HIGH POWER BEAM TEST OF A 1.6-CELL PHOTOCATHODE RF GUN AT PAL*

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Abstract

The photocathode RF gun with four holes at the side of the full cell will be tested soon at the gun test stand which consists of a 1.6 cell cavity, a solenoid magnet, beam diagnostic components and auxiliary systems such as ICT, spectrometer, YAG scintillator and screens, Faraday cup, etc. Basic diagnostics such as the measurements of charge, energy and its spread, transverse emittance will be performed. It is expected that these diagnostics will confirm a successful fabrication of the RF gun. In this presentation, we will show the status of the RF gun aging in PAL and detail plan of measurements on various beam parameters. The results with the simulation code PARMELA will be presented to prepare measurement devices properly.

INTRODUCTION

An S-band photocathode RF gun has been developed at PAL with the concerns of use for injector of the fourth generation FEL, fs-THz facility and Femtosecond Electron Diffraction (FED) [1-5]. The second RF gun which is the upgrade version of the first RF gun is now installed at fs-THz facility site in PAL. It is operating at 10 Hz and fed by 2856 MHz RF system. It generates the electron beam with 200 pC of charges, 5 MeV of energy, 1.5 mm-mrad of normalized rms emittance and is now ready to serve for users from the second half of this year in earnest.

Table 1: The Target Parameters of the RF Gun Design

Parameter	Designed value
Resonant Frequency	2856 MHz
Mode Separation	9.6 MHz
Charge	1 nC
Normalized RMS Emittance	≤ 1 mm-mrad
Beam Energy	5 MeV
Repetition Rate	50 Hz

Fabrication of the third RF gun was finished successfully and the RF gun will be installed at the gun test stand in PAL for high power beam test. Design of the third RF gun has been changed significantly though its design is based on the former model of PAL. Considering the purpose of the RF gun, main issues of the RF gun design is to generate low emittance electron beam and to realize high duty factor, that is, high repetition rate of stable gun operation. Some notable changes of the design and fabrication process have been applied to the third RF gun to satisfy these requirements. The target parameters of the RF gun design are shown in Table 1.

Characteristic features of the design and fabrication process of the RF gun under developing are presented in this paper. Details of the experiment plan and the result of the electron beam simulation with PARMELA is also presented.

RF GUN

Cold test has been done with the cold model made of copper in early 2010 [6]. RF field distribution is controlled with four rod which is attached at the full cell of the cold model. The resonance frequency is tuned mainly by gaskets with different thicknesses. Finally optimized cavity dimension was determined so that the RF gun can generate the electron beam with designed parameters.

Figure 1: RF gun developed in PAL.

The RF gun is based on the S-band 1.6 cell type. To improve its performance and stability, some designs and fabrication processes are changed as following:

- To eliminate transverse emittance growth due to traveling wave, dual feed scheme is applied.
- To eliminate transverse emittance growth due to quadrupole field, two additional ports are made in full of the gun [7].
- To increase mode separation, large coupling iris radius and short coupling iris length are used in the RF gun design.

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- To improve transverse shape of the beam, normal laser incidence scheme is chosen instead of oblique incidence.
- To reduce pulsed heating, coupling hole is rounded with radius of 4.5 mm.
- To decrease dark current and electric discharges, gasket is used instead of helicoflex seal.
- For ease of fabrication, coupling between gun and waveguide is done at the side of each waveguide. This coupling scheme save many efforts to make the coupling coefficent β = 1 [1, 4].

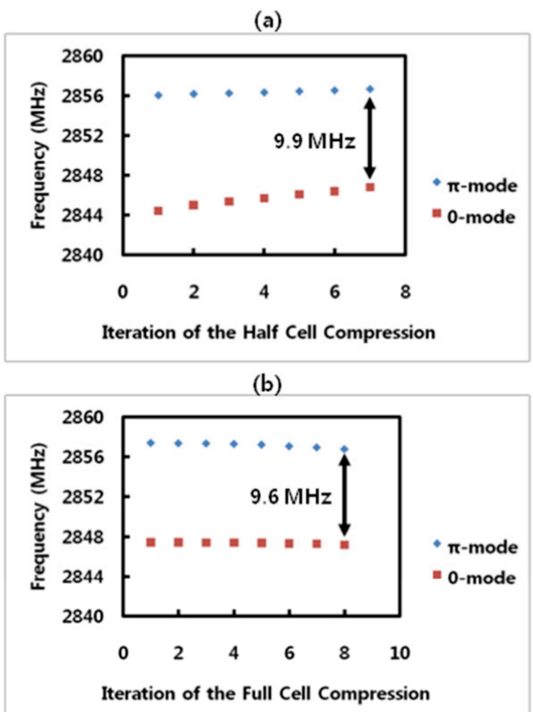

Figure 2: Tuning procedure. (a) half cell case. (b) full cell case.

Table 2: Measured Data of the Fabricated RF 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	12700

Finally resonant frequencies were measured and tuned with network analyzer to confirm the designed value. Half cell was tuned first by compression of the gasket between the half cell and the cathode until the moment when the mode separation reached to the value of 9.9 MHz. And then the full cell was tuned by pushing with tuning jig to the value of 9.6 MHz. The results of resonant frequency and mode separation were almost same as the designed values [8]. In addition, they could be controlled further by temperature change. All these tuning procedures for the half cell and the full cell are shown in Fig. 2. Optimized π-mode resonant frequency was 2856.0 MHz at 41.5 ℃ and mode separation was 9.6 MHz. Coupling coefficient was 1.09 and calculated quality factor was 12700. All these values are listed in Table 2.

Now the RF gun is kept in an intermediate level of vacuum as shown in Fig. 1. This gun will be installed in the test stand at March 2011.

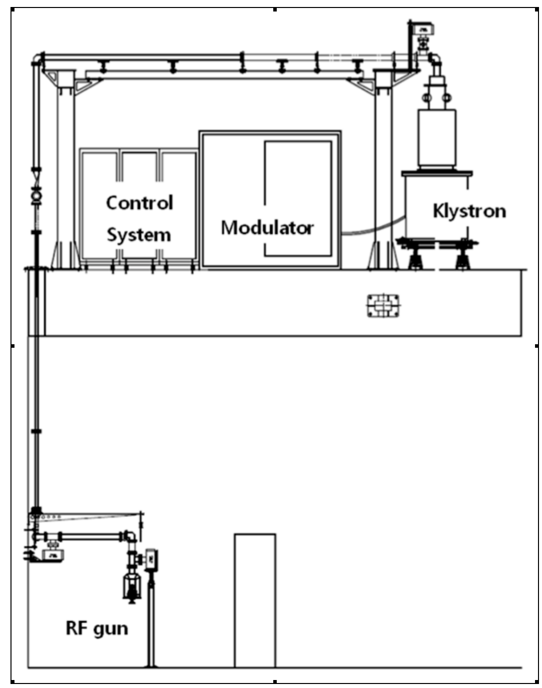

Figure 3. RF gun test site located in linac tunnel of PAL.

GUN AGING

RF gun test stand located in linac tunnel of PAL and its RF systems are shown in Fig. 3. Waveguide system was changed due to other project in PAL and we are now waiting its restoration. RF systems are located in upper floor of the test site. Home-made klystron can feed stable RF power up to 50 MW. It can generate 10 MW at 50 Hz with one or two microsecond pulse width [9]. It is enough to feed the power for our experiment to generate electron beam of 5 MeV at 50 Hz.

Baking will be performed at around 150 ℃ with consideration of the capabilities of other test component. As mentioned above RF gun aging will be performed with RF power up to 10 MW which corresponds to the modulator voltage of around 30 kV with 2 μs of pulse width. We expect that it will take about two months and first beam will be generated in June or July.

BEAM MEASUREMENT/SIMULATION

A schematic view of the test stand is shown in Fig. 4. Multi slit system which is not presented in the figure will also be installed in the test stand.

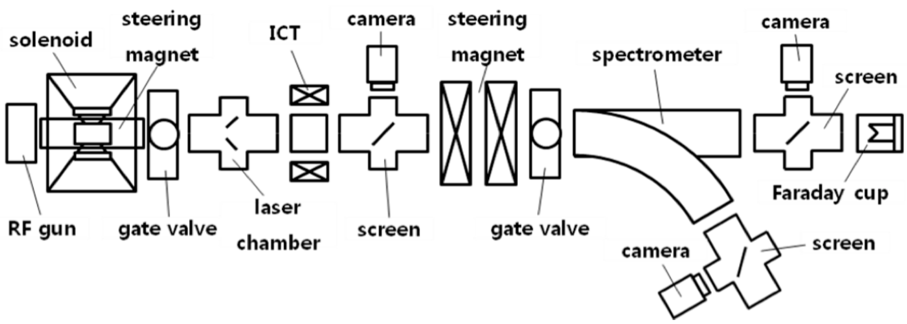

Figure 3: Schematic view of the test stand.

Charge Measurement

Beam charge will be measured by an ICT (Bergoz) located at downstream of the solenoid and a Faraday cup installed at the end of the test stand. The sensitivity of the ICT is 5 V·s/C and its output pulse length is 20 ns. The Faraday cup is matched to 50 Ω.

Energy and Energy Spread Measurement

Electron beam energy and its spread will be measured by spectrometer which consists of 60° bending magnet and screen [10]. Steering magnet will be installed right before spectrometer to align electron beam.

Transverse Emittance Measurement

Emittance will be measured with multislit method [5, 11]. Space-charge dominated beam which passes slit turns into emittance-dominated beam and space-charge dominance is determined by the following relation [12].

$$R_b = \sqrt{\frac{2}{3\pi}\frac{I}{\gamma I_0}\left(\frac{d}{\varepsilon_n}\right)^2}$$

Here I is the current of the electron beam, I_0 is Alfvén current, d is width of the slit. When R_b is very small, electron beam is considered as emittance-dominant and accurate measurement is possible

Beam Size and Emittance Simulation

PARMELA simulation on the beam size and emittance has been performed to determine the exact position of the slit and YAG scintillator, phosphor screen [13]. The results are shown in Fig. 5.

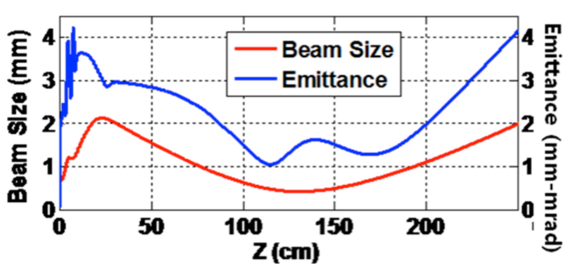

Figure 4: PARMELA simulation results of the rms beam size and normalized transverse rms emittance.

SUMMARY AND DISCUSSION

The fabrication of the third photocathode RF gun at PAL has finished. Installation of the RF gun is slightly delayed than original plan due to the restoration of the waveguide system. Baking and aging of the gun and solenoid part will be started soon and the generation of the first beam is expected to be possible in June or July this year.

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