PHASE TUNING RESULTS OF THE WAVEGUIDE NETWORK SYSTEM AT PAL

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Abstract

We report the results of the phase tuning of the waveguide network system with the C-clamp tool and the resonance frequency tuning for the SLAC energy doubler. The high power waveguide network which dividing and feeding the power to the four accelerating structures. The phase length is adjusted within +/- 0.25 degrees with a transmission phase measuring method. The resonant frequency range for the SLAC energy doubler is 2856 MHz +/- 5 kHz, but a target range is 2856 MHz +/- 1 kHz. We measured the phase length and an amplitude with a vector network analyzer. The test setup consists of a SLED, a waveguide network, directional couplers, phase stable cables. All components of the waveguide networks were manufactured at VITZRO TECH and tested at the accelerator tunnel in the Pohang Accelerator Laboratory (PAL).

INTRODUCTION

PAL-XFEL is X-ray free electron laser (XFEL) aiming at generating coherent X-rays of wavelength range of 0.1 to 10nm [1, 2]. Figure 1 shows the accelerator layout of the PAL-XFEL linac. The PAL-XFEL includes a 10 GeV S-band normal conducting linac section, which is 700m long and consists of 40 RF pulse compressors (SLED), 174 S-band accelerating structures with 50 klystron/modulators and on X-band RF system for linearization. The total length of the building is 1,110 meters [3].

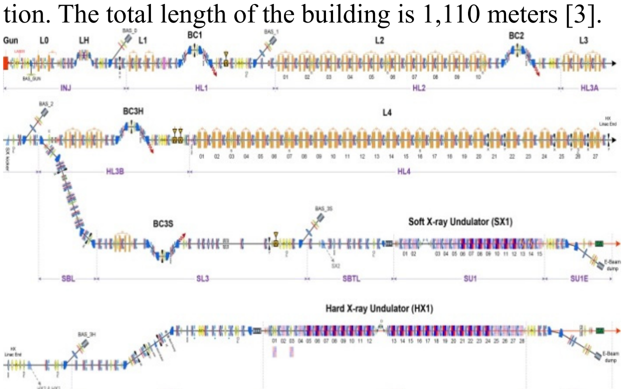

Figure 1: Accelerator layout of the PAL-XFEL.

Before generating a RF conditioning, the phase of a waveguide and a resonance frequency of a SLED should be adjusted. This adjustment is a step that should be passed in order to increase the efficiency of generating RF signals. Also, the waveguide systems are very sensitive to temperature. The PAL x-ray free electro laser project started in 2011. The new building construction started in summer 2012. The accelerating RF components in the tunnel were constructed from March to December 2015. The phase of the waveguide network systems and SLED resonance frequency tuning works were finished at December 2015 for 5 months.

RF NETWORK SYSTEM

The RF power energy is transmitted from a klystron to waveguide network systems. The function of the network systems is transmitting the power from high power pulse klystron in the gallery to four branch accelerator structures in the tunnel. We used a Vector Network Analyzer (VNA). Table 1 is a number of the waveguide components.

Table 1: Number of the Waveguide Components

Section	A/S	SLED	A/S tuning	SLED tuning
L0	2	-	-	-
L1	4	-	4	-
L2	40	10	40	10
L3A, B	16	4	16	4
L4	108	27	108	27
X-ray linac	4	1	4	1
Deflector	4	-	2	-
Total No.	179	42	174	42

Water Temperature Monitoring

The gallery air of the linac is performed with the controller temperature set around 25 +/- 2degree. The operation temperatures of a SLED and the accelerator are range 30 +/- 0.1 degree. It can be changed and tuned by controlling the temperature of the cooling water. Figure 2 is water temperature monitoring results for the surface of a SLED and the accelerator and a heater output.

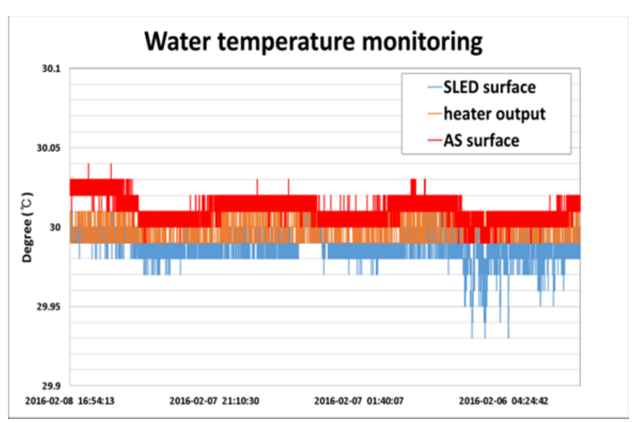

Figure 2: Water temperature monitoring results.

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SLAC Energy Doubler

The SLAC energy doubler (SLED) is one of the key devices of linear accelerators. The SLED is based upon two high resonant cavities which are connected by a 3 dB hybrid coupler to minimize the reflection. The SLED system provides more than doubling of the RF energy strength [4]. The RF energy is stored in two cavities, which are sensitive to temperature changes. A lot of steps have been done to keep stable, water cooling with temperature stabilization about +/- 0.1 degree. The resonance frequency was equalized to within 2856MHz +/- 1 kHz of an ideal. The pulse compressor technical parameters are listed in Table 2. Figure 3 is front view of a SLED in tunnel.

Table 2: SLED Specification

Description	**S-band SLED specification**
Operation frequency	2856±5 MHz
Operating temperature	30±1 ℃
Max peak RF power	400 MW
Pulse length	≤1 us
Repetition rate	60Hz
Max average RF power	≤23 kW
Coupling coefficient	5±0.3
Q value	> 100000
Detune(remote control)	Enable
Waveguide	WR-284 OFC
Cooling flow rate	>40 L/m

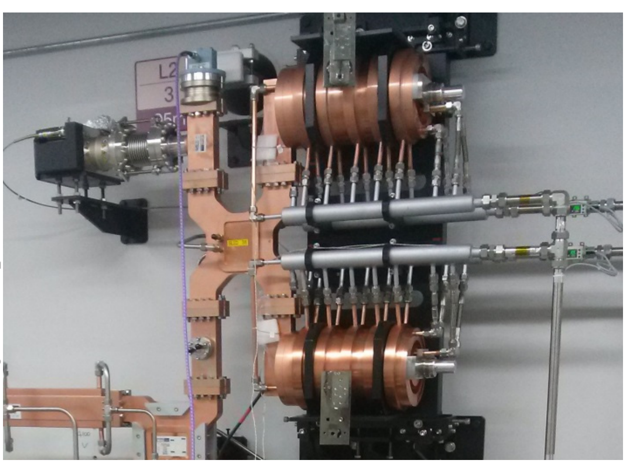

Figure 3: Front view of a SLED.

Waveguides

Figure 4 shows one unit of the waveguide network system in tunnel. The high power RF source is the maximum 80MW pulse klystron. The RF network system is composed accelerating structures, a RF pulse compressor, waveguide systems and a high power pulse klystron. All high power RF components will operate under vacuum.

Figure 4: Photograph of the waveguide network system.

RESULTS OF THE TUNING

A schematic of the microwave network is shown in Fig. 5. In order to obtain the maximum energy of the electron beam, this experiment should be reduced to the phase errors between other accelerator networks. If the phase synchronization is inaccurate, the beam energy will be reduced and more distributed. This paper presented the results of a waveguide and sled tuning. And we was compared with before and after of data. We chose the transmission measurement system with the vector network analyser. To obtain the exactly tuning target, we were studied and measured the data repeatedly.

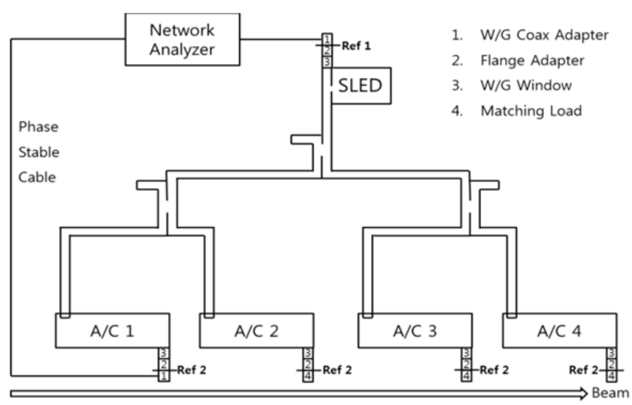

Figure 5: Schematic of the microwave network.

A VNA measurement method is used to confirm the electrical phase length from a single input port through the four accelerator ports of the network during adjustment. One port is used for measurement. The others are connected a waveguide fixed termination. A phase velocity of the four branch waveguide networks need to be adjusted for minimum error range within +/- 1 degree using a C-clamp tool. It is squeezing tool (Fig. 6).

Figure 6: C-clamp tool.

A waveguide of four accelerator branch consists of 63 parts. After assembling the waveguide components, the results of the phase lengths of one module confirmed maximum 18 degree errors. A phase adjustment was tuned to the various points with a maximum 1.5 to 2 degree. After the phase adjustment, the phase error was adjusted to +/- 0.25 degree. Figure 7 is results of a waveguide phase tuning.

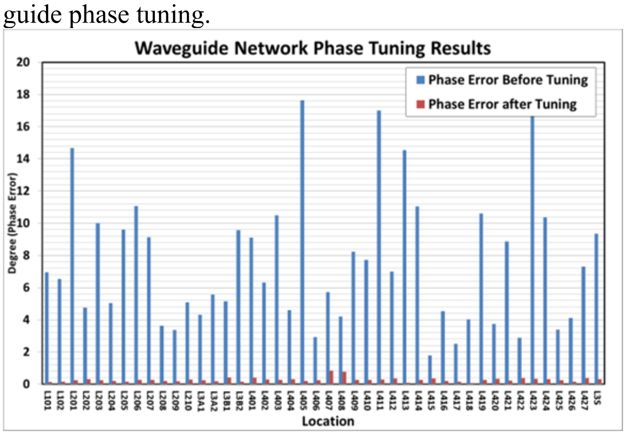

Figure 7: Results of a waveguide phase tuning.

A diagram of the measurement equipment and microwave network is shown in Fig. 8. A SLED adjustment of a resonance frequency was experimented under vacuum. A tuning experiment was run the operation and the waveguide phase tuning at the same time.

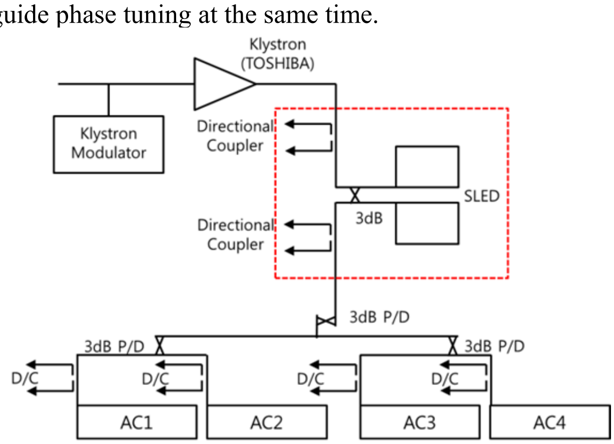

Figure 8: Schematic of the SLED tuning system.

The RF energy of a SLED are stored in two cavities, it must be adjusted to equal the resonant frequency of each cavities. The results of before adjustment for the SLED resonance frequency confirmed maximum 800 kHz errors. The resonator tuning range is 2856 MHz +/- 5 kHz, but a target range is 2856 MHz +/- 1 kHz. We got a good result in a target range. Figure 9 is results of a SLED resonance frequency tuning.

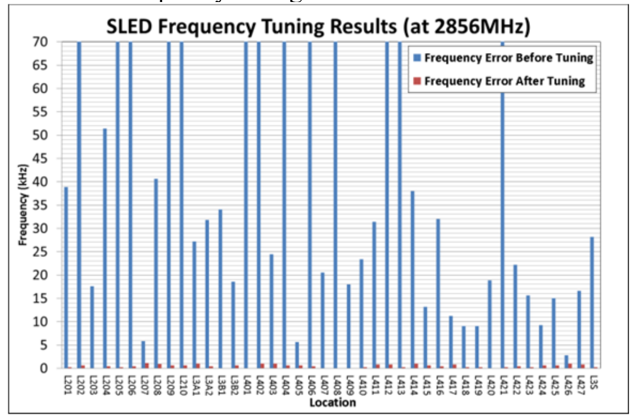

Figure 9: Results of a SLED resonance frequency tuning.

CONCLUSION

The tuning test of the waveguide network phase and a SLED resonance frequency had been done successfully. We had spent to achieve the required process for about five months. In order to obtain reliability data of the experiment, the check was repeated numerous times. The results of the waveguide network phase and the SLED frequency tuning was suitable for target which is +/- 0.25 degree and 2856 MHz +/- 1 kHz. In future studies, we will try to find the trends of changing temperature for a SLED and accelerators at RF hot test.

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