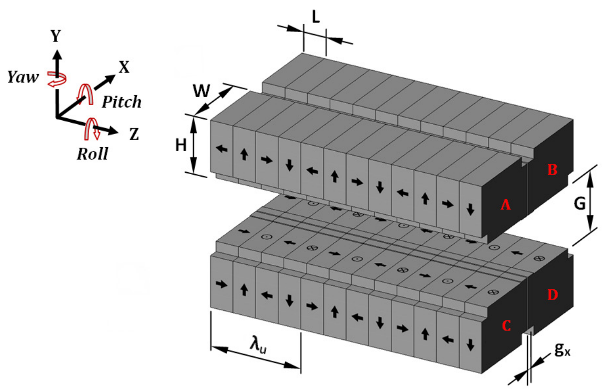

Figure 2: Schematic diagram of Apple-II type EPU

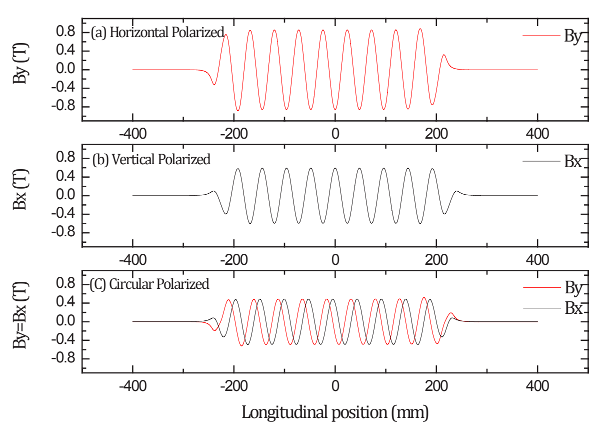

Figure 3: Magnetic field of horizontal, vertical and circular polarization on the axis

The great magnetic force arising during machine operation must be withstood by a robust mechanical frame. The support guideline of the frame design for EPU48 is, as well known, subject to the worst-load situation of table 3. The inclined (inc.) or helical (hel.) mode is defined with two diagonal arrays (B&C) moving anti-parallel (B toward +Z and C toward -Z) or parallel (B&C toward +Z), respectively. The positive and negative signs denote the force direction in accordance with coordinates in figure 2.

Table 3: Maximum Magnetic Force /kN Acting on Magnet Arrays at Minimum Gap 13 mm for EPU48 in Helical and Inclined Modes

	stationary array		**mobile array**		**upper pair**	
	hel.	**inc.**	**hel.**	**inc.**	**hel.**	**inc.**
F_x	30.5	30.5	-30.5	-30.5	-	3.3
F_y	-18.5	-18.5	-18.5	-18.5	-36.9	-36.9
F_z	-4.5	-32.8	4.5	4.5	-	-26.5

ENGINEERING DESIGN

Through the familiar interactive magnetic-force function of the gap and phase displacement adjustment, the engineering design of the EPU48 must clearly recognize these issues and overcome the problems. As a result, the conceptual design of EPU48 is proceeding via finite-element calculations to optimize the mechanical engineering. It consists mainly of a gap/phase driven mechanism, interlock protection devices, mechanical supporting frame, back beam and levelling/positioning device etc.

Phase-driven Mechanism

Three cross-type linear guides shown in figure 4 are the needle, roller and slide pad [4][5]. In the past, many configuration distributions involving these passive transmission components were proposed to take account of complicated strong forces. Figure 5 summarizes these common arrangement layouts, although some design details might differ slightly.

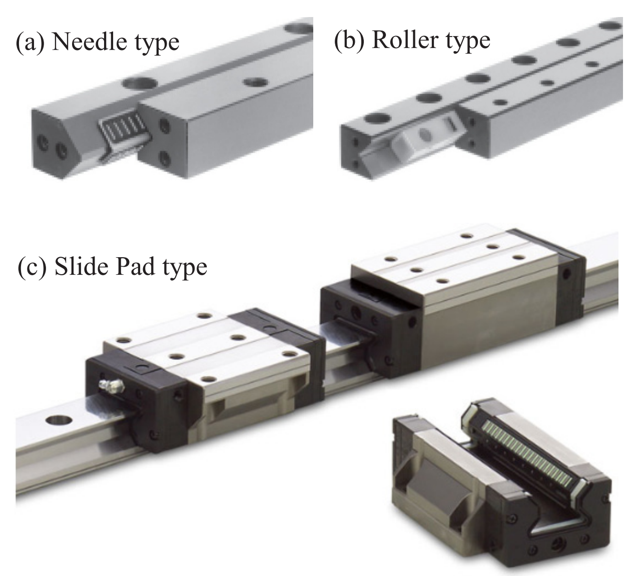

Figure 4: Cross-type linear guides

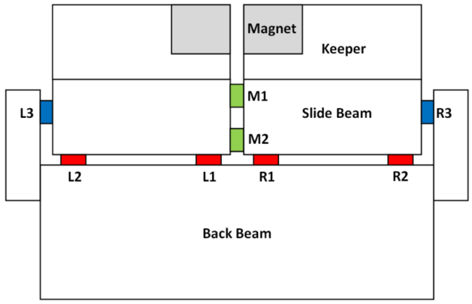

Figure 5: Passive transmission distribution

In previous experience of EPU56 and EPU46 devices, part of this was arranged in L3-M1-M2 by roller type and L2-L1-R1-R2 by needle type, respectively [6][7]. During assembly of the guide, it shall be set to preload on the rail more carefully. The EPU48 would be planned to select the linear guide-slide pad type and combining L2-L1-M1-R1-R2 in a settled form as a phase-driven mechanism. This way is predicted to bring benefits of decreased time and simplified assembly without decreasing the stiffness of the structure.

Support frame and Gap Movement Mechanism

Figure 6 represents the geometric profile of the EPU48 mechanical design. Each of two magnet arrays is mounted onto upper and lower girders. Each girder connects with two saddles, and the saddle is installed on a ball screw. The movement of the ball screw is effected with a driven chain. For smooth vertical motion, a mechanism for the gap movement is equipped with cross-type slide pad guides. The C frame is intended to be constructed by cast production. The fabrication could more readily realize extreme stiffness than the method of welding and fastening.

Because of the gap/phase displacement adjustment with closed servo loops, a huge torque and axial force occur. The magnetic force and gap/phase driven force are located in a non-concentric line because of the design of the driving mechanism. Hence the mechanism is required to be robust to resist moment and force. The way of girder lifting/suspending by jacks directly differs in requiring greater space in the vertical direction to accommodate the travel of the shaft, and the region surrounding the jack support is required to be more robust.

Interlock and Protection System

To assure safe operation of the gap and phase of the machine and to protect components from free failure, the EPU48 is equipped with software and hardware protection. The hardware protection includes optical sensors, highly precise mechanical switches, a stopper for the end of travel, a tilt sensor and emergency stop button.

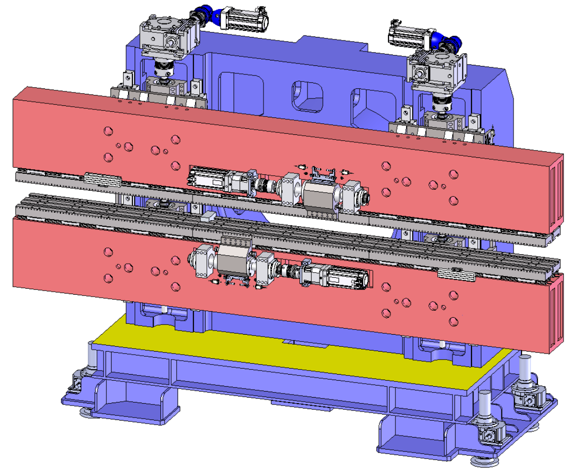

Figure 6: Conceptual Design of EPU48

CONCLUSION

Relative to prior EPU56 and EPU46 at NSRRC, the EPU48 operating at smaller gap 13 mm would result in increased magnetic force. To accommodate the magnetic-circuit arrangement, a stable and precise carriage is hence a significant request for EPU48. Based on the action of magnetic force and considering the thermal effect in various materials, a conceptual profile of a mechanical frame has been designed and drawn as above. Some aspects of the base frame with positioning/levelling device and the gap monitoring mechanism are subject to continuing design and discussion. The detailed design of the entire EPU48 will be determined in the middle of the year, following which engineering construction will proceed.

REFERENCES

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