

THE STATUS OF A 1.6-CELL PHOTOCATHODE RF GUN AT PAL*

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Abstract

The RF power conditioning of the photocathode RF gun with four holes at the side of the full cell named as '*Pohang gun*' is in progress. The first goal of the conditioning is the operation of the gun with RF pulse width of 1.5 μ s, repetition rate of 30 Hz, field gradient at the cathode of 130MV/m. We operated the RF gun successfully with the conditions within last few months. It was first operational experience with such conditions in PAL. Now we have a plan to operate RF gun with higher repetition rate up to 60 Hz.

INTRODUCTION

Pohang accelerator laboratory (PAL) and Pohang University of Science and Technology (POSTECH) has developed S-band photocathode RF gun since 2005 [1-4]. The third RF gun has been fabricated almost at the end of the last year [5, 6] which will be named as '*Pohang gun*'. The gun was installed at the gun test stand in PAL. Electron beam of RF gun for PAL-XFEL has some mandatory requirement such as low emittance, high repetition rate, stability, etc. To meet these requirements, the *Pohang gun* has been designed [5]. Dual coupler holes and two additional holes as pumping port are introduced in the RF gun. By applying four holes at the full cell, emittance growth due to RF field asymmetry can be prevented [3, 7]. Rounding edges are also introduced for all four holes. Due to the rounding edge, heating of the cavity body and breakdown were significantly decreased during the period of power conditioning.

In this paper, specification of the RF gun fabricated at PAL and details of RF power conditioning progress are presented. Characteristic features of the *Pohang gun* are presented in the second section. Progress of RF power conditioning is presented in the third section. Some measured data concerning to multipacting is presented in the fourth section. Summary and future plans are given in final section.

RF GUN

The *Pohang gun* which is fabricated in PAL is drawn in Fig. 1. Dual RF feed scheme is applied to increase the repetition rate of the RF gun.

Pohang gun were designed with dual feed coupler with two additional holes to the side of the full cell and rounding edges at each holes. By applying four holes

scheme it is expected to lower emittance growth due to dipole mode and quadrupole mode induced by field asymmetry. The effect of four holes scheme is studied in Ref. [7]. Two additional holes can also be used as pumping port thus it brings easier vacuum control. Rounding edges are introduced at each holes to reduce the effect of pulsed heating and it really shows its effectiveness during the period of RF conditioning. In addition the number of occurrence of breakdown is greatly reduced when compared with the experience of power conditioning of the second RF gun developed in PAL [4]. Applying tuning scheme with gasket was also successful consequentially.

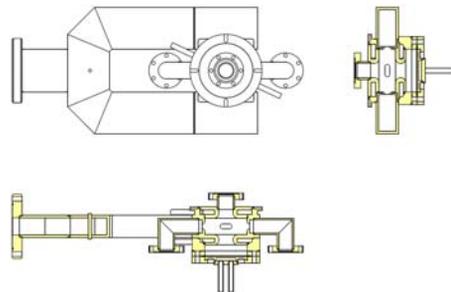


Figure 1: The *Pohang gun* developed in PAL.

RF gun still needs some modification to solve heating problem. We will modify the design of iris shape and cooling channels inside cavity body to maintain stable temperature to operate RF gun. A field monitoring antenna at the end of waveguide coupler will be installed for feedback system in next gun.

RF POWER CONDITIONING

In Fig. 2, a gun test stand in PAL is drawn and installed RF gun is also shown in the inset figure. After installing RF gun in the test stand, gun cavity was baked out with maximum temperature of 150°C for three weeks. Final vacuum level was 1.0×10^{-9} torr with three ion pumps on.

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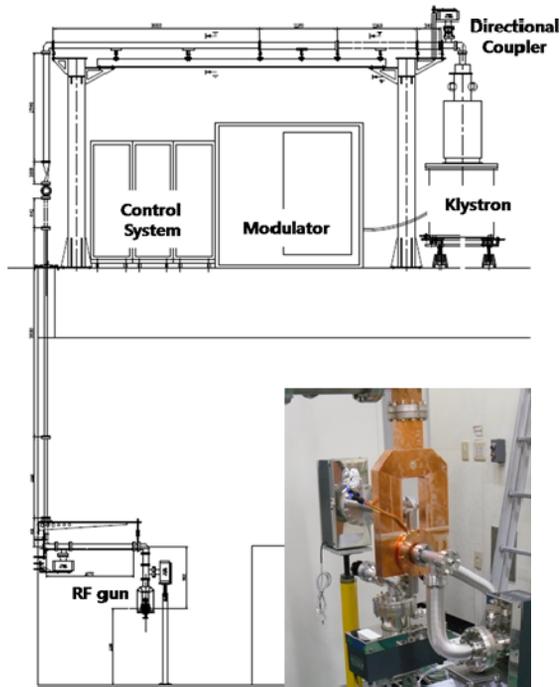


Figure 2: RF gun test stand located in linac tunnel of PAL.

After RF gun was installed in the gun test stand, resonant frequencies were measured to confirm the designed value at 3 dB coupler in test stand area finally. Measurement results are listed in Table 1. They showed almost same results with designed frequencies. Coupling coefficient and Q-factor in Table 1 were measured during cold test last December [5].

Table 1: Measurement Results of the Pohang Gun

Parameter	Designed value
0-mode Resonant Frequency	2846.4 MHz
π -mode Resonant Frequency	2856.0 MHz
Mode Separation	9.6 MHz
Coupling Coefficient	1.09
Q-factor	10730

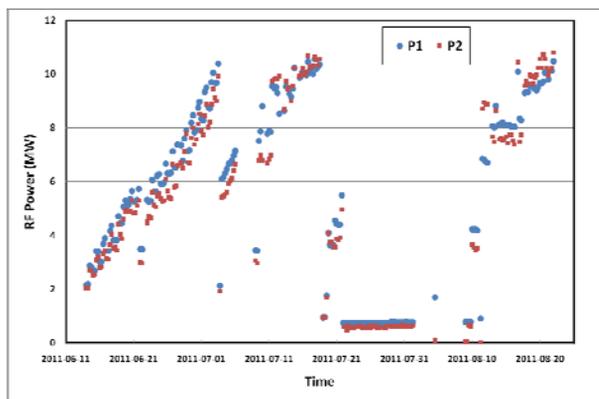


Figure 3: A diagram showing RF power conditioning progress. P1 values are presumed from forward RF signal and P2 values are from conversion table of klystron.

Power conditioning for RF gun has begun from May 2011 and still in progress. It has been carried out through three stages. The first stage was the operation with pulse width of 0.8 μ s at 10 Hz and it takes about 40 days to reach the goal, that is, supplying RF power over 11 MW to the RF gun. Such RF power can generate field gradient at the cathode over 130 MV/m without considering RF power loss through waveguide system. The second stage was the operation with pulse width of 1.5 μ s at same repetition rate. It takes 16 days to reach the goal. The third stage was the operation with same pulse width of 1.5 μ s at 30 Hz. It takes 15 days to reach the goal. The progress of power conditioning up to now is shown in Fig. 3. The values with blue dot are presumed from forward RF signal and the values with red dot are from conversion table of klystron.

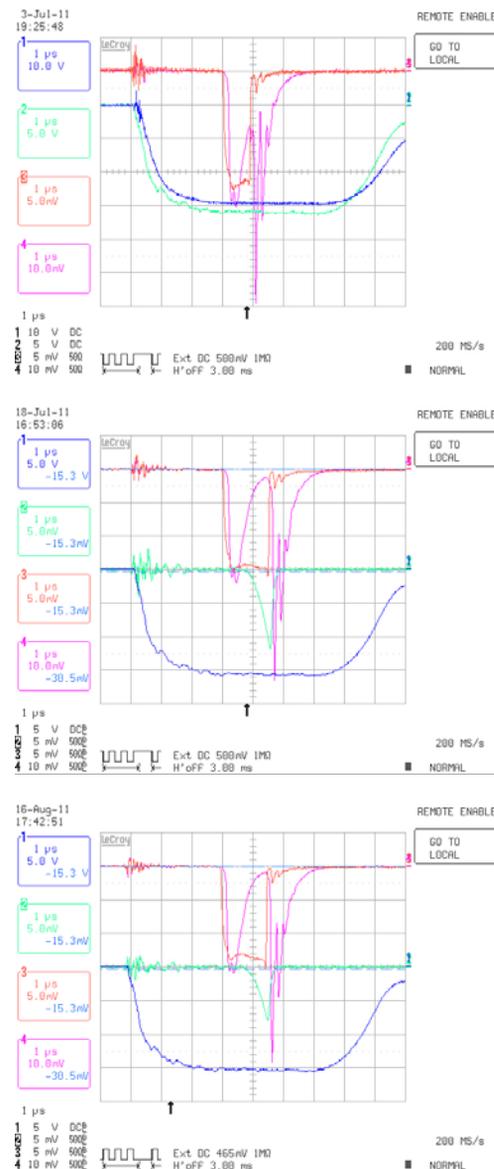


Figure 4: The RF power fed to the RF gun at the first stage (top) with 0.8 μ s, 10 Hz, 11 MW, the second stage (middle) with 1.5 μ s, 10 Hz, 10.5 MW, the third stage (bottom) with 1.5 μ s, 30 Hz, 10 MW.

All three stages were carried out with small bath for circulation of cooling water, but temperature of the gun cavity became unstable during the third stage due to its increased heat load. Now we are installing new water-circulating system for cooling of the cavity. We will continue power conditioning with repetition rate up to 50 Hz as a next stage. This target is temporal value set from the RF system capability in the test stand. We expect that the *Pohang gun* can be operated up to 60 Hz.

Forward and reflected RF power signals are shown in the Fig. 4. Blue line represents klystron voltage in top figure and klystron current in the other two. Cyan line represents klystron current in top figure and dark current in the other two. Red line and magenta line represent forward and reflected RF signals respectively. In case of pulse width of 0.8 μs , reflection RF power dose not decay to zero but it decays to almost zero in case of 1.5 μs . But reflection power is still remained and it influences to the forward RF power further. If the RF gun is operated in this condition, it is hard to generate stable beam. Thus we will install a circulator in the middle of the waveguide system to solve this problem.

MULTIPACTING

Inner surface of the RF systems can be cleaned by RF power conditioning [8]. Protruding portions inside of the RF system including gun cavity can be burned away. During this procedure, gases including electrons come out and raise pressure inside of the RF system. Thus, careful control of RF power is needed because harmful damage to the RF system can be occurred. There exist specific region where an exceptionally large amount of gases come out. It depends on RF power and intrinsic conditions of each RF system.

Dependency of gun pressure on RF power fed to the gun is shown in Fig. 5. This plot was obtained from data of 25 cases during conditioning procedure. In our RF system, there exist threshold-like values around 2MW and 7MW marked with arrows. If RF power supplied to the gun increases larger than these values, generation of gases decreases remarkably.

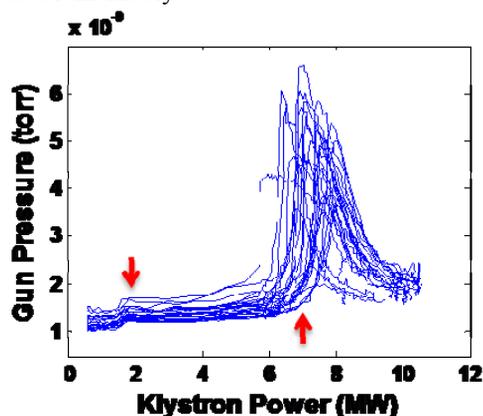


Figure 5: Dependency of the gun pressure on klystron power. Threshold-like value of RF power is marked with red arrows.

SUMMARY AND FUTURE PLAN

RF gun operation with RF pulse width of 1.5 μs and repetition rate of 30 Hz was achieved. RF power applied to the RF gun was 11 MW which can generate field gradient of 130 MV/m at the cathode. During conditioning procedure, the number of occurrence of breakdown is reduced significantly. But two major problems, that is, heating problem and non-zero reflection problem are still remaining. We will modify the design of the RF gun. If these problems are solved, it is expected to generate lower emittance beam by applying four holes scheme.

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