IMPROVEMENT OF AN S-BAND RF-GUN CAVITY WITH A CS-TE PHOTO-CATHODE

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Abstract

A 1.6cell S-band photo-cathode RF-Gun is one of the good alternatives of the short pulse electron source. Therefore, we are operating as a high brightness short pulse electron source for studying a reaction of radiation chemistry [1], an inverse Compton scattering at Waseda University [2] and as an injector at KEK-ATF.

To improve an electron beam quality and reduce a dark current, our group decided to improve the RF-Gun cavity. The resonance frequency tuning of the half cell of existing RF-gun was performed by the torque control of Helicoflex seal on the cathode plate and two moving rod type tuners with a tuning hole were installed on the full cell.

Newly designed RF-Gun cavity has four compact tuners on each cell, which can be tune the frequency to deform the cavity wall, to remove the Helicoflex seal and tuning holes that were considered to be the major cause of electric discharge and/or dark current source [3].

According to these improvements, the Q-value and shunt impedance of the cavity is 20% larger than that of existing guns. As the result, the reduction of dark current is demonstarated and the beam energy is reached up to 5.5MeV at 10MW RF input.

INTRODUCTION

An S-band photocathode RF-Gun has been operated at Waseda University for applied researches such as a pico-second pulse radiolysis experiment [1] and a soft X-ray microscope based on an inverse Compton scattering [2].

A RF-Gun is one of the good alternatives of the high quality and short pulse electron source, because of its high gradient on the electron emitter causing small beam emittance and the controllability of an electron bunch length. A RF-Gun is operated not only for applied researches, but as an injector of the electron damping rings.

To improve the electron beam current and quality, we decided to use a Cs-Te as a photocathode, which have higher quantum efficiency by order 2 than that of a pure copper. A Cs-Te cathode has been used as a electron source at KEK Accelerator Test Facility (ATF) [4] and DESY-PITZ [5] etc.

The conventional RF-Gun with 1.6 cells has been performed at KEK-ATF. However, increased dark current and electric discharge are troubles. To reduce electric discharges and dark current for better performances, it is considered that the Helicoflex seal and tuner holes on the full cell should be the source of the electric discharge and dark current. To solve these problems, a new RF-Gun cavity has been developed. A new RF-gun cavity has two improvements. One is that the end plate and the half cell is brazed without a Hericoflex seal. The other is to adapt new tuners on each cell without tuning holes. A preliminary characteristic RF-gun test was carried out at Waseda University.

DESIGN CONCEPT

RF Cavity

The design of a new RF-gun cavity was based on the conventional type operated at KEK-ATF. Fig. 1 (a) shows the configuration of the conventional cavity. It consists of three components such as a full cell(7), a half cell(5) and an end plate(2). The cathode plug is attached with a Be-Cu contact using a load-lock system installed behind the end plate. The full and half cells are brazed. The end plate is attached to the half cell through a SUS plate and a Helicoflex seal, which can be tune the resonant frequency of the half cell by changing a torque provided to a Helicoflex seal. On the other hand, resonance frequency of the full cell is tuned by a conventional tuner with a tuning hole.

However, these methods decrease Q-value. And these tuning techniques are considered to be the major cause of electrical discharge and/or dark current source. In case of,, the new RF-gun the end plate is brazed to the half cell to remove the complicated structure around the Helicoflex seal and to simplify the fabrication procedure.

Frequency Tuner

In the case of conventional RF-gun, the frequency tuning for the full cell with a 10 mm diameter tuning rod with a hole shown in Fig. 2 (a). As described in the preceding section, this structure is considered to decrease the Q-value and be the source of discharge. A new tuning scheme was also required for the half cell to tune the frequency instead of Helicoflex based tuning method.

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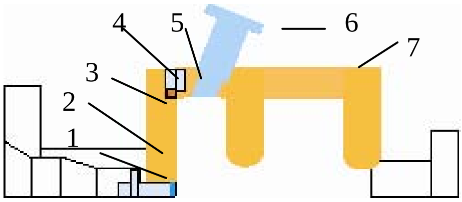
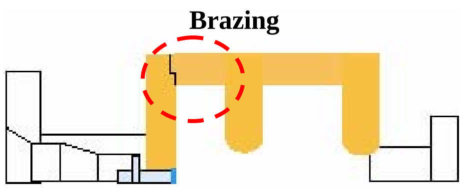


(a) Conventional type RF-gun at KEK-ATF
1) Cathode plug, 2) End plate, 3) Helicoflex seal,
4) SUS plate, 5) Half cell, 6) Laser port, 7) Full cell



(b) New type RF-Gun

Figure 1: RF-Gun cavity design.

Therefore, we have developed a new compact tuner using the mechanical deformation of the cavity wall. The schematic drawing is shown in Fig. 2 (b). By pushing/pulling the cavity wall directly from outside, the inner surface is deformed and a resonance frequency can be tuned. The adjustable frequency range of tuners are about 1.6 MHz. Four new tuners are attached on each cell to achieve the required tuning range (2856MHz).

(a) Conventional type tuner with tuning holes
(b) New type tuner

Figure 2: Schematic drawings of frequency tuner.

FABRICATION AND CAVITY PARAMETER MEASUREMENT

The new cavity was designed with the simulation code SUPERFISH. The peak electric fields were balanced in each cell, which is the best balance to accelerate an electron beams by the simulation result of PARMELA. As a results showed that shunt impedance and Q-value were improved by removing complicated structure around a Hericoflex seal.

To reduce dark currents and electric discharges, the inner surface of the cavity was machined diamond tuning. The picture of fabricated RF-gun is shown in Fig. 3. The measured performance of the new RF-gun cavity is shown in Table 1. As a result, effective shunt impedance and Q-value increased about 20 % due to change the cavity design. With the bead perturbation method, R/Q is calculated by eq.1. Δf is delta frequency, ΔV is volume of the bead, ε is permittivity and f_0 is the resonance frequency of pi mode. Shunt impedance and Q-value are calculated from Eq.1.

$$\frac{R}{Q} = \frac{\left| \int \sqrt{|\Delta f|} dz \right|^2}{\pi f_0^2 \varepsilon \Delta V} \qquad (1)$$

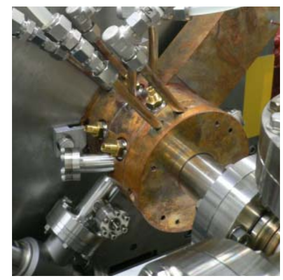


Figure 3: New RF-gun for Waseda Univ.

Table 1: RF-Gun Cavity Parameters

	Existed KEK-ATF	KEK-LUCX*	New Waseda Univ.
Q value	-	7900	12000
Coupling factor β	-	0.6	1
Effective Shunt Imp. [MΩ]	1.75	1.87	2.49

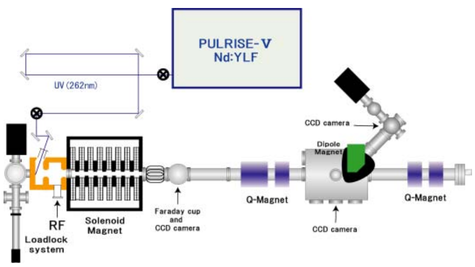
*KEK-LUCX [6] and KEK-ATF uses same type (BNL-type 4) of RF-gun with a Cs-Te cathode

EXPERIMENTS

New RF-Gun System at Waseda Univ.

At Waseda Univ., we have operated the RF-gun (BNL-type 4) with a Cu cathode and investigated a reaction of radiation chemistry[1] and an inverse Compton scattering[2] for advanced experiments, the operation of new RF-gun system has been started in the summer of 2007. Our system shown in Fig. 4 is table-top size (2.5×3 m) including all the beam line and a pico-second Nd:YLF laser system (Pulrise V: Sumitomo Heavy Industry, Ltd.). An electron beam was generated with the the 4th harmonic of Nd:YLF, 262 nm UV laser, which was irradiated to the Cs-Te cathode after the profile optimization.

The beam line is mainly composed of the compact load-lock system, the RF-gun, a solenoid magnet, Q-magnets, the X-ray interaction chamber and the bending magnet. Photoelectron beams are emitted from the Cs-Te cathode Fig. 5 is a picture of the compact load-lock system which is about 1×1 m, consisted of the transport chamber and the main chamber. To keep high Q.E. of the cathode, the cathode plug can be easily replaced in vacuum when its Q.E. gets lower. A fresh Cs-Te cathode is transported from the cathode evaporation system located at KEK-ATF and replaced under ultra high vacuum inside of the beam line.



Figire 4: The beam line layout at Waseda Univ.

Dark Current Measurement

Dark current from the new RF-gun cavity was measured using a Faraday Cup (F.C.) that was located at downstream of the Solenoid magnet. The figure 5 shows the comparison of dark currents between the existed RF-gun and the new RF-gun. A dark current was about 800pC/pulse at 10MW. It is much lower than that of existed RF-Gun with a Cu cathode. According to this result, we have successfully performed reduction of dark currents at same RF power in the cavity. It is found that this effect make accelerating fields much higher.

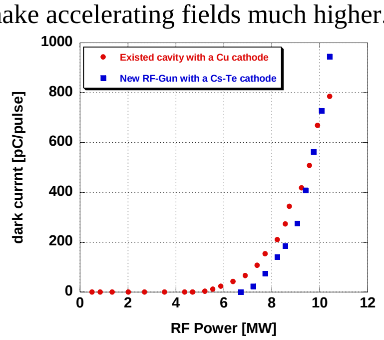


Figure 5: Results of dark current measurement with RF input power of 10.0 MW and pulse width of 2.0 µsec (Typical operation parameters at Waseda Univ.).

Electron Beam Charge and Energy Measurement

Fig. 6 shows one of results of beam charge and energy measurements. The highest energy is about 5.5MeVat RF power 10MW. It was 20% higher than that of existed RF-Gun's data. Table 2 shows that beam characters with new RF-gun is obtained significantly higher than that of existed RF-gun with a Cu cathode.

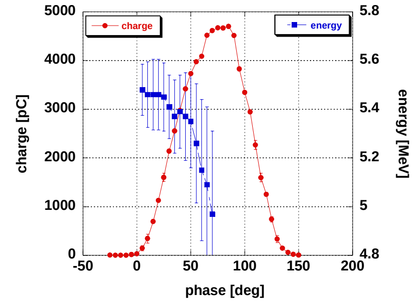


Figure 6: The result of electron beam charge and energy measurements with RF input power of 10.6 MW, pulse width of 2.5µsec and cathode Q.E. of about 0.05%.

Table 2: Electron Beam Parameters

	Existed RF-gun (Cu cathode)	New RF-gun (Cs-Te cathode)
Charge [nC/bunch]	~1	1~
Energy [MeV]	~4.6	~5.5
Energy spread [%]	1~	1~
Emittance [πmmmrad]	3~	-*
Bunch length [psec]	10	-*

* They will be measured in near future.

SUMMARY AND FUTURE PLAN

According to our investigation of new design RF-Gun cavity, the Q-value and effective shunt impedance improved 20% larger than that of existing RF-Gun. As a result, reduction of dark current have been successfully performed, and the beam energy have increased up to 5.5MeV at 10MW at Waseda Univ.. We are ready to install new RF-gun and measure beam characteristics with optimization of Cs-Te cathode at KEK-ATF.

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