PAL-XFEL ACCELERATING STRUCTURES *

Heung-Soo Lee*, Young Jung Park*, Young-Do Joo*, Hoon Heo*, Kyoung-Min Oh**, Sung-Joo Noh**, Woon Ha Hwang*, Sung-Duk Jang*, Soung-Soo Park*, Hiroshi Matsumoto***, Heung-Sik Kang*, Jung Yun Huang*, In-Soo Ko*
Pohang Accelerator Laboratory, Pohang, Kyungbuk 790-784, Korea, ** VITZRO TECH. in Korea, *** KEK in Japan

Abstract

We need 172 accelerating structures for the PAL-XFEL 10 GeV main linac. It takes long time for these structures to be delivered. So we are trying to find suppliers of the accelerating structures. First, we made an order of 40 accelerating structures to Mitsubishi Heavy Industry (MHI), which have Quasi-symmetrical type couplers to reduce the higher order components such as dipole, quadruple and sextuple components of the electric field in the coupling cavity. And Research Instruments (RI) has fabricated a 3m long race track type accelerating structure for the PAL-XFEL accelerator. Also, Vitzrotech which is a domestic company and IHEP in China are under developing accelerating structures for PAL-XFEL respectively. We will describe the current status of accelerating structures and high power test results of the newly developed structures in this paper.

INTRODUCTION

There are three-stage bunch compressors in the PAL XFEL accelerator. The first-stage is located at the position where the electron beam energy is 330 MeV. The second and third stages are positioned respectively on the beam energy of 3.0 GeV and 3.45 GeV as shown in Figure 1. We classify the main linac into four sectors. Linac L1 is the first sector which increases electron beam energy from 135 MeV to 330 MeV. There are 4 accelerating structures without any SLED. Linac L2 is between the first and the second bunch compressors. Linac L3 is between the second and the third compressors. And the rest of the main linac is L4 sector.

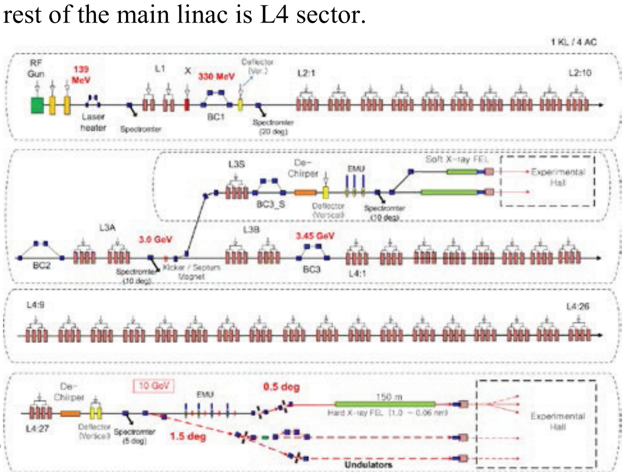

Figure 1: PAL-XFEL layout.

*Work supported by MEST (Ministry of Education, Science and Technology) and POSCO.

PAL-XFEL MAIN LINAC

PAL-XFEL linac has 710 m long length and there are 44 S-band klystrons, 42 SLEDs and 172 accelerating structures to enhance the electron beam energy except injector linac. The RF system of the L1 sector consists of two klystrons and four accelerating structures without any SLED as shown in Figure 2. We will install quasi-symmetrical type accelerating structures for reducing higher order components of the electric field. The specification of the accelerating structure is described in Table 1.

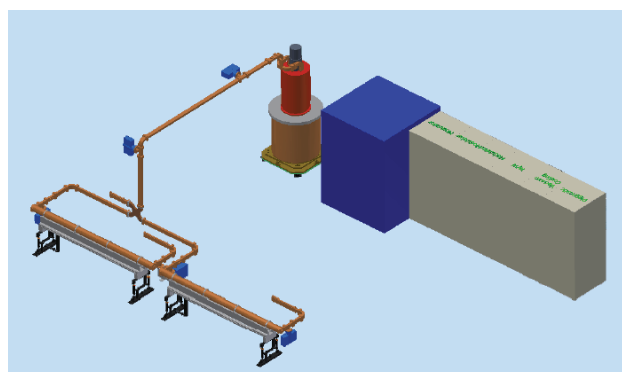

Figure 2: RF system layout of the linac L1.

In addition, the rest of the main linac has four accelerating structures and a SLED in each klystron and modulator as shown in Figure 3. There are 40 accelerating structures with 10 SLEDs in the L2 sector and 20 structures with 5 SLEDs in the L3 sector. Four accelerating structures are also used with a SLED in soft X-ray linac branch as shown in Figure 1. And 108 accelerating structures are used with 27 SLEDs in the L4 linac.

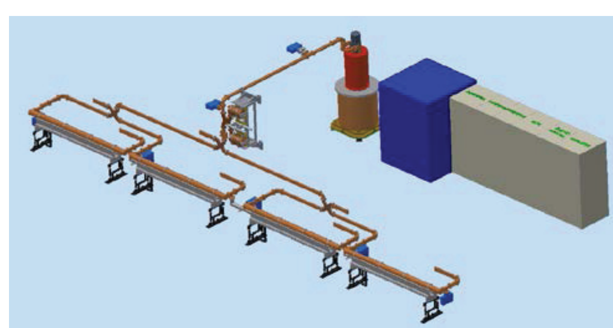

Figure 3: RF system layout of the L2, L3 and L4.

ACCELERATING STRUCTURES

There are several types of the accelerating structures like traveling or standing wave type and constant impedance or constant gradient type[1]. The PAL-XFEL main linac has a S-band RF system like the PLSII linac. The accelerating structure is traveling and constant gradient type which has characteristics like table 1. It is known that the field asymmetry of the coupler of the accelerating structure cause the emittance growth of the electron beam[2]. Therefore, we decide to use accelerating structures with quasi-symmetrical type couplers for the main linac, to reduce the emittance growth due to time depedent multipole fields.

Table 1: Characteristics of PAL-XFEL S-band Accelerating Structure

Operation frequency	2856.00MHz (30℃, in vacuum)
Accelerator type	Constant-Gradient, Traveling-Wave
Operation mode	$2\pi/3$
Attenuation constant	0.57 neper
Shunt impedance	≧53MΩ/m
Filling time	～0.83μs
Q	>13000
Phase error	$\Sigma\theta i<\pm 2.5$deg
Operation temperature	30℃±0.1℃
Overall length	3.120 (acceleration length 2.91475) m

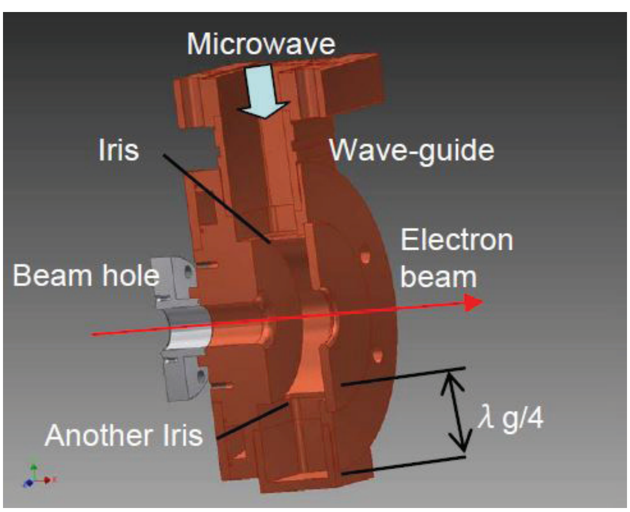

Figure 4: Quasi-symmetrical Type Couple (drawned by MITSUBISHI HEAVY INDRUSTRIES, LTD).

RF TUNING RESULTS

We have now two kinds of the accelerating structure which are fabricated by Mitsubishi Heavy Industry (MHI) in Japan and by Research Instrument (RI) in Germany. The cumulated measured phase data of the MHI structure and the RI prototype are shown in Figure 5 and Figure 6 respectively. The MHI data is better than the RI data as shown in pictures. But the RI data is also within the specification.

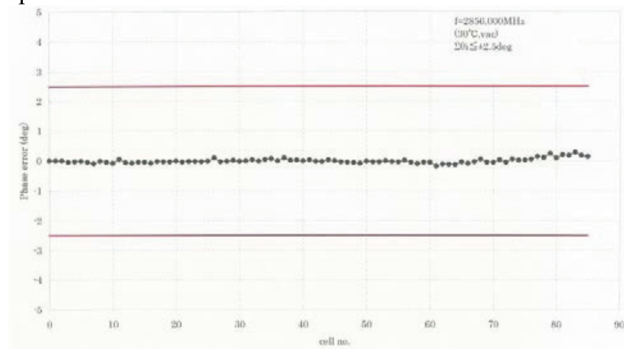

Figure 5: Cumulated phase deviation from normal 120 ° phase difference of the MHI structure (by using a metallic plunger).

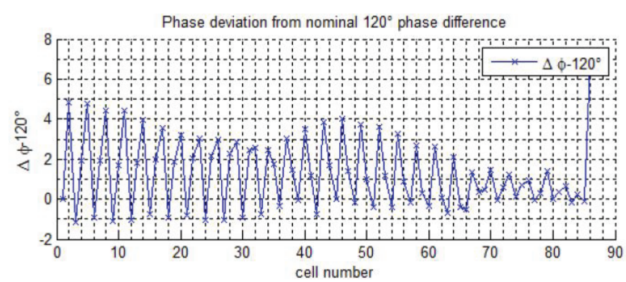

Figure 6: Cumulated phase deviation from normal 120 ° phase difference of the RI structure (by using a bead).

HIGH POWERTEST FACILITY AND TEST PROCEDURE

A SLAC 5045 klystron tube is used as the RF source for the high power microwave generation and waveguide components are also installed as shown in Figure 7 to deliver RF power to the accelerating structure. Three Faraday cups and a bending magnet are installed to check the dark current of the structure and beam energy of the dark current.

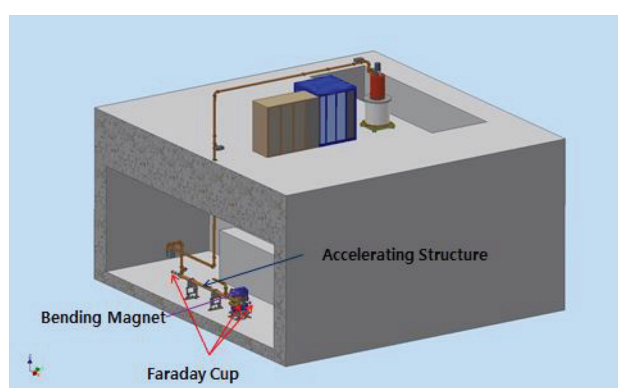

Figure 7: Layout of the high power test facility.

First, the RI prototype structure is installed as shown in Figure 8 and tested to check the maximum field gradient (2 7MV/m) required for 10 GeV operation. The high power test has been conducted by four steps in the

ISBN 978-3-95450-122-9

first phase by setting the RF pulse length of low level as 0.5, 0.75, 1.2 and 1.5 µs. But there is a little difference between the pulse length of the klystron output and the setting pulse length. Also the repetition rates are increased from 5 to 60 Hz in the second phase.

Figure 8 : Photo of the tunnel of the high power test facility for the accelerating structure (RI structure installed).

HIGH POWER TEST RESULTS

While doing the RF processing, we have measured the RF processing times for each pulse length which is the time to reach the maximum RF power level in the structure. And they are displayed in Figure 9. The repetition rate of the modulator is 5 Hz in this processing. When we have set the RF length 1.5 µs, the real measured RF pulse length of the klystron output has been about 1.2 µs. It has taken about three days to expand the RF pulse length to 1.5 µs at 5 Hz operation. Additionally, about two days have been spent to enhance the repetition rate from 5 to 60 Hz with the RF pulse length of 1.5 µs.

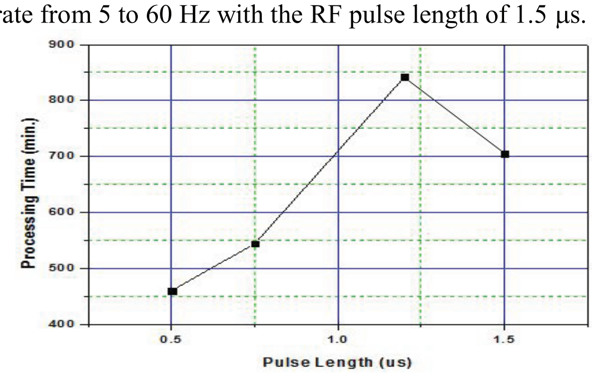

Figure 9: Processing time to reach the maximum RF power (5 Hz operation).

Also, dark currents have been measured with Faraday cups for each case. Figure 10 shows the dark currents for each pulse length in the repetition rate of 60 Hz after finishing the RF processing. And the dark currents of the MHI structure are observed during the RF processing in the repetition rate of 5 Hz and displayed in Figure 11.

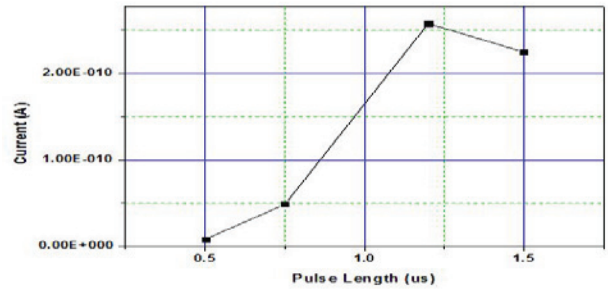

Figure 10: Dark currents of the RI accelerating structure (60 Hz operation).

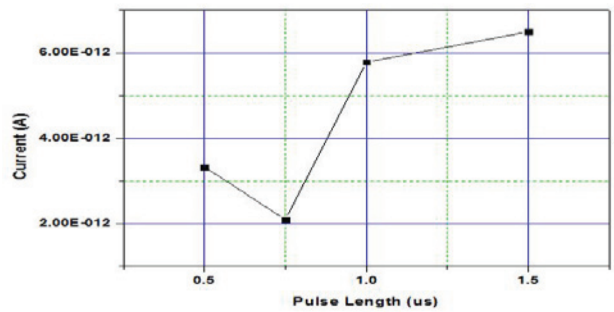

Figure 11 : Dark currents of the MHI accelerating structure (5 Hz operation).

SUMMARY

The test results of the RI structure have been successful. About 5 days have been spent to complete the required RF processing of 60 Hz repetition rate and 1.5 µs pulse length for the RI structure. About three days are used to increase the pulse length of 1.5 µs at the repetition rate of 5 Hz and about two days used to lift up the repetition rate of 60 Hz at the pulse length of 1.5 µs. And the dark current of the RI structure is about 250 pA at the repetition rate of 60 Hz with pulse length of 1.5 µs. The MHI structure is now under the RF processing. But the dark current of the MHI structure is about three times less than that of the RI structure.

REFERENCE

[1] R. B. Neal, "COMPARISION OF THE CONSTANT GRADIENT AND UNIFORM ACCELERATOR STRUCTURES," M Report No. **259**, SLAC (1961).

[2] Zenghi Li, Jose Chan, Lynn D. Bentson, David H. Dowell, Cecile Limborg-Deprey, John F. Schmerge, David Schultz Liling Xizo, "COUPLER DESIGN FOR THE LCLS INJECTOR S-ABND STRUCTURES", Particle Accelerator Conference, (16-20 May 2005).