ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-THPH28

THE DEVELOPMENT OF PAL-XFEL BEAMLINE

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Abstract

Pohang Accelerator Laboratory X-ray Free Electron Laser (PAL-XFEL) is a research facility, which is designed to generate extremely intense (assuming 1×10^{12} photon/pulse at 12.4 keV) and ultra-short (10-200 femtosecond) pulsed X-rays. Now two beamlines were constructed, the one is hard X-ray and the other is soft X-ray. Each beamline is consisted of UH (Undulator hall), OH (Optical hall), and EH (Experimental hall). We have two hutches, XSS (X-ray Scattering Spectroscopy) and NCI (Nano-crystallography and Coherence Imaging) in hard X-ray beamline. They are connected each other, and sharing main optics (Mirrors and DCM, etc). PAL-XFEL is a very precise facility and has very large heat power, so mechanical analysis is required. Now vacuum components of beamline are installed and completed performance test. In here, beamlines of the PAL-XFEL is introduced in briefly, and two components, GMD (Gas Monitor Detector) and MICOSS (multifarious injection chamber for molecular structure study), are also reported.

INTRODUCTION

PAL-XFEL (Pohang Accelerator Laboratory X-ray Free Electron Laser) project, which provides 10 times the brightness of the beam than the third generation and a very short pulse of <100 fs, started construction in 2011. The installation of all machines and devices was completed at the end of 2015 and the commissioning was proceeded in 2016. The XFEL (X-ray Free Electron Laser) has been officially provided to users from 2017. Figure 1 shows the PAL-XFEL installed near the PLS-II (Pohang Light Source II).

Figure 1: Scene of PAL-XFEL and PLS-II.

The PAL-XFEL features as the world's most notable source of radiation in recent years are using higher electron energy and a longer undulator than PLS-II to produce much shorter and stronger light. The average brightness is about 100 times and the maximum brightness is more than 100 million times stronger, and the pulse length is shorter than 1/100, which makes it suitable for dynamic phenomenon research. PAL-XFEL beamline is divided into UH (Undulator hall), OH (Optical hall) and EH (Experimental hall). There are three experimental area at EH, which are XSS (X-ray Scattering Spectroscopy), NCI (Nano-crystallography and Coherence Imaging), and SSS (Soft X-ray Scattering and Spectroscopy).

Beamline [1,2]

Figure 2 shows the layouts of the hard X-ray and soft X-ray beamlines. The performance of various optical devices which are consisted of beamline were verified during the commissioning. In the PAL-XFEL beamline, the role of the diagnostic device is very important and needs to be developed separately. Therefore, various diagnostic devices were developed. GMD (Gas Monitor Detector) that one of the diagnostic device has been developed with a lot of verification test and modification and installed at the beamline. In experimental area, NCI beamline's SFX (Serial Femtosecond Crystallography) experiment uses micro focused X-ray pulse and needs to provide efficient operational performance. Thus, the MICOSS (the multifarious injection chamber for molecular structure study) is developed. By using this system, clear diffraction patterns can be obtained for lysozyme microcrystal experiment.

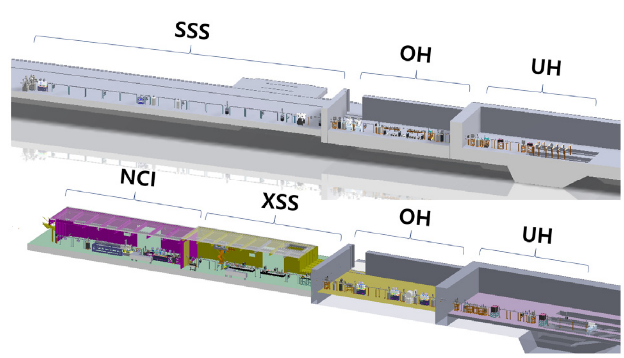

Figure 2: The layouts of hard x-ray beamline (bottom) and soft x-ray beamline (top).

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Mechanical Eng. Design of Synchrotron Radiation Equipment and Instrumentation MEDSI2018, Paris, France JACoW Publishing
ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-THPH28

Gas Monitor Detector (GMD) [1,2]

GMD can measure the intensity of X-ray beam by using photoionization of Xenon gas. A gas-based transmissive measurement such as GMD has some advantages:

- On-line intensity monitoring of each pulse is possible
- The wavefront of the coherent beam is preserved
- The gas target does not degrade with time
- The gas detector is not easily saturated by the peak power of the highly intense and strongly XFEL
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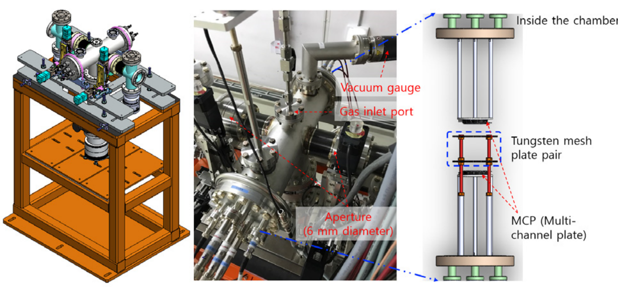

Figure 3: GMD installed at UH and schematic drawing.

The GMD of PAL-XFEL is installed at the downstream of the solid attenuator in the UH and uses xenon gas with < low × 10^{-5} torr. Figure 3 shows the schematic drawing and installed GMD at UH. Xenon gas can be controlled by motorized leak valve as shown in Fig. 4. Since the gas is used, it is necessary to maintain a vacuum without any influence on the beam. Accordingly, the chamber is further provided with a vacuum maintained by differential pumping at both ends of the detector. UH area is important area for beam transporting. Vacuum test has been performed many times to get the stable result. Table 1 shows differential pumping test result. The vacuum level was kept stable when leak valve was changed.

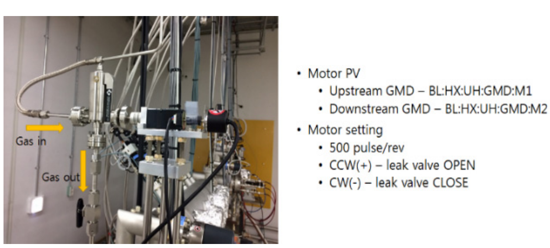

Figure 4: Motorized leak valve of GMD.

Table 1: Differential Pumping Test Result

Motor	Upstream GMD FRG (GMD cell)	Solid attenuator	Downstream GMD FRG (GMD cell)	Safety shutter IG #5	Safety shutter IG #6
-1500	8.06×10^{-7}	3.85×10^{-8}	1.70×10^{-7}	2.1×10^{-8}	3.5×10^{-9}
-1200	8.05×10^{-7}	3.83×10^{-8}	1.73×10^{-7}	2.1×10^{-8}	3.6×10^{-9}
-1000	8.05×10^{-7}	3.84×10^{-8}	1.86×10^{-7}	2.1×10^{-8}	3.6×10^{-9}
-750	8.04×10^{-7}	3.93×10^{-8}	3.01×10^{-7}	2.4×10^{-8}	3.9×10^{-9}
-500	8.03×10^{-7}	4.42×10^{-8}	9.82×10^{-7}	3.7×10^{-8}	5.6×10^{-9}
-250	8.03×10^{-7}	1.11×10^{-8}	9.88×10^{-6}	2.0×10^{-7}	2.7×10^{-8}
0	8.08×10^{-7}	5.68×10^{-8}	4.08×10^{-5}	1.2×10^{-6}	9.7×10^{-8}

GMD's aperture size is 6 mm in diameter, and it caused to block or interfere the XFEL. Therefore, it should be tested about the vibration sensitivity. Figure 5 shows the characteristics of vibration displacement at the four measurement points. The results at each measuring position are summarized in Table 2. All of them are in nm range, so it proved that the aperture of the GMD did not affect to the XFEL.

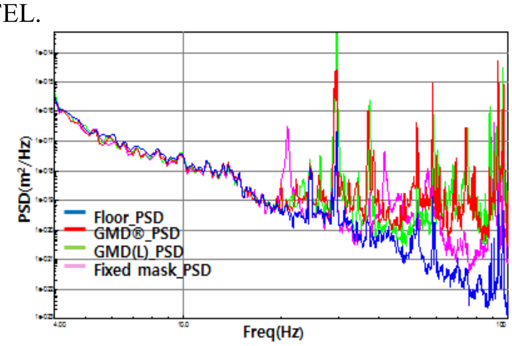

Figure 5: The characteristics of vibration displacement around GMD.

Table 2: The RMS and Peak to Peak Values at Four Measurement Points

	RMS	Pk-Pk
1-Floor	12.7 nm	36 nm
2-GMD(Right)	55.8 nm	159 nm
3-GMD(Light)	105 nm	296 nm
4-Fixed mask	129 nm	36.5 nm

Multifarious Injection Chamber for Molecular Structure Study System (MICOSS) [3]

The MICOSS has been developed for SFX experiments and installed at NCI beamline. It is composed of several instruments such as a dedicated sample chamber, sample injectors, sample environment diagnostic system, and detector stage for convenient distance manipulation.

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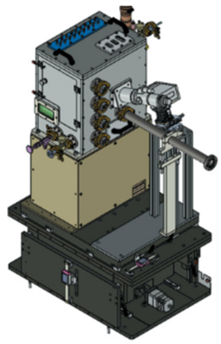

Figure 6: Schematic drawing of MICOSS and position manipulation stage.

Figure 6 and figure 7 show the design including stage system and manufactured chamber, respectively.

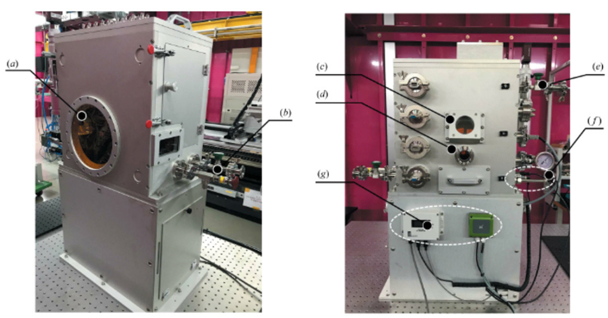

Figure 7: Manufactured MICOSS: (a) window for passing diffraction signal to detector, (b) pumping port, (c) view port for microscope, (d) XFEL pulse input port, (e) helium gas input port, (f), (g) Sensors & signal.

Sample Injector Sample injectors do main function for SFX experiment, and they are developed into two types, multi injector type and LCP (Liquid Cubic Phase) injector type as shown in Fig. 8.

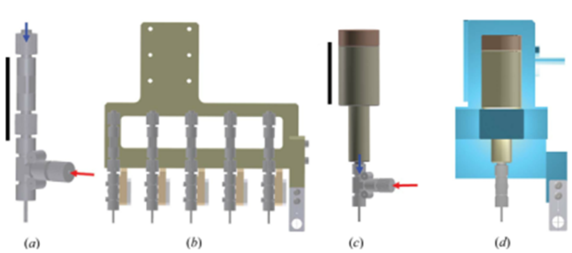

Figure 8: Two sample injector types: (a), (b) Multi-injector nozzle; (c), (d) LCP injector nozzle.

Chamber A helium-gas filled sample chamber provides relatively a low signal to noise. Basically, motorized stage of the MICOSS has 3 directions, X, Y and Z. It designed for easy access to exchange sample and sample injectors. The MICOSS also has motorized Photodiode (PD) and cross wire for sample positioning. Oxygen & humidity sensor can monitor the inner status of the chamber. Figure 9 shows the inner design of the chamber.

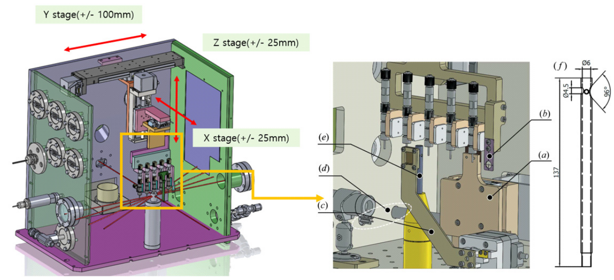

Figure 9: Sample injector: (a) pinhole position, (b) cross wire holder, (c) PD manipulator, (d) oxygen & humidity sensors (e), (f) sample catcher.

CONCLUSION

The construction of PAL-XFEL beamline has been completed, and the performance verification and the commissioning of several experiments are successfully done. The PAL-XFEL is operating for scientific experiments. During the construction and commissioning, key devices are developed, and the performance is verified. In the future, components of the beamlines will be upgraded for better scientific results.

ACKNOWLEDGEMENTS

The authors would like to thank beamline support team for helpful discussions and gratefully acknowledge.

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