UPGRADED PHOTOCATHODE RF GUN AT PAL*

Juho Hong, MoonSik Chae, In Soo Ko†, Sugn-ik Moon, Yong Woon Parc,
POSTECH, Pohang, Korea
Changbum Kim, Sung-Ju Park, PAL, Pohang, Korea

Abstract

A Brookhaven National Laboratory (BNL) type S-band photocathode RF gun is used at Pohang Accelerator Laboratory (PAL) to produce femtosecond tera hertz (fs-THz) radiation. In order to upgrade the fs-THz Facility at PAL, we need to develop the performance of the RF gun. The requirements for new RF gun are following: 1 nC beam charge, 60 Hz repetition frequency and 1 mm mrad normalized rms transverse emittance. A dual feed photocathode RF gun is designed satisfy these requirements. Two additional pumping ports are used to remove the field asymmetry. A large radius and short length of the iris increases the mode separation. The coupling scheme is changed to make the fabrication simpler. The RF gun structure had been modeled using 3D field solver to provide the desired RF parameters and to obtain the field profile. In this paper the new RF gun design and the cold test results will be presented.

INTRODUCTION

A photocathode RF gun at PAL is based on S-band BNL GUN-VI type RF gun. A first photocathode RF gun has been fabricated to be used at fs-THz Facility. However, there are a lot of dark current and electric discharges [1]. To reduce the dark current and the electric discharges for better performances, the helicoflex seal and tuner holes on the full cell should be removed from the RF gun. In a second photocathode RF gun, these problems are solved by improvements of cathode structure and tuner in full cell. Now the second RF gun is operated with 200 pC beam charge, 1.5 mm mrad normalized rms transverse emittance, 5 MeV beam energy and 10 Hz repetition frequency.

The field asymmetry due to the side RF coupling scheme can be a serious problem. It will kick the electron beam during passage through the RF gun even if the beam is aligned to the center of the RF gun. This kick will leads the emittance growth [2, 3]. To eliminate the field asymmetry in the RF gun, we have proposed dual feed and two additional pumping ports RF gun, namely four ports RF gun.

In this paper, we are mainly concerned with the electrical properties of the RF gun.

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† isko@postech.ac.kr

DESIGN OF FOUR PORTS RF GUN

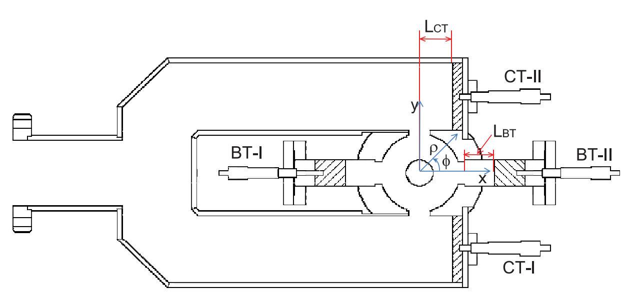
Features of Four Ports RF Gun

The design has been optimized to allow operation at higher repetition frequency and to eliminate the field asymmetry. The new features incorporated into the four ports RF gun are as follows:

- To eliminate the RF emittance growth due to the traveling wave, dual RF feed is chosen.
- To eliminate the RF emittance growth due to the quadrupole field, two additional pumping ports are added.
- To Increase 0 and π-mode separation from 3.4 to 9.6 MHz, relatively large coupling iris radius and short coupling iris length are designed.
- To fabricate easily, coupling between RF gun and waveguide is done at the side part of the waveguide.
- To reduce the pulsed heating, relatively large rounding is given at the port holes.
- To decrease the dark current and the electric discharges, a gasket is used instead of the helicoflex seal.

Cold Model Cavity

The cold model cavity is developed and fabricated. Fig. 1 shows the cold model cavity of four ports RF gun. Two boundary tuners (BTs) and two coupling tuners (CTs) are located on opposite sides of the full cell cavity at vertical and horizontal direction as shown in the Fig. 1.



The front of view.

Figure 1: RF gun for cold test.

RF Parameters

The main RF parameters of the four ports RF gun are given in Table 1. In this table, E_F and E_H are peak values of longitudinal accelerating field in full cell and half cell, respectively.

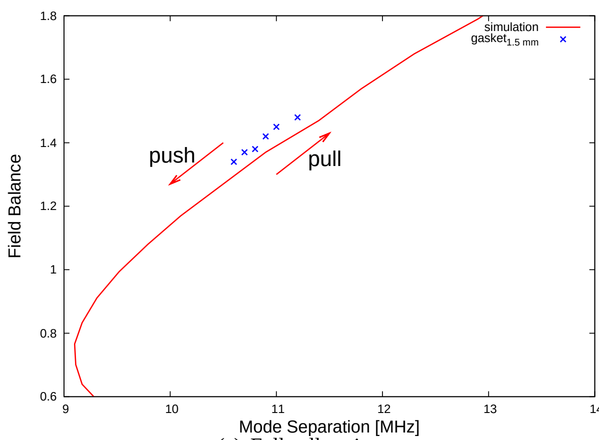
Table 1: RF Parameters

Parameter	Description	Design	Cold test
f_π (MHz)	π-mode frequency	2856	2856
f_0 (MHz)	0-mode frequency	2846.35	2846.41
Δf (MHz)	mode separation	9.65	9.59
Q_0	quality factor	12926	10730
β	coupling coefficient	1.0	1.0
E_F/E_H	field balance	1.0	1.0

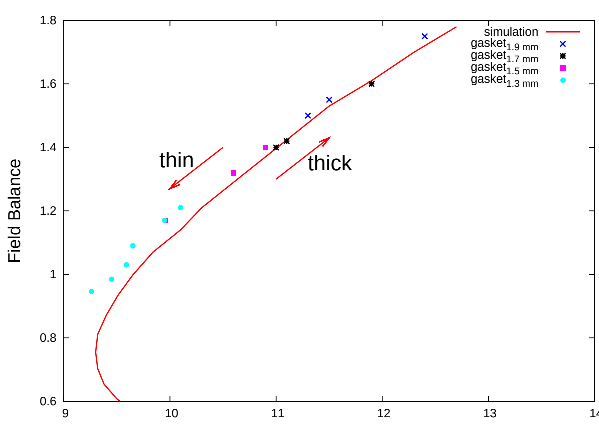
COLD TEST

Frequency

The frequency tuning and the field balance was studied as a function of mode separation. During the full cell and half cell tuning, we measured the longitudinal accelerating field (E_z), f_0 and f_π. The field balance versus mode separation is given in Fig. 2. Finally, we got the field balance$= 1$ with $f_\pi = 2856$ MHz and $\Delta f = 9.59$ MHz. The field profiles as function of z when mode separations are 11.45, 9.59 and 9.26 MHz are shown in Fig. 3.



(a) Full cell tuning.



(b) Half cell tuning.

Figure 2: Field balance as a function of mode separation.

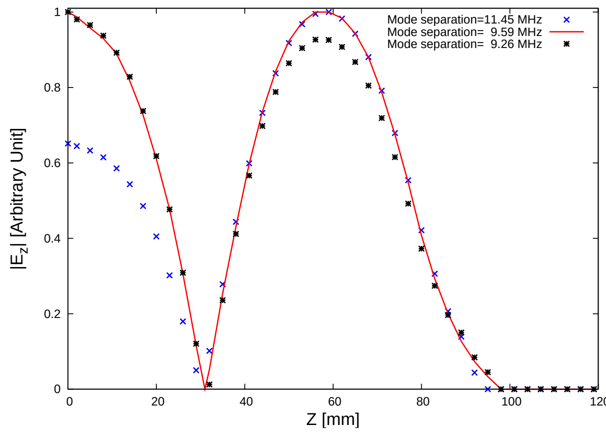


Figure 3: Field profile of $E_z(0, 0, z)$ in the RF gun.

RF Asymmetry

We can change boundary condition on the surface of full cell cavity using the BTs. The field asymmetry of E_z can be changed by moving the BTs position as denoted by L_{BT} in Fig. 1. The offset between the field center and mechanical center (dipole offset) is directly measured by bead scan technique along the x and y-axis [2]. Near the center of beam tube, E_z can be fitted by

$$E_z(x, 0, 0) = A + B(x - x_0)^2,$$
$$E_z(0, y, 0) = C + D(y - y_0)^2,$$

where x_0 and y_0 are the dipole offsets at x and y-axis, respectively. The normalized E_z are shown in Fig. 4. In this

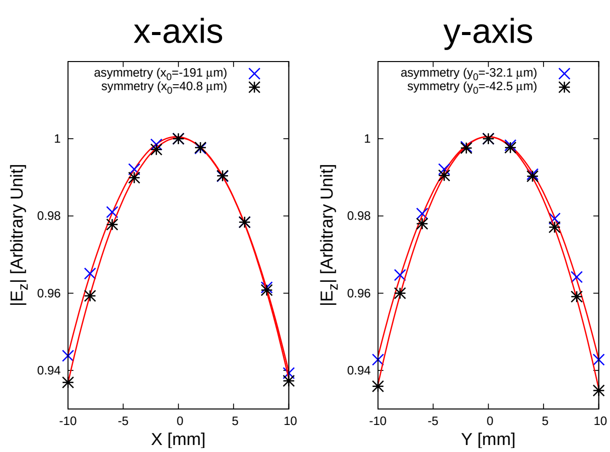


Figure 4: Dipole offset.

figure, the 'symmetry' is the case when both tuners are removed. The 'asymmetry' is the case when BT-I is removed and BT-II is fully pushed in. At the symmetry case, x_0 is improved from -1.91×10^{-1} to 4.08×10^{-2} mm.

The E_z in the full cell cavity can be expressed as an infinite sum of modes represented by

$$E_z = E_0 \sin(\omega t - k_y y + \theta_0) \cos(kz) \sum_{n=0}^{\infty} a_n \rho^n \cos(n\phi),$$

where E_0 is the peak value of E_z, ω is the resonant frequency, k_y and k are the wave numbers, a_n is the Fourier coefficients of high multipole fields, ρ and ϕ are radial coordinate and azimuthal coordinate in cylindrical coordinates, respectively [3]. The normalized $E_z(\rho = 10\ \mathrm{mm}, \phi)$ is displayed in Fig. 5. According to Fig. 5, we can find the improvement of field asymmetry when L_{BT} is increased.

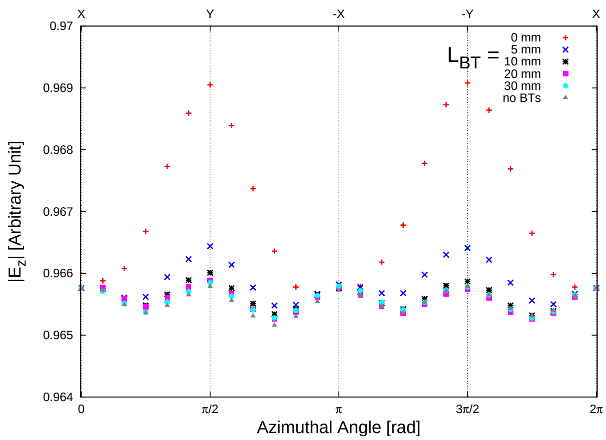


Figure 5: Field profile of $E_z(r = 10\ \mathrm{mm}, \phi)$ in the full cell cavity.

The $E_z(\rho = 10\ \mathrm{mm}, \phi)$ in the full cell cavity for different three cases are shown in Fig. 6. In This figure, the 'CASE-I' is the case when BT-I is removed and BT-II is fully pushed in. The 'CASE-II' is the case when both tuners are fully pushed in. The 'CASE-III' is the case when both tuners are removed. The CASE-III can be considered as the four ports RF gun. In each case, we can calculate the Fourier coefficient of the infinite series. The absolute normalized Fourier coefficients of the first four modes are shown in Table 2. From the Fig. 6 and Table 2, we can recognize that the field asymmetry is improved by adding two additional ports in the RF gun.

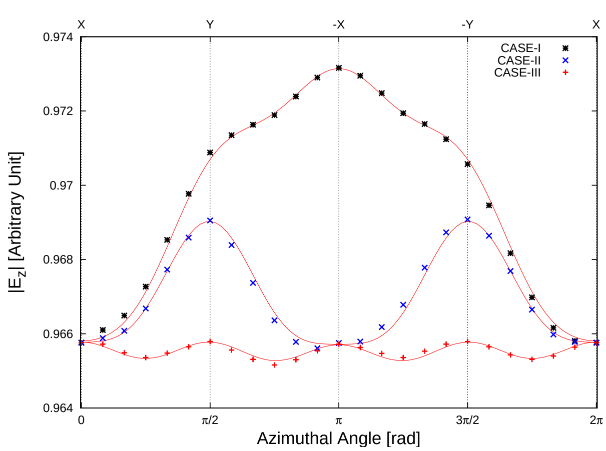


Figure 6: Field profile of $E_z(r = 10\ \mathrm{mm}, \phi)$ in the full cell cavity for different three cases.

Table 2: Absolute normalized Fourier coefficients of the first four modes.

n	CASE-I	CASE-II	CASE-III
0	1	1	1
1	3.64×10^{-4}	5.44×10^{-6}	3.93×10^{-6}
2	6.28×10^{-6}	1.69×10^{-5}	1.75×10^{-7}
3	1.35×10^{-7}	2.59×10^{-8}	2.69×10^{-9}

Coupling Coefficient

The β versus L_{CT} is measured. The measured data is shown in Fig. 7. In this figure, we can find that coupling is changed form under coupling to over coupling. We got the critical coupling at $L_{CT} = 23.4$ mm.

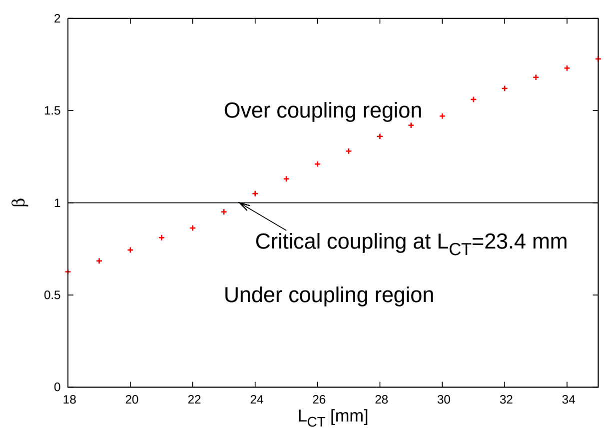


Figure 7: β versus L_{CT} in the RF gun.

CONCLUSION

To eliminate the field asymmetry in the RF gun, we have proposed the four ports RF gun. In case of four ports RF gun, The field asymmetry is improved. The adjustable frequency tuning ranges are about $\pm$ 2 MHz about full cell and half cell tuning. The β can be changed easily by side coupling scheme used in this study. For the next step, the research of cathode material and laser profile will be conducted.

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