HIGH-POWER RF TEST ON THE MASS-PRODUCTED C-BAND RF COMPONENTS FOR XFEL/SPRING-8

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Abstract

We report on high-power rf test results of the C-band accelerator system for the X-ray free electron laser (XFEL) at the SPring-8 site. In the XFEL main accelerator, 64 C-band systems will be used in total, whose components are under mass production at several industries in Japan. We performed high-power rf tests with three sets of the mass-produced components in an XFEL test bunker. We operate the C-band components with an accelerating gradient, as high as 40 MV/m. We measured the high-voltage breakdown rate and the dark current emission.

INTRODUCTION

XFEL/SPring-8 is X-ray free electron laser (XFEL) aiming at generating coherent X-rays of wavelength less than 0.1 nm. Figure 1 shows the accelerator layout of the XFEL/SPring-8 LINAC. It is composed of a low-emittance injector with a thermonic electron gun, the main accelerator using a C-band system and three bunch compressor systems.

The accelerating gradient of the C-band is designed to be 35 MV/m, and the length of the C-band is 300 m. In order to accelerate electrons of 415 MeV to 8 GeV, 64 units of these components will be used.

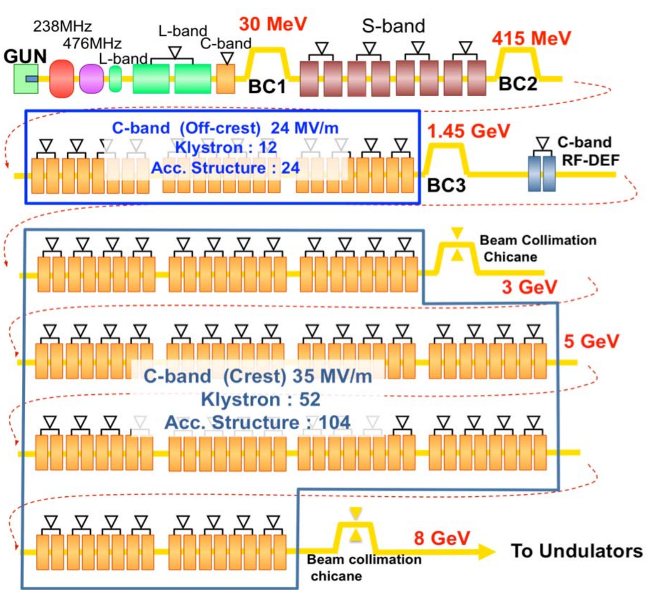

Fig.1: Accelerator layout of XFEL.

HIGH POWER RF TEST AT THE C-BAND TEST BUNKER

Figure 2 shows the test bunker. The C-band accelerator system is composed accelerating structures [1], an rf pulse compressor [2], wave-guide system, a pulse klystron [3], a compact modulator and a solid-state switching high-voltage charger [4].

The XFEL test bunker was constructed to confirm high power performance of the rf components [5]. Figure 3 shows a birds'eye view of the test bunker. We have tested three sets of different C-band components 1) from June 2008 to September 2008, 2) from January 2009 to February 2009, 3) from July 2009 to February 2010.

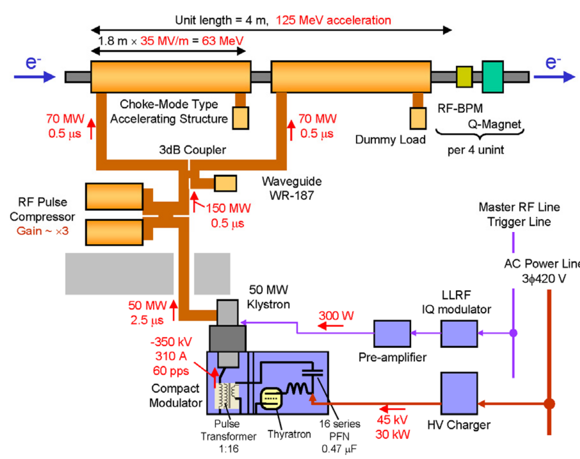

Fig. 2: System chart of the C-band unit.

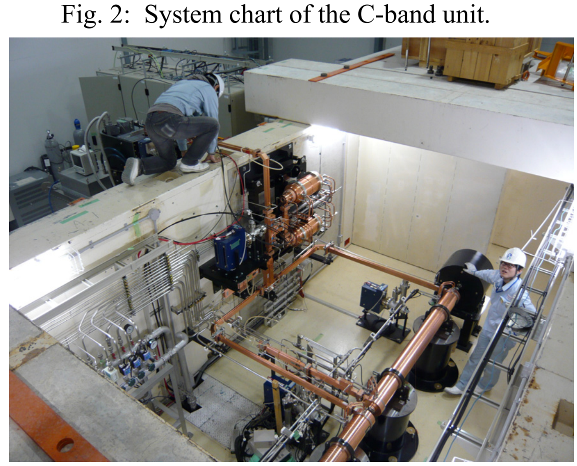

Fig. 3: Birds'eye view of the test bunker.

The rf power measurement

Figure 4 shows the waveforms under the nominal operation condition. The klystron voltage was -356 kV. The klystron output power and the rf pulse width were 48 MW and 2.5 μsec square pulse, respectively. The klystron output rf was multiplied by the RF pulse compressor (SLED). The SLED output power became 280 MW after phase inversion at 2 μsec. After passing the accelerating structure, the RF output power was 30 MW at the peak output.

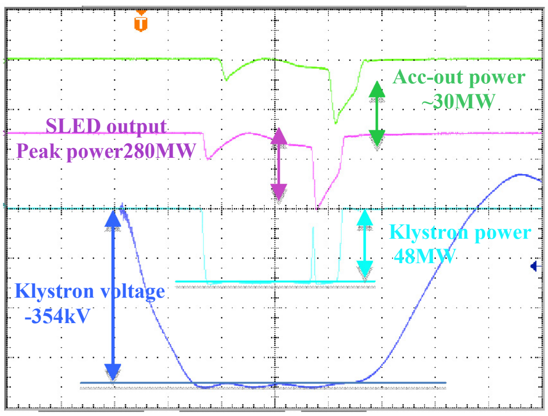

Fig. 4: Waveform of the klystron voltage, klystron output, SLED output, after passing the accelerating structure RF power.

Figure 5 shows the accelerating gradient which is estimated with the rf power of the SLED output depending on the klystron output rf power. We measured the RF power using the power-meter and the IQ detector. The maximum accelerating gradient was 42 MV/m with 48 MW klystron power.

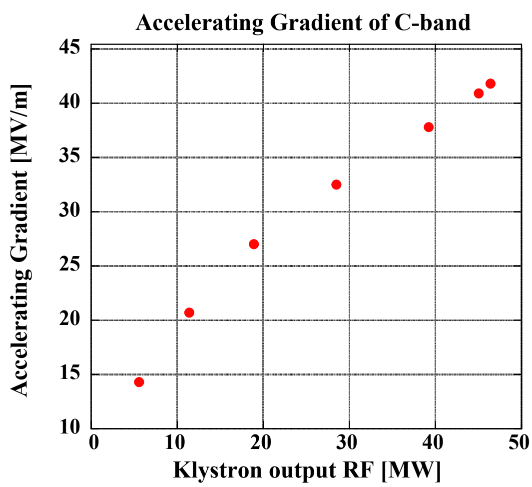

Fig. 5: Accelerating gradient depending on the klystron output RF power

Dark current emission of the C-band accelerating structure.

In order to measure the dark current emission, we measured the electrical charge captured by a Faraday cup. The faraday cup was installed at the ends of the accelerating structure. The diameter of the cup was 620 mm, and distance from the accelerating structure to the Faraday cup was 170 mm. Figure 6 shows the dark current depending on the accelerating gradient. The dark current has decreased under the high-power RF operation. After 300 hours, it became constant at around 30 pC to 40 pC per pulse at 40MV/m. In our accelerator, electrons-beam current is about 300 pC per pulse. Beam halo due to the dark current which is emitted from 128 accelerating structures is one of the important issues. Therefore, we installed two beam collimation chicanes located at 3 GeV and 8 GeV in order to eliminate only dark current.

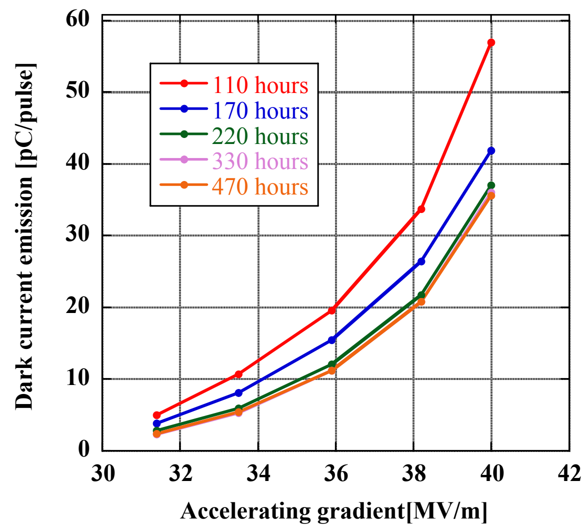

Fig. 6: Dark current depending on the accelerating gradient.

Trip rate during high gradient operation

We measured the trip rate of the high-power rf operation test. We operated the high-power rf aging for 100 hours. As a result, the accelerating gradient achieved 39 MV/m. We recorded the number of interlocked stops due to the rf discharge during the continuous operation. Figure 7 shows the trip rate of C-band system. The trip rate in 39MV/m has decreased about 40% after 200 hours of aging operation.

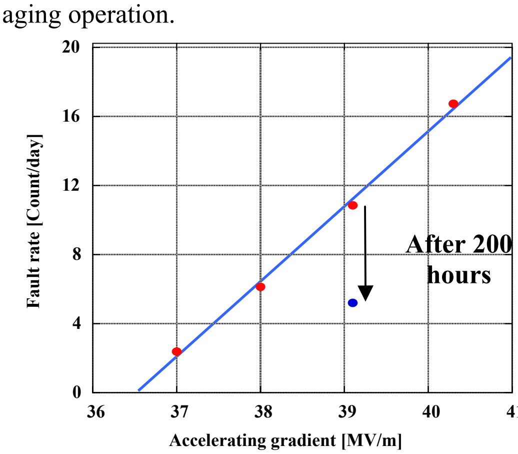

Fig. 7: Trip rate each unit day dependence of the accelerating gradient.

Temperature dependence of the SLED output.

SLED has two high-Q cavities, whose resonant frequency is well adjusted to 5712 MHz using a differential screw tuner. In addition, a final adjustment can be obtained by the temperature controlled by the cooling water during high-power operation.

Figure 8 show the waveforms of the SLED output depending on the cavity temperature. A cavity temperature is changed with the precise temperature regulation system [6]. Temperature can be adjusted from 28.5 to 31.0 degrees.

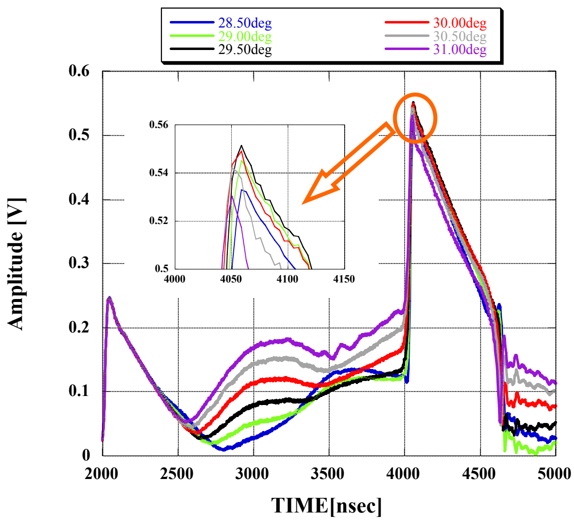

Fig. 8: Waveforms of the SLED power depending on the cavity temperature

Figure 9 shows the peak power of the SLED output depending on the cavity temperature. When the cavity temperature changes by about 1.0 degree, the peak power of SLED decreased by about 8 %.

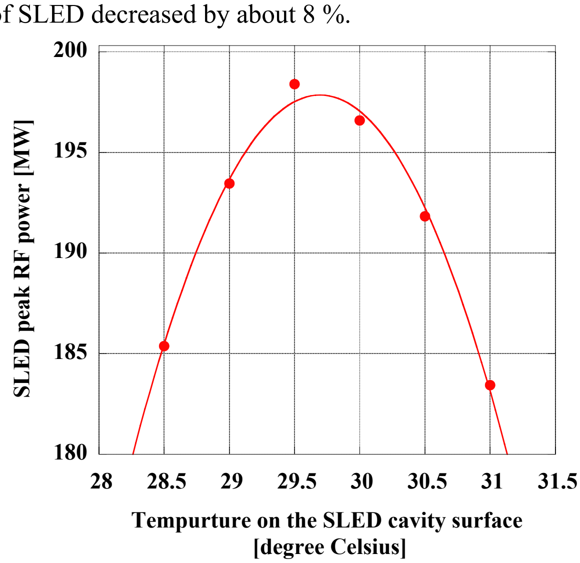

Fig. 9: Peak power of SLED output.

SUMMARY

We have performed high-power rf tests of the C-band mass-production accelerator system. The accelerating gradient in the accelerating structure of 42 MV/m was obtained.

The installation of C-band accelerator is almost completed, and the rf asing of the XFEL accelerator will begin in October 2010.

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