ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPRI104

DESIGN AND FABRICATION OF BUNCH COMPRESSOR SUPPORT SYSTEM FOR PAL XFEL

H.G.Lee, D.H.Na, S.B.Lee, B.G.Oh, H.S.Suh, Y.G.Jung, D.E.Kim, K.H.Park, H.S.Kang, K.W.Kim
Pohang Accelerator Laboratory, POSTECH, KOREA

Abstract

Pohang Accelerator Laboratory(PAL) is developing a SASE X-ray Free Electron Laser based on 10 GeV linear accelerator. Bunch compressor support systems are developed to be used for the linear accelerator tunnel. The support system design is based on an asymmetric four-dipole magnet chicane in which asymmetry and variable R_{56}. can be optimized. This flexibility is achieved by allowing the middle two dipole magnets to move transversely. Moving system consist of servo motor, rodless ball screw actuator and linear encoder. In this paper, we describe the design of the stages used for precise movement of the bunch compressor magnets and associated diagnostics components.

INTRODUCTION

A bunch compressor (BC2) support system has been fabricated and tested for the PAL XFEL. The machine of the PAL XFEL consists of four main sections: the linear accelerator, the hard x-ray undulator hall, the soft x-ray undulator hall and the experimental area. The accelerator, schematically shown in Figure 1, comprises the gun, the laser heater, four accelerating sections groups (L1–L4), four bunch compressors (BC1, BC2, BC3_H and BC3_S) and the spreader. The physics design of the magnetic bunch compressor is based on an asymmetric four-dipole chicane configuration [1]. The BC purpose is to reduce the electron bunch length, thus increasing the peak current, taking advantage of the beam correlated energy spread. Due to the accelerating process, there is an inherent longitudinal energy spread in the electron bunch. Passing through four bending magnets chicane, the path length is energy dependent and the electron bunch is compressed. At each bend, the electron bunch head delays with respect to the tail. Mounting high homogeneity magnetic field dipoles and having diagnostic devices centre on the beam at each chicane position are the main advantages of the movable chicane.

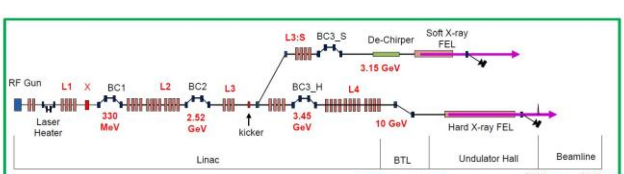

Figure 1: The schematic layout of the 3-BC lattice.

BUNCH COMPRESSOR OVERVIEW

The BC support system, shown in Figure 2 and Table 1, consist of four dipole magnets (DM), two tweak quadrupole magnets and skew quadrupole magnets, BPM, collimator, screen and CSR monitor. The position of such diagnostic devices remains fixed with respect to the central dipoles.

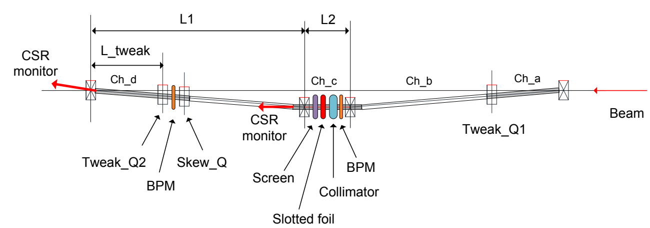

Figure 2: Layout of the BC support system.

Table 1: Major Parameters of the BC Support System

	BC1	BC2	BC3
Dipole angle , deg	5.5	3.7	2.3
Dipole length , m	0.2	0.6	0.6
L1 , m	4.4845	7.1905	7.597
L2 , m	1.2	1.6	1.6
L_tweak , m	1.146	1.3483	2.349
Aperture diameter of Tweak Quad , mm	44, Q11 (0.1 m)	44, Q11 (0.1 m)	44, Q11 (0.1 m)

The support systems of BC2 are composed of two fixed support and a moving support. The two central dipoles are mounted on a moving support that can have up to 465.6 mm motion orthogonal to the beam axis. A servo motor provides movement to the central stage and a linear encoder controls its exact position. The position accuracy of dipoles is within 50 μm. The chicane is symmetric (DM1–DM2 distance is equal to DM3–DM4 distance).

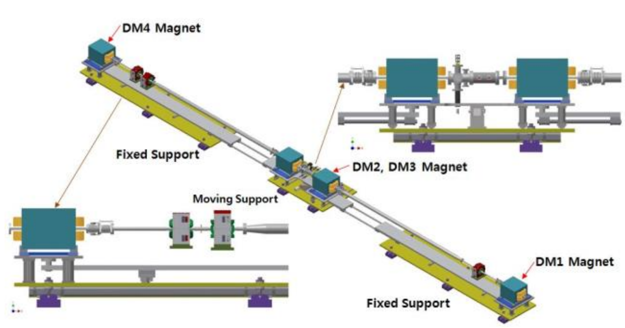

Figure 3: 3D modelling of BC2 support system.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPRI104

Tweak Q1 (Q2) is placed between DM1 (DM3) and DM2 (DM4). The quadrupole magnets rotate and remain at a fixed distance (1348.3 mm) from the pivot points B1 and B4. Figure 3 shows the BC2 layout and its overall 3D modeling.

MECHANICAL DESIGN

The BC2 support structure consists of three structural steel tables with 30 mm thick aluminum top plates. The moving table top plate house two sets of linear motion guide rails, each with a roller bearing cart, on which an aluminum sliding main plate is mounted. The main plate supports the two central dipoles and an adjustable aluminum plate. This plate carries the DM2, DM3 dipole magnet, and the BPM mounted on support independently adjustable. The dipole movements are controlled by means of a transverse support table for dipoles DM2 and DM3. The table travel on a pair of linear rails each with two linear guide blocks.

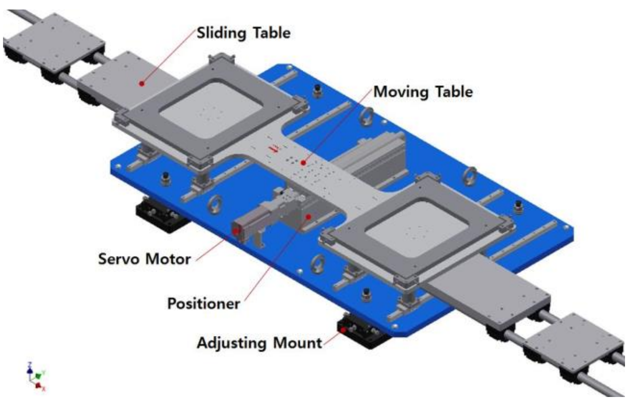

Figure 4: Component of moving support.

Figure 4 shows the component of the moving support system which is composed of basic support, moving table, sliding table, positioner and servo motor [2][3]. The mechanical parameters of the BC2 support systems are summarized in Table 2. The 406XR Positioner is capable of carrying relatively high loads up to a distance of 500 mm. Its quick and accurate positioning capability can be attributed to a high strength extruded housing, square rail ball bearing system, and precision ground ballscrew drive. It is equipped with 5mm lead ballscrew, linear encoder, electromagnetic break and limits switch. The detail design of moving mechanism shows Figure 5.

Table 2: Parameters of the BC2 Moving Support

Description	Moving Support
Dimension of Support[LxWxH][m^3]	5.0 x 1.3 x 0.53
Static torque of Servo Motor[N.m]	8.2
Working range of Positioner[mm]	500
Gear ratio	10:1
Resolution of Linear Encoder[μm]	0.5
Limit Switch & Hard Stopper	

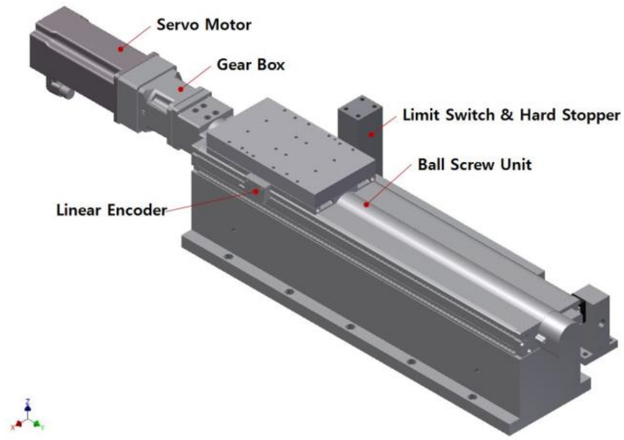

Figure 5: Detail design of moving mechanism.

Figure 6 shows the component of the fixed support system. DM1 and DM4 are mounted on the two fixed supports. Two rotating platforms supporting tweak quadrupole and skew quadrupole magnet are guided by two circular rails and a cam follower by adjustable ball transfer units. The cam follower is a compact bearing with a high-rigidity shaft and a built-in needle bearing. Most suitable as a guide roller for cam mechanisms and linear motion guided.

Each platform is driven by a rigidly connected ball spline unit on the fixed table and connected to the movable platform by a sliding constraint. There are four pivot assemblies which are mounted on rotating platforms for its equipments. The ball bearing is assembled inside a bearing housing pressed firmly by a cover plate and a collar nut. The pivot is fastened to the magnet support table and the rotating platform is attached to the bearing housing. The beam pivots are accurately located under each dipole centre, and therefore all devices are rigidly connected to the beams stay aligned with the dipoles geometrical centre. The basic structural steel beam design is aimed at minimizing deformations, guarantee of system position accuracy and reproducibility, keeping under control the total mass and the overall dimensions.

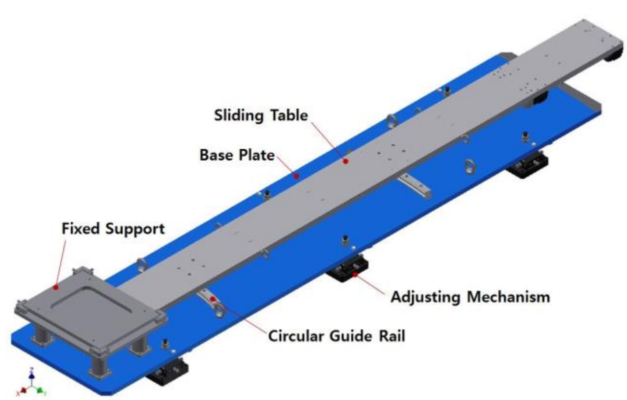

Figure 6: Component of fixed support.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPRI104

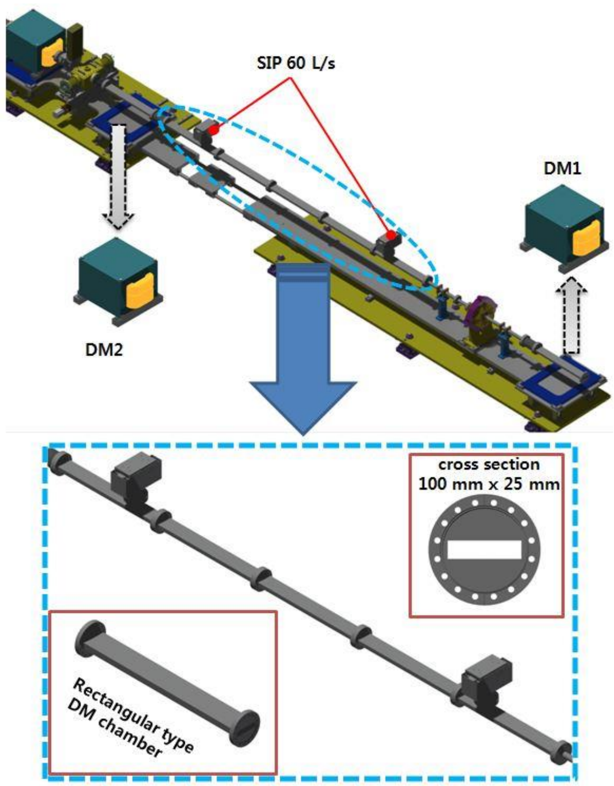

Figure 7: Bending magnet and drift vacuum chamber.

VACUUM CHAMBER DESIGN

On the basic design of LCLS Bunch compressor vacuum chamber, we implemented some modification, fabricated and tested [4][5][6]. Bellows at each side of the bending magnet are installed to respond the bending angle for vacuum chamber. The four dipole magnet chambers, also drift vacuum chamber, are made from extruded 6063-T5 aluminum alloy, chosen for its high mechanical accuracy, better electrical conductivity, high strength and superior weldability and is suitable for use as a vacuum chamber material. Aluminum alloys allow easy extrusion of complicated cross sections using porthole dies, and the Al-Mg-Si alloy provides superior performance in extrusion. So relative permeability(μ_r) is under 1.03. Figure 7 shows the bending magnet and the drift vacuum chamber. All chambers are approximately 800 mm long with internal 100 mm x 25 mm rectangular cross section. An internal surface roughness of 0.2 μm was achieved with chemical treatment. The flange of the aluminum chamber is generally made of bi-metal method, especially friction welding which welded to the aluminum and stainless steel. Another method is that TiC coating on aluminum flange for high hardness. PAL-XFEL bunch compressor is adopted both methods. No detectable leak ($< 1\times10^{-10}$ mbar ℓ/s) is permitted for each components. We designed under 1×10^{-7} mbar after 48hr pumping. For maintained vacuum performance, We installed four sputter ion pumps(SIP) for 60 L/s. Diagnostic section, between DM2 and DM3, consist of Strip-line BPM, Slotted foil and Screen monitor. Two sputter ion pumps near diagnostic instrument to reduce pressure rise induced by collimator, slotted foil and screen. One cold cathode gauge is placed to measure pressure at collimator. Figure 8 show the 3D modelling of diagnostic section for moving support system.

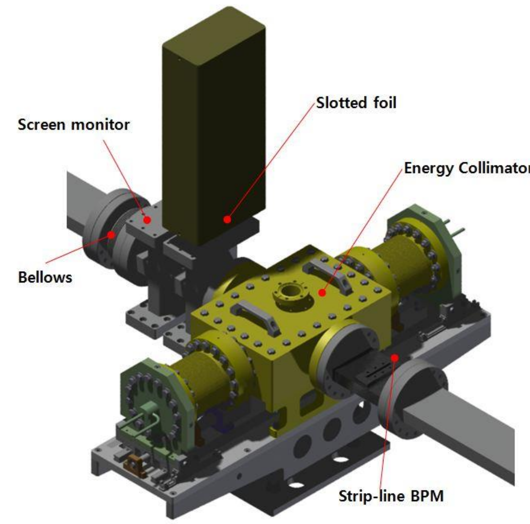

Figure 8: 3D modelling of diagnostic section.

SUMMARY

In this report, the status of the PAL-XFEL bunch compressor system is briefly described. Three bunch compressor lattices for PAL XFEL are designed so as to minimize emittance growth due to CSR and mitigate microbunching instability. The support system (BC2) has been successfully fabricated, assembled and load tested. But, we have to assemble the vacuum chamber and its component in the near future.

REFERENCE

[1] H.S.Kang, J.H.Han, T.H. Kang, I. S. Ko, “Start to end simulation of three bunch compressor lattice for PAL-XFEL ”, IPAC2012, New Orleans, USA.
[2] E. Rotela, S. Sharma, A. Barcikowski, et al., “MECHANICAL DESIGN OF A FLEXIBLE BUNCH COMPRESSOR FOR APS LINAC” APS, ANL.
[3] D. Lacivita, G. Lanfranco, G. Pangon, et al., “FERMI@ELETTRA bunch compressor chicane mechanical design” Diamond Light Source Proceedings, Vol 1, e19, page 1 of 4 MEDSI-6, (2010).
[4] D. La Civita et al., “FERMI@ELETTRA bunch compressor chicane mechanical design“, Diamond Light Source Proceedings, Vol 1, e19, (2010).
[5] Gian Luca Orlandi, et al., “BUNCH-COMPRESSOR TRANSVERSE PROFILE MONITORS OF THE SwissFEL INJECTOR TEST FACILITY”, IBIC2012, Tsukuba, Japan.
[6] “LCLS CDR”, SLAC-R-593, April 2002.