

HIGH POWER RF TEST ON THE C-BAND RF COMPONENTS OF 8 GEV ACCELERATOR FOR XFEL/SPRING-8

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Abstract

We report the high power rf test results of the C-band accelerator system for 8GeV main linac in the X-ray free electron laser (XFEL) at SPring-8, where 64 C-band system will be used. Each C-band accelerator system is composed of two accelerator columns of Choke-mode-type accelerating structure, the rf pulse compressor, the 50 MW pulse klystron, compact modulator and solid state switching high voltage charger. It is designed to operate at rather high accelerating gradient as high as 35 MV/m, therefore it is crucial to evaluate high gradient performance and reject some component with defect or poor performance before installation. The hardware components are under mass production at several companies in Japan. Some of these systems have been installed and tested in high-power test bunker up today (May 2009). This paper we report the test result.

INTRODUCTION

XFEL/SPring-8 is X-ray free electron laser(XFEL) aiming at generating coherent X-ray of wavelength less than 0.1 nm. Figure 1 shows the aerial photo of the XFEL buildings in January 2009 at SPring-8 site. The 400 m long accelerator building houses the electron gun, the injector system, and C-band accelerator system. Undulator building behind houses maximum five undulator lines, while only one beam line will be prepared for the initial phase. Construction of these buildings has been completed in April 2009. After the geometrical survey and the floor grinding, we will start installation of the components in this summer. We plan to start the rf processing next autumn.

Total length of our facility is 700 m. This is much smaller than the other similar machines in US and Europe. In order to perform an XFEL lasing within a short machine length, we used following three key technologies.

- (1) Low-emittance injector with a thermonic electron gun.
- (2) C-band high gradient accelerator with Choke-mode-type accelerating structure.
- (3) In-vacuum short-period undulator.

In order to verify the developed key technologies to satisfy the FEL lasing, we constructed a test accelerator named SCSS by using these technologies. We succeeded in lasing of extreme ultraviolet light in 2006. [1]

Figure 2 shows the one unit of C-band accelerator system, which is composed of two C-band choke-mode-type accelerating structures, the rf pulse compressor, the wave guide system, the 50 MW pulse klystron, the compact modulator, and a solid state switching high voltage charger [2,3,4,5]. In order to accelerate the electron of 400 MeV to 8 GeV, 64 units of these components will be used.



Figure 1: Aerial photo of the XFEL building in January, 2009.

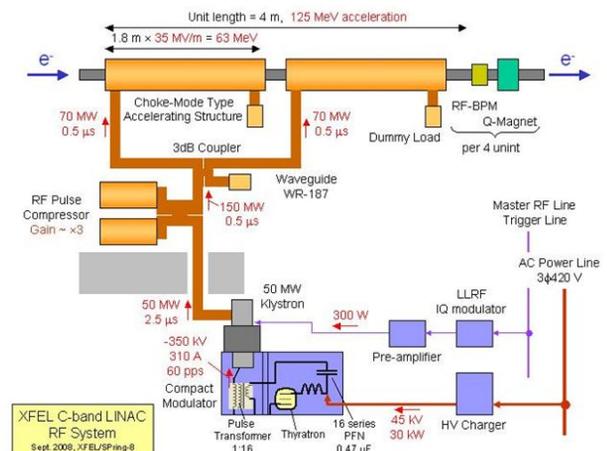


Figure 2: C-band accelerator system.

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HIGH POWER RF TEST AT C-BAND TEST BUNKER

XFEL test bunker was constructed to confirm the high power performance of the rf components. So far, two C-band units have been tested by April, 2009[6].

Figure 3 shows the test bunker, where we test two accelerating structures, the rf pulse compressor, the wave guide system as one set of C-band, sampled from mass production line. Figure 4 shows the compact modulator and C-band klystron, which is driven by a solid state switching high voltage charger.

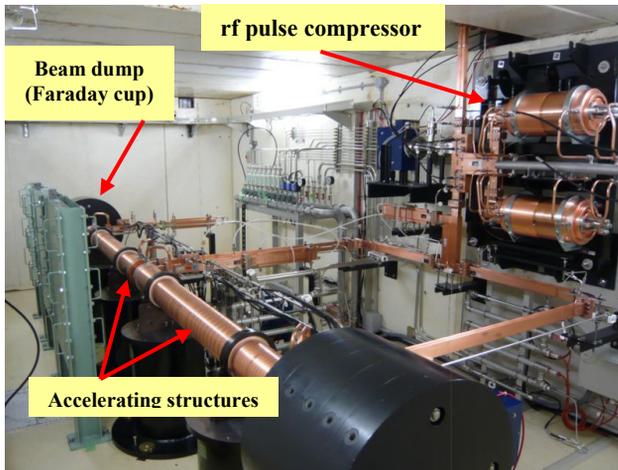


Figure 3: Accelerating structures and waveguide system under test in the test bunker.

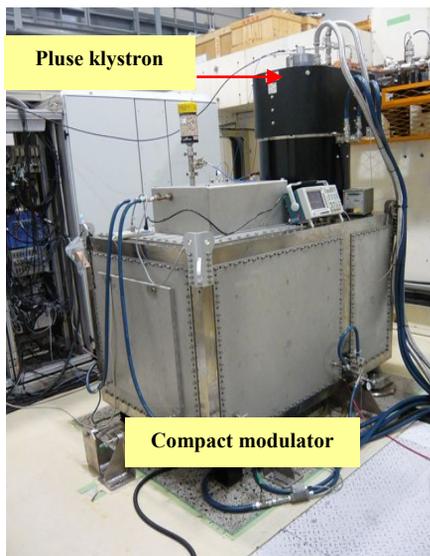


Figure 4: Pulse klystron and compact modulator.

The RF Power Measurement.

Figure 5 shows the waveforms monitored in our C-band system at the nominal operation condition, where the klystron voltage and the beam current was -356 kV and 318 A, respectively. The klystron rf output power is 48 MW and pulse width is 2.5 μ sec. The rf pulse

compressor multiplies the rf input power by a factor of three. The accelerating gradient was estimated from the average power level during the filling time of 300 nsec as the rf pulse compressor output. We use the power-meter and IQ detector to vary these power level. The estimated acceleration gradient is 40 MV/m.

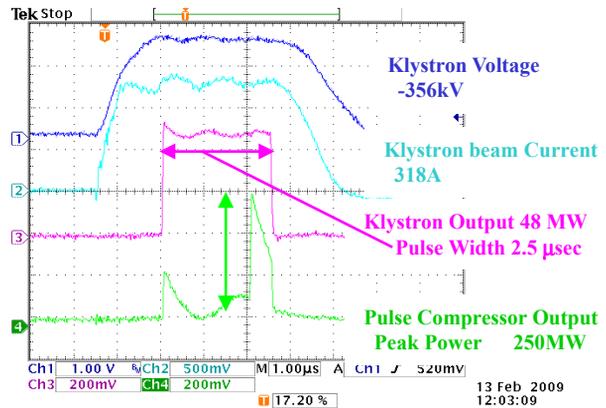


Figure 5: Waveforms of the klystron voltage, klystron beam current, the klystron output, and the pulse compressor output.

Dark Current Emission of the C-Band Accelerating Structure

We measured the dark current emission during the rf processing. Since we use a travelling wave type accelerating structure, the dark current mainly flows to downstream direction. The dark current is measured by the integrated electrical charges using the Faraday cup installed at the ends of the accelerating structure. Diameter of the Faraday cup is 620 mm, and distance from accelerator to the Faraday cup is 170 mm. Figure 6 show the dark current dependence on the acceleration gradient. Comparison of the dark current after 300 hours and 350 hours of rf processing also shown in Figure 6.

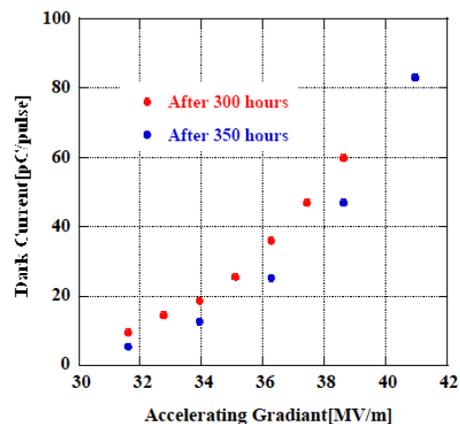


Figure 6: Dependence of dark current on the accelerating gradient.

The dark current has decreased when the rf processing reached to 50 hours. According to numerical simulations, most of all the dark current can be eliminated at chicane magnet right before the undulator line, thus it will not cause big noise background to the X-ray experiments.

Fault Rate of RF Processing Operation

During the rf processing, we use an automatic control system, which gradually increases the rf power, by monitoring the vacuum pressure and maintaining it within a limit value. When the vacuum pressure raised, the rf processing is automatically interrupted or stopped. Figure 7 show the fault rate of vacuum pressure at rf processing in each week. Figure 8 shows the vacuum pressure and charging voltage of HV charger for rf processing after the 96 hours and 330 hours. After the rf processing, fault rate is decreased. We concluded four week processing time will be enough for nominal operation.

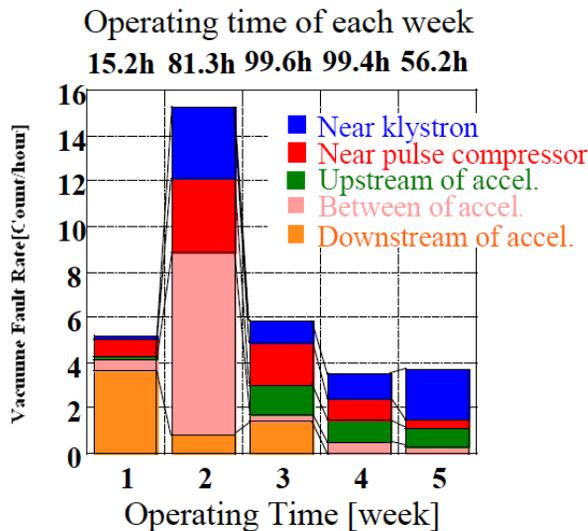


Figure 7: Weekly trend of the fault rate of vacuum pressure during the rf processing of each weeks.

SUMMARY

We are performing the rf processing of the C-band accelerator system. The rf processing has been completed on two units so far. The field gradient in the accelerating structure was estimated from the rf power at the rf processing, where 40 MV/m was obtained. The dark current decreases by the processing time, and become accessible value after four week.

The installation of C-band accelerator is scheduled to begin from the summer of 2009, and the rf processing of the XFEL accelerator will begin by the autumn of 2010.

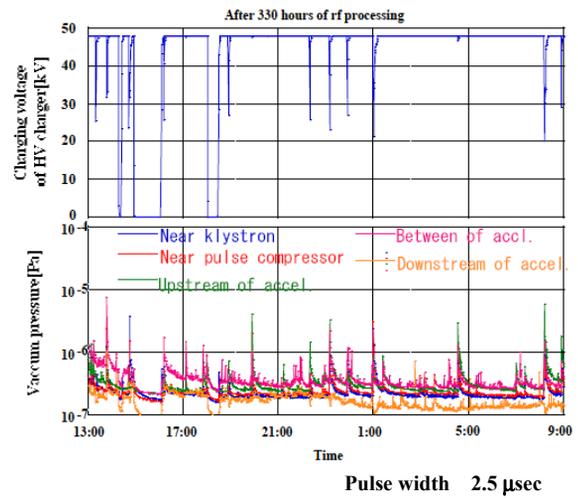
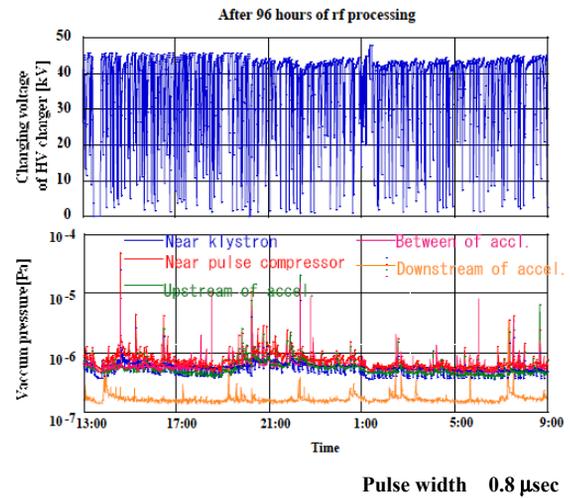


Figure 8: The trend of the vacuum pressure and charging voltage. (Up) After 96 hours of rf processing. (Down) After the 330 hours of rf processing.

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