MICRO-MOVER DEVELOPMENT AND TEST IN THE PAL-XFEL

B. G. Oh, Y. J. Suh, J. H. Han, H. Heo, J. H. Hong, C. B. Kim, H. S. Kang, K. H. Park, D. E. Kim,
Pohang Accelerator Laboratory, POHANG, KOREA

Abstract

Two micro-movers, which are able to control the horizontal, vertical and longitudinal positions as well as the yaw and pitch angles remotely, were developed and installed in the PAL-XFEL linac. The solenoid micro-mover in the gun section allows beam-based alignment of an electron beam to the solenoid field and the gun RF field. The X-band cavity micro-mover minimizes the transverse wake field effect caused by transverse misalignment between the beam and X-band cavity. Two micro-movers has similar specifications and the same mechanism, but the sizes are different from each other. In this paper, we present the design, manufacture and test results of the micro-movers.

INTRONDUCTION

Solenoid mover(SM) is fine-adjust the position and angle of the Solenoid while checking the position of the electron beam to the electron beam goes through the center of the solenoid. X-band mover(XM) minimizes Emittance increased by fine adjustment of the beam and X-band cavity. Movers are designed by dividing the two layer for movement in each direction within a narrow space. The cam and crank mechanism in the upper layer adjusts to Y and Pitch direction [1]. The lower layer adjusts to X, Z and Yaw direction [2]. There are three motors and four Blocks which can move freely in two directions. Table 1 shows the specification of accuracy and repeatability for each direction. Both Figure 1 and Figure 2 show the shape of the SM and the XM.

Table 1: The Specifications of Each Direction

Direction	Travel range		Accuracy	Repeatability	
	SM	XM		SM	XM
X	±3mm	±2mm	±5µm	±50µm	±20µm
Y	±2.5mm	±2mm	±5µm	±50µm	±20µm
Yaw	±1.9˚	±0.8˚	±0.005˚	±0.05˚	±0.01˚
Pitch	±1.59˚	±0.4˚	±0.005˚	±0.05˚	±0.01˚

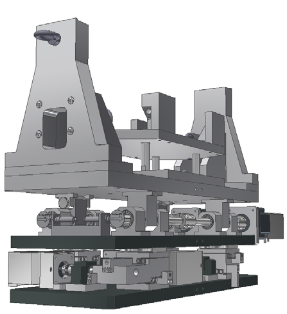

Figure 1: Shape of SM.

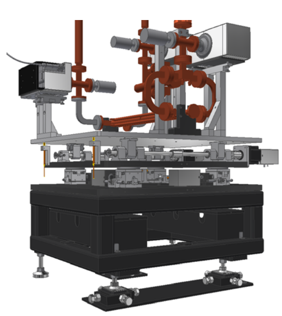

Figure 2 : Shape of XM.

MECHANISM FOR Y AND PITCH

Both cam and crank mechanism applied to the two motors was designed to be driven in the Y direction and the pitch. One shaft for the adjustment to the Pitch has applied the crank mechanism. It is able to rotate freely without locked by cam. Figure 3 shows a mechanism for movement in the Y and Pitch direction by the two axes.

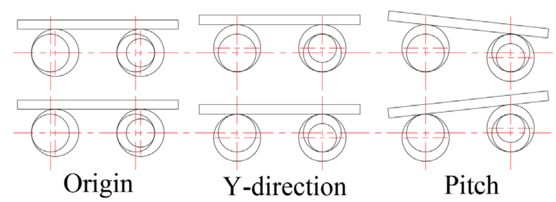

Figure 3: Principle of mechanism for Y and pitch.

Through the kinematic analysis it can be seen the trajectory of the position of the highest point which changes according to the rotation of the cam. In Figure 4 you can see it.

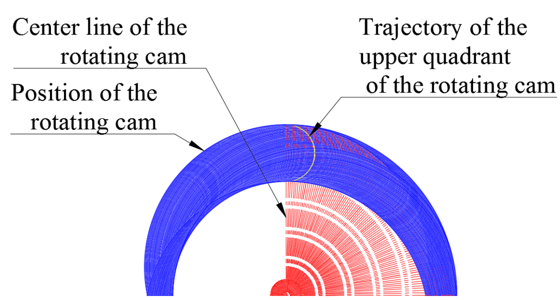

Figure 4: The trajectory of highest point.

Equation can get to know the angle of the pitch and height of the Y through the diagram shown in Figure 5, using the trajectory.

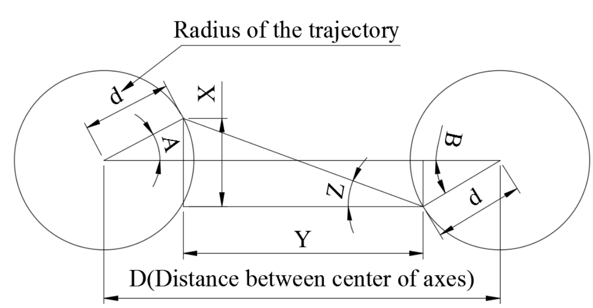

Figure 5: Finding algorithm for height and angle.

Copyright © 2016 CC-BY-3.0 and by the respective authors

ISBN 978-3-95450-147-2

Vertical height value can be seen with the equation (1). Pitch angle is used in the equation (3).

$$X = d\cdot\sin A + d\cdot\sin B \quad (1)$$

$$Y = D - (d\cdot\cos A + d\cdot\cos B) \quad (2)$$

$$Z = \tan^{-1}\left(\frac{d\cdot sinA + d\cdot sinB}{D-(d\cdot cosA + d\cdot cosB)}\right) \quad (3)$$

It shows the Y and Pitch adjustment unit designed through the above procedure in Figure 6 and Figure 7.

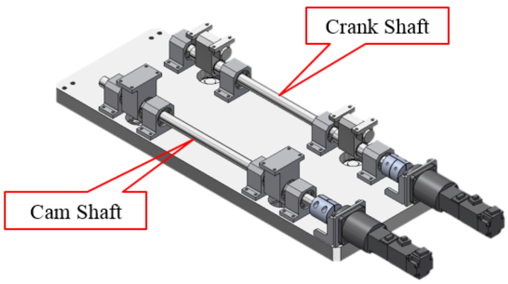

Figure 6: Sub assembly of SM.

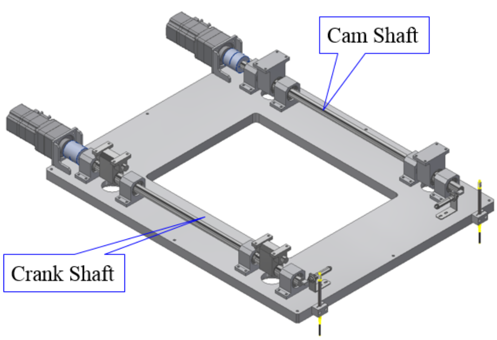

Figure 7: Sub assembly of XM.

MECHANISM FOR X, Z AND YAW

Mechanism such as UVW stage was applied to the solenoid mover. The UVW stage is the union movement possible structure by three motors. It is consist of three motors and four blocks. Each block is capable of movement in two directions. Figure 8 shows the form of each block. Figure 9 and Figure 10 show the Yaw adjustable unit consisting of three motors and four blocks.

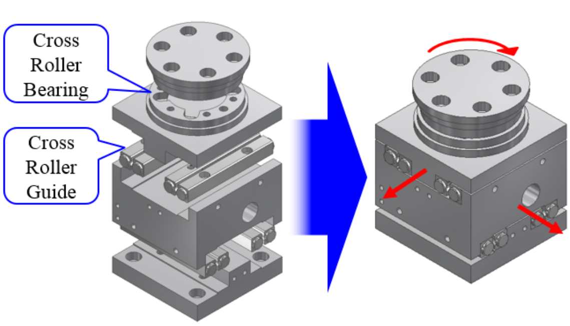

Figure 8: Sub assembly of block.

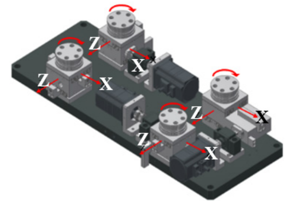

Figure 9: Sub ass`y of SM.

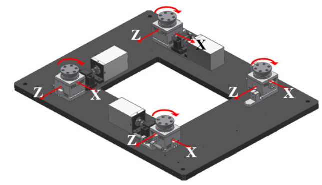

Figure 10: Sub ass`y of XM

Above structure can be straight and diagonal movement. It is possible to rotational movement as well as rotate the eccentric movement. Figure 11 shows the state Yaw movement.

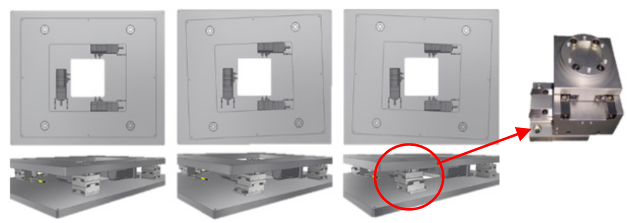

Figure 11: The state of yaw, origin(left), CCW(center) and CW(right).

When there is a request of movement, it needs to calculate the distance each of the motors to be transferred. Figure 12 and 13, the equation can be obtained through a kinematic analysis. Using the equation it can be seen the distance each of the motors to be transferred.

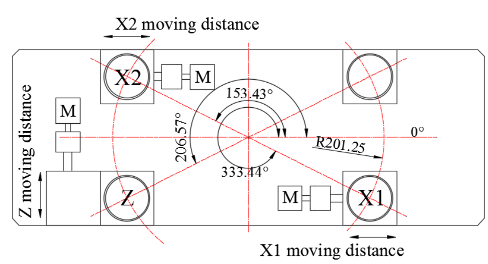

Figure 12: Yawing principle of SM.

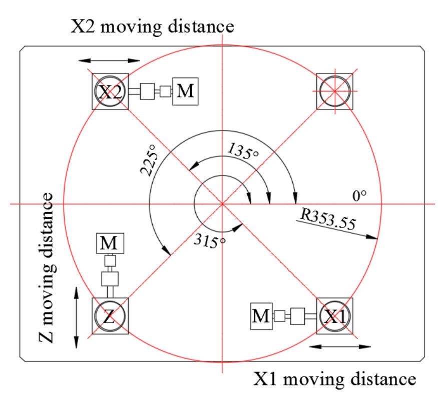

Figure 13: Yawing principle of XM.

Copyright © 2016 CC-BY-3.0 and by the respective authors

Travel distance of X1, X2 and Z, respectively can be seen through the (1), (2) and (3) of the following equations.

$$\delta X1 = R\cdot\cos(\delta\theta+\theta X1+\theta 0) - R\cdot\cos(\theta X1+\theta 0) \quad (1)$$

$$\delta X2 = R\cdot\cos(\delta\theta+\theta X2+\theta 0) - R\cdot\cos(\theta X2+\theta 0) \quad (2)$$

$$\delta Z = R\cdot\sin(\delta\theta+\theta Z+\theta 0) - R\cdot\sin(\theta Z+\theta 0) \quad (3)$$

Two movers are different from each other, the positions of the blocks. But equations are applicable for both two movers.

MANUFACTURE AND TEST

It checked the accuracy of critical parts during production. After the entire assembly it was tested for accuracy using a heavy weight dummy. It is a little better than the repeatability of the XM of the SM. So, it increased the accuracy by using components that have a high degree of clearance. Figures from 14 to19 show the fabrication and test process of two movers.

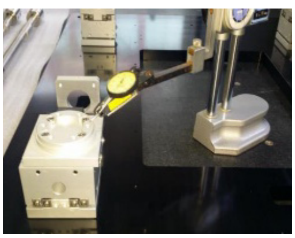

Figure 14: Inspection.

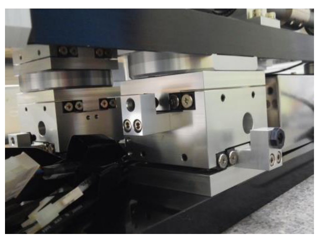

Figure 15: Sub assembly.

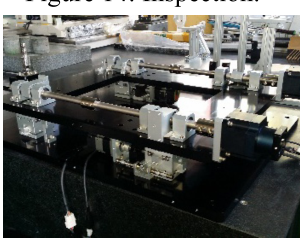

Figure 16: Sub assembly.

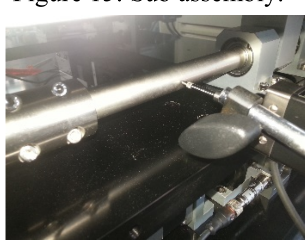

Figure 17: Inspection.

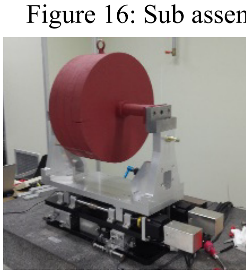

Figure 18: Dummy test.

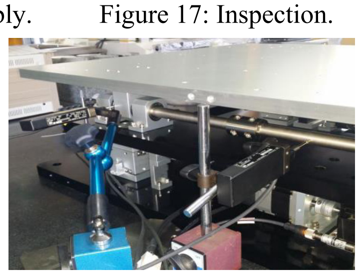

Figure 19: Accuracy test.

TEST RESULT

Test result of two movers performance satisfies all the specifications for the transfer accuracy and repeatability. Performance test results of the SM was satisfied with the accuracy ± 5µm, and it was also satisfied about the repeatability ± 50µm including backlash. And the test result of the XM was also satisfied about the accuracy ± 5µm, and the repeatability ± 20µm including backlash. In Figure 19 shows the test result of accuracy, and in Figure 20 shows the test result of repeatability.

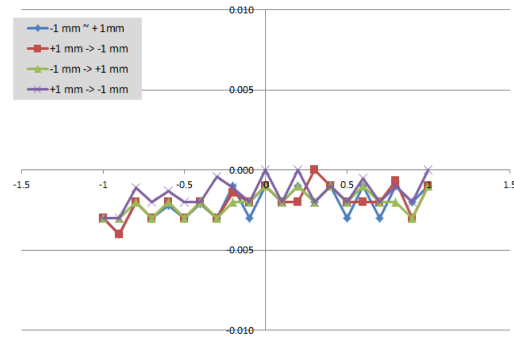

Figure 20: The test result of accuracy.

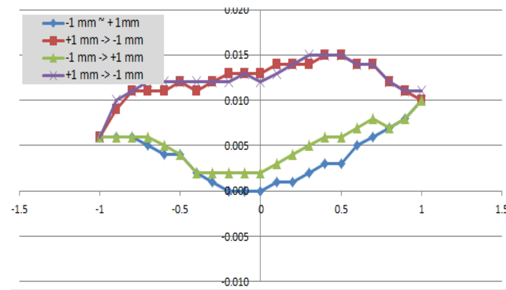

Figure 21: The test result of repeatability.

CONCLUSION

The two movers installed on gun section and the X-band linearizer section, respectively. Completed the fine alignment. All checked over, and underwent electron beam test now. We finally found that there is no problem to move to the desired position. In Figure 21 and 22 show installed state in which the SM and the XM.

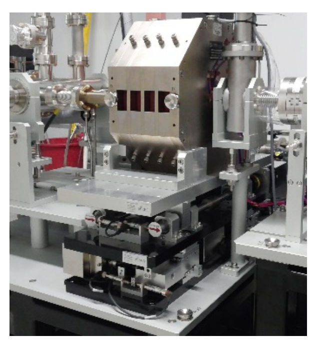

Figure 22: Installed SM.

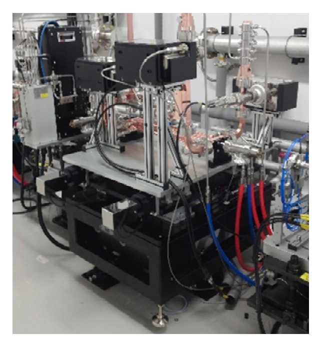

Figure 23: Installed XM.

REFERENCES

[1] Y. Morita *et al.*, "Development of a Mover having One Nanometer Precision and 4mm Moving Range", in *Proc. IWAA06*, San Francisco, USA, 2006, paper TH003.

[2] Dongwon Shin *et al.*, "Kinematic Comparative Analy-sis of UVW stage for Precision Motion Control", in *Proc. KSPE2013*, Busan, Korea, Autumn 2013.

Copyright © 2016 CC-BY-3.0 and by the respective authors