TECHNICAL OVERVIEW OF CAVITY BPM MOVER FOR PAL XFEL

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Abstract

Pohang Accelerator Laboratory (PAL) has been developing a SASE X-ray Free Electron Laser based on 10 GeV linear accelerator. The cavity BPM mover was developed to be used in the intersections of the Undulator Systems. The main specifications include submicron repeatability for a 50 kg cavity BPM adjusting system within compact dimensions and a ±1.5 mm stroke in the vertical and horizontal direction. Compact linear motion guide based on 5-phase stepping motors have been chosen. A closed-loop control system has been developed to achieve this repeatability. For the feedback, one digital probe sensor for each axis was used. Mechanical switches are used to limit movement. In addition, hard-stops are included for emergency. In this report, we describe the design of the stages used for precise movement and results of mechanical measurements including reproducibility will be reported.

INTRODUCTION

PAL-XFEL will provide X-rays in ranges of 0.1 to 0.06 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][2]. 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. To achieve high resolution requirement, the PAL-XFEL undulator section will use the cavity BPM. It can achieve sub-micron resolution for single pulse measurements by using the resonant mode of cavity.

The cavity BPM system will be installed in between each undulator with other diagnostics tools. The cavity BPM Mover had been fabricated, tested and installed for the PAL XFEL. It will be used in the intersections of the Undulator Systems. The inter-undulator sections, shown in Figure 1, consist of phase shifter, quadrupole magnet with mover, beam loss monitor, two corrector magnets and cavity BPM with mover. The position of such diagnostic devices remains fixed with respect to the central dipoles. The main specifications include submicron repeatability for a 10 kg cavity BPM within compact dimensions and a ±1.5 mm stroke in the vertical and horizontal direction. Compact linear motion guides based on 5-phase stepping motors have been chosen. A closed-loop control system has been developed to achieve this repeatability. For the feedback, one digital probe sensor for each axis was used. Mechanical switches are used to limit movement. In addition, hard-stoppers are included for emergency.

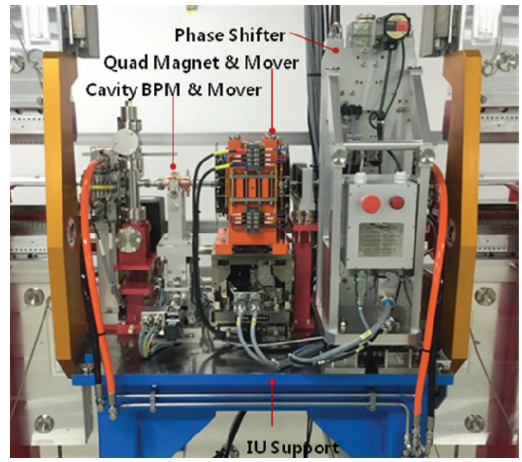

Figure 1: Lay-out of Inter-Undulator Section.

OVERVIEW OF CAVITY BPM MOVER

Table 1: Main Specification for 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 exploded view of 3D modeling. A robust and compact mover is required according to specifications therefore concept 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

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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.

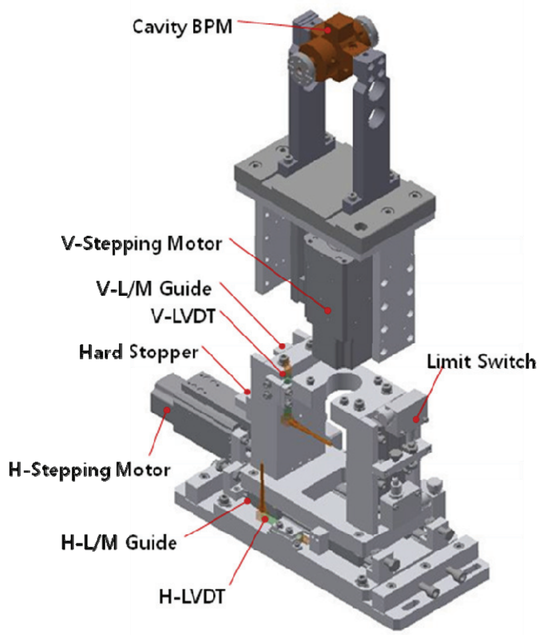

Figure 2: Exploded view of 3D modelling for cavity BPM Mover.

REPEATABILITY TEST

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 [3]. 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.

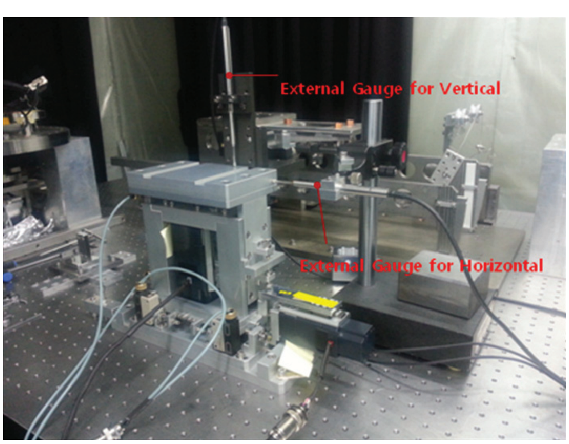

Figure 3: Test set-up for repeatability.

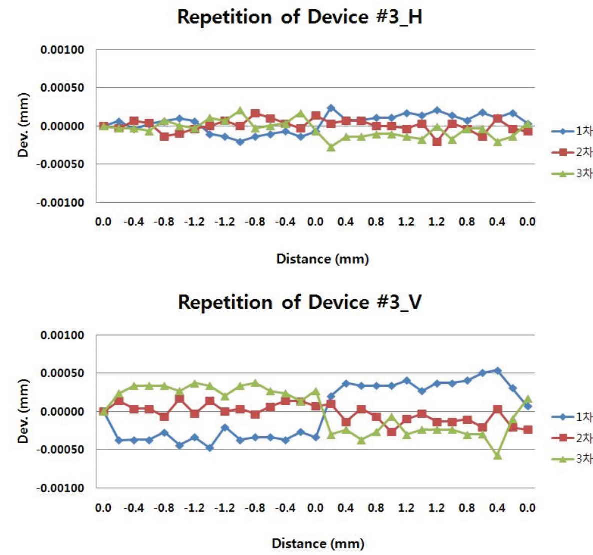

Figure 4: Repetition of cavity BPM Mover. Maximum deviation is ±0.6 μm of vertical measurement for number 3 Mover.

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.

CONTROL SYSTEM

In order to provide good support of cavity BPM position, cavity BPM mover is constructed with 2 axis motors. The number of Cavity BPM mover Controller is 7ea and each controller controls an 8ea (channel) motor. It use maximum channel (8channel) to reduce controller number. A cavity BPM mover contains 2 stepping motor for horizontal and vertical adjustment and equipment specifications are as Table 2. Each motor can be moves ± 1.5mm each of Horizontal direction, Vertical direction. Each motor have 2 limit contact type sensors. Also each motor have 2 hard stoppers. Operator can control 1 μm unit. Motor-driven feedback is based on the resolver of step motor.

Table 2: Device Specifications

	Actuator/Motor(encoder)		range	resolution
H stage	Motor	DRL 60PB4G-05MG	5mm	0.04 μm
	LVDT	DP/5/S (Orbit3)	5mm	<0.1 μm
	Limit	D4E-1C20N		
V stage	Motor	DRL 42PB2G-04MG	5mm	0.08 μm
	LVDT	DP/5/S (Orbit3)	5mm	<0.1 μm
	Limit	D4E-1C20N		

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An Experimental Physics and Industrial Control System (EPICS) will be used for the control system of the PAL-XFEL. In this system, EPICS was also applied by SMC-108. Controller is used SMC-108 and SMC-108 has a built-in a EPICS IOC inside. The controller system are adopted Linux. EPICS base version is 3.14.12.4. Motor record version is 6.8.8. Autosave version is 5.1. Sequence version is 2.1.13. EPICS IOC is connected to the control network by Ethernet(LAN) port on the front side. Operation status can be monitored by using a web server and outside access will be controlled by a public gate way in the public network. Operation interfaces in the control room will be connected to control servers and gateways by using the control network. Local IOCs will be connected by main channel access network and protected by gateways from direct access of operators or outside users. Figure 5 shows the controller cable connections and LAN port.

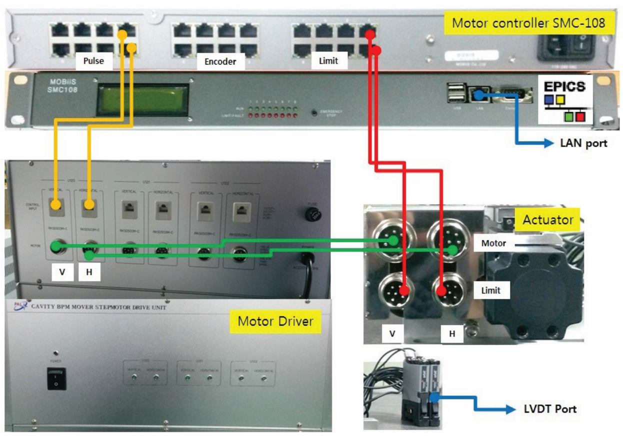

Figure 5: Controller cable connection and real figure.

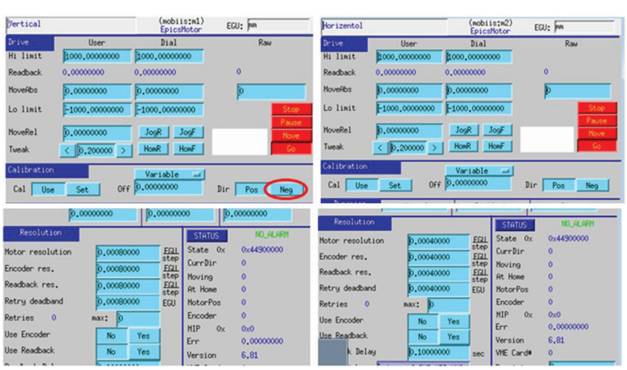

Figure 6: MEDM set up HMI.

SMC-108 is providing by basically MEDM. User must set up in MEDM to control all motors. At this time, user must should know gear ratio and screw pitch exatly. Because, It is very important work when user setting to motor controller(SMC-108). Figure 6 shows MEDM set up HMI. LVDT is displayed through another external IOC. LVDT displays just current position value. LVDT data are change every 3 seconds. Operation HMI is made by the CSS and operation overview is Figure 7. Figure 8 shows detail operation HMI. Operator can be control mover by input value and also control step by step. HMI provides two input mode. Also LVDT values can be monitored by CSS.

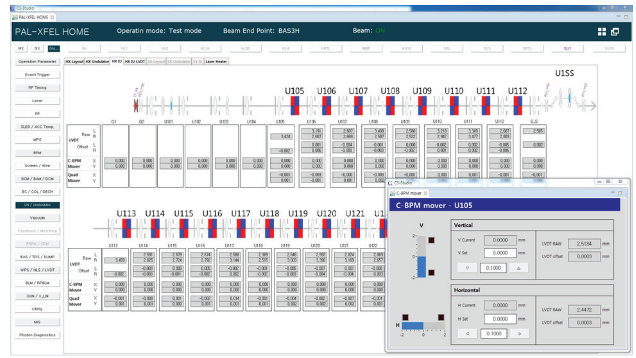

Figure 7: Operation Overview HMI.

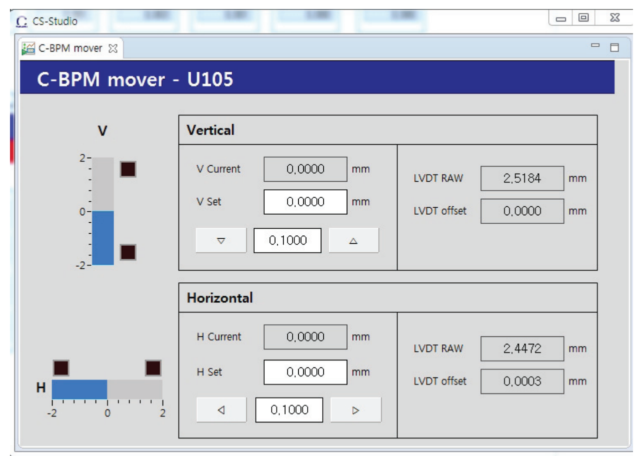

Figure 8: Detail operation HMI.

SUMMARY

In this report, the status of the PAL-XFEL cavity BPM mover system is briefly described the mechanism of structure and control system. It was already supplied and tested from domestic company. 26 cavity BPM movers have been installed in hard x-ray Undulator hall and 14 will be installed in soft x-ray Undulator hall in the near future.

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