ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-WEPH17

ADJUSTING MECHANISM OF INTER-UNDULATOR SECTION FOR PAL-XFEL

H.G. Lee, B.G. Oh, S.B. Lee, Y.G. Jung, H.S. Suh, S.H Jeong, D.E. Kim, K.H. Park, J.H. Han, H.S. Kang, H.S. Lee, Pohang Accelerator Laboratory, Pohang, Korea

Abstract

Pohang Accelerator Laboratory (PAL) has developed a SASE X-ray Free Electron Laser based on 10 GeV linear accelerator. The inter-Undulator (IU) support section was developed to be used in the intersections of the Undulator Systems. The IU supports consist of phase shifter, quadrupole magnet with mover, beam loss monitor, cavity BPM with mover, two corrector magnets and vacuum components. The adjusting mechanism of IU Support has manual alignment system to be easily adjusting the component. The mover of quadruple magnet and cavity BPM with submicron repeatability has auto-adjusting systems with stepping motor. The mover main specifications include compact dimensions and a ±1.5 mm stroke in the vertical and horizontal direction. Linear motion guide based on 5-phase stepping motors have been chosen. This paper describes the design of the stages used for precise movement and results of mechanical measurements including reproducibility will be reported.

INTRODUCTION

PAL-XFEL has been providing X-rays in ranges of 0.1 to 0.6 nm for hard X-ray line and 3.0 nm to 1.0 nm for soft X-ray line by using the self-amplified spontaneous emission (SASE) Schematic [1]. For undulator system, there are 20 undulators for hard X-ray line and 7 planar undulators with additional two EPUs (Elliptically Polarized Undulator) are expected for soft X-ray line. To generate X-ray FEL radiation, the PAL-XFEL undulator section requires high resolution beam position monitoring systems with <1 μm resolution for single bunch. It will be used in the intersections of the Undulator Systems to achieve high resolution requirement.

The inter-undulator sections, shown in Figure 1, consist of phase shifter, quadrupole magnet with mover, beam loss monitor, two corrector magnets, cavity BPM with mover and vacuum components. The quadrupole mover developed based on the EU-XFEL concept with some modifications [2]. It includes submicron repeatability for quadrupole magnet and a ±1.5 mm stroke in the vertical and horizontal direction. Compact linear actuators based on 5-phase stepping motors have been chosen. Vertical actuator works in a wedge configuration to take mechanical advantage. A closed-loop control system has been developed to achieve this repeatability. For the feedback, one LVDT sensor for each axis was used. Mechanical switches are used to limit movement. In addition, hard-stops are included for emergency.

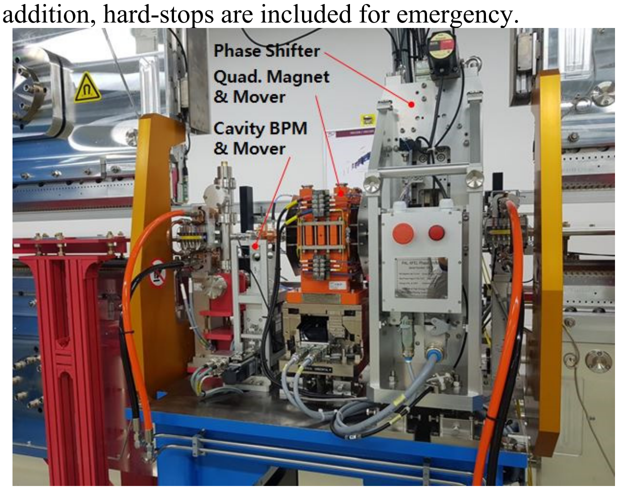

Figure 1: Lay-out of inter-undulator section.

OVERVIEW OF CAVITY BPM MOVER

The cavity BPM(C-BPM) system has installed in between each undulator with other diagnostics tools. The cavity BPM Mover had been fabricated, tested and installed for the PAL XFEL [3]. The main specifications include submicron repeatability for a 10 kg cavity BPM with support within compact dimensions and a ±1.5 mm stroke in the vertical and horizontal direction. Linear motion guide based on 5-phase stepping motors have been chosen. For the measurement of the position, one digital probe sensor for each axis was used. Mechanical switches are used to limit movement. In addition, hard-stoppers are included for emergency.

Table 1: Main Specification for C-BPM Movers

	Value	Details
Dimensions	332x140x255.5 mm^3	Long, wide, high
Axes	2(H & V)	±1.5 mm stroke
Load	10 kg	
Repeatability	< 3 μm	
Control Device	Digital probe closed-loop	EPICS
Ranges	±1.5 mm Limit Switch	±1.6 Hard Stopper
Driving System	5 Phase Stepping Motor	With brakes
Measure System	Digital Probe (DP/5/S)	< 0.15 μm
Limit Sensor	D4E-1C20N	

The main specifications for these movers are included in Table 1. The movers are composed of each stepping motor for horizontal and vertical, digital probe, limit switch and harder stopper. Figure 2 shows the 3D view of cavity BPM system. A robust and compact mover is required according to specifications therefore concept

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design includes some important features. The drive mechanism adopts a 5-phase stepping motor with ball screw for Oriental Motor's. The motor achieves high positioning accuracy in a space-saving design. The compact and lightweight body houses the rotating components as well as the linear motion mechanism of the stepping motor. The load position can be held with electromagnetic brake when the power is cut off. Since the work will not fall in case of power failure or disconnection, it can safely use equipment in which the work moves vertically. Linear motion (LM) guides and high-precision motors have been selected for both axes. LM guide in each row of balls is placed at a contact angle of 45° so that the rated loads applied to the LM block are uniform in the four directions (radial, reverse radial and lateral directions). Two digital probes are used to measure at horizontal and vertical direction movement.

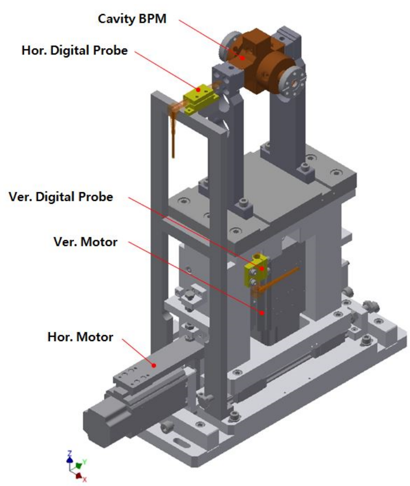

Figure 2: 3D view of cavity BPM Mover.

REPEATABILITY OF C-BPM MOVER

The repeatability is the most important specification of the movers, as submicron level must be reached. The testing set up is displayed at Figure 3. The cavity BPM mover is measured at both axes with external reference gauges. The positioning to a certain LVDT position reaches always exactly the same actual position from external references in a perfect repeatable system. The sets of measured movements are 0.2 mm steps along the vertical axis and the horizontal axis for the whole movement range. Results for direct movements from a given position have been found to have very high repeatability.

Design has showed also a high ability to keep position under certain possible conditions. Under such conditions, Repeatability is below ± 1 micron at every set of movements for both axes. Figure 4 shows the repeatability of the number 3 cavity BPM mover. Upper graph is the measuring data for horizontal movement and lower is the vertical movement. The maximum deviation is ±0.3 μm for horizontal movement and the vertical movement is ±0.6 μm.

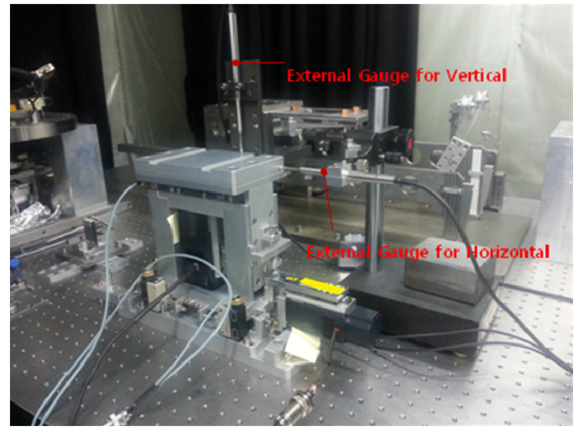

Figure 3: Test set-up for repeatability of cavity BPM Mover.

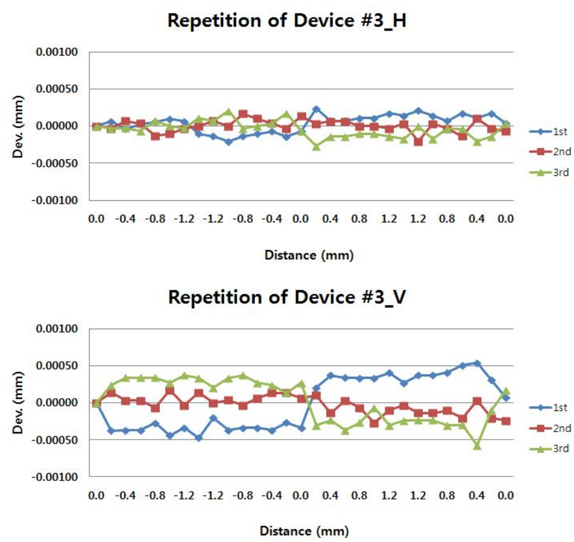

Figure 4: Repetition of cavity BPM Mover. Maximum deviation is ±0.3 μm of horizontal and ±0.6 μm of vertical measurement for number 3 Mover.

OVERVIEW OF QUAD MOVER

Quad mover has developed to be used for the Hard X-ray and Soft X-ray undulator line. On the basis design of EU-XFEL quad mover, we implemented some modification, fabricated and tested. The modification parts are the position of horizontal and vertical LVDT. It was located outside of the moving mechanism and sensors are touched directly the moving parts. The main specifications, shown in Table 2, include submicron repeatability for a 70 kg quadrupole magnet within compact dimensions and a ±1.5 mm stroke in the vertical and horizontal direction. Compact linear actuators based on 5-phase stepping motors have been chosen. Vertical actuator works in a wedge configuration to take mechanical advantage. A closed-loop control system has been developed to achieve this repeatability. For the feedback, one LVDT sensor for each axis was used. Mechanical switches are used to limit movement. In

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addition, hard-stops are included for emergency. Figure 5 shows the front and rear view of quad mover.

Table 2: Main Specification for Quad Movers

	Value	Details
Dimensions	360x220x175 mm^3	Long, wide, high
Axes	2(H & V)	±1.5 mm stroke
Load	70 kg	
Repeatability	< 1 µm	
Control Device	LVDT closed-loop	EPICS
Ranges	±1.5 mm Limit Switch	±1.6 Hard Stopper
Driving System	5 Phase Stepping Motor	With brakes
Measure System	LVDT (SM222.4.1.S)	SCHREIBER
Limit Sensor	PN41	SAIA-Burgess

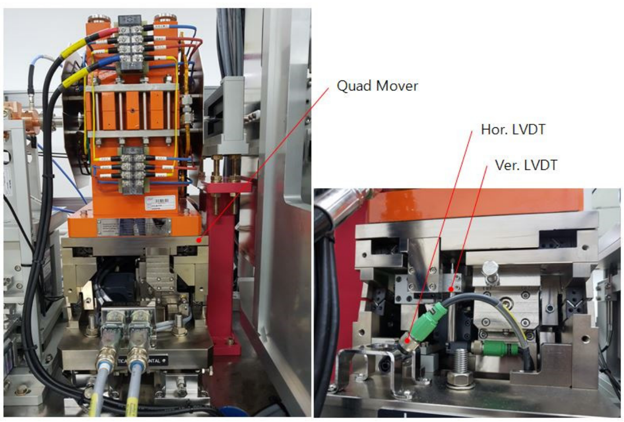

Figure 5: Front and rear view of quad mover. Left is front view and right is rear view. LVDT is attached out-side of moving parts.

A robust and compact mover was required, therefore concept design include the following important features.

High-precision linear motion guide had been selected for both axes X and Y. The wedge design has a slope so the force needed to lift the load is lower than the direct weight of the load. At the same time, diagonal movement instead of a vertical one results in a finer resolution for vertical axis. The measuring position of LVDT is very important because of backlashes. So, measuring point of LVDT is attached directly moving parts for vertical and horizontal. A closed-loop control system is implemented in order to achieve submicron repeatability. Two LVDTs are placed outside the mover to get a continuous measurement of each axis absolute position. Each LVDT has been arranged to measure just one axis at a constant contact point, which means that the LVDT and the measurement surface have no relative movement apart of the measured in-axis separation. Limit switches were added at the ends of movement of both axes to ensure that even under a failure of the LVDT sensors the mover will be reach a safe stop position. Moreover, mechanical stoppers have been implemented to exclude any possibility of over-travelling.

REPEATABILITY OF QUAD MOVER

The repeatability is the most important specification of the quad movers, as submicron level must be reached. It was measured at both axes with external reference gauges. The positioning to a certain LVDT position reaches always exactly the same actual position from external references in a perfect repeatable system. The sets of measured movements are 0.2 mm steps along the vertical axis and the horizontal axis for the whole movement range. We have to measure 5 times at both axes. Results for direct movements from a given position have been found to have very high repeatability. Under such conditions, repeatability is below ± 1 micron at every set of movements for both axes. Figure 6 shows the repeatability of the number 14 Quad Mover. Upper graph is the measuring data for horizontal movement and lower is the vertical movement. The maximum deviation is ±0.8 µm for horizontal movement and the vertical movement is ±0.6 µm.

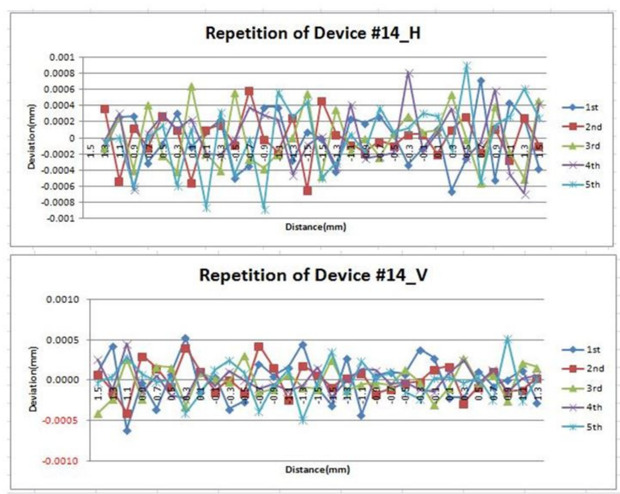

Figure 6: Repetition of Quad Mover. Maximum deviation is ±0.8 µm of horizontal measurement and vertical is ±0.6 µm for number 14 Mover.

SUMMARY

In this report, the status of the moving mechanism for the PAL-XFEL Inter-Undulator section is briefly described. It was supplied and installed to Hard X-ray and Soft X-ray Undulator hall. The C-BPM mover was installed 49 units and the quad mover was installed 30 units. The C-BPM Mover and the Quad Mover was supplied and tested from domestic company.

REFERENCE

[1] I.S. Ko, J.-H. Han, "Current status of PAL-XFEL project", in *Proceedings of 27th Linear Accelerator Conference*, Geneva, Switzerland, August 31-September 5, 2014, paper MOIOB04, pp. 26-30.

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[2] J. Munilla *et al*, "Design, Manufacturing and Tests of Closed-Loop Quadrupole Mover Prototypes for European XFEL", in *Proceedings of 2nd International Particle Accelerator Conference*, San Sebastian, Spain, Sept. 2011, paper MOP0026, pp. 535-538.

[3] H.G. Lee *et al*, "Technical Overview of Cavity BPM Mover for PAL XFEL", in *Proceedings of 7th International Particle Accelerator Conference*, Busan, Korea, May 2016, paper TUPMB013, pp. 1136-1138.