DEVELOPMENT OF AN S-BAND Cs_2Te-CATHODE RF GUN WITH NEW RF TUNERS*

Y. Kamiya†, Y. Kato, A. Murata, K. Sakaue, M. Washio, RISE, Tokyo 169-0072, Japan
T. Takatomi, J. Urakawa, N. Terunuma, M. Kuriki, N. Kudoh, KEK, Ibaraki 305-0801, Japan
R. Kuroda, AIST, Ibaraki 305-8568, Japan

Abstract

A photo-cathode RF gun is one of the good alternatives for the electron injector, because of its high gradient on the electron emitter causing small beam emittance, and better operationality especially for electron bunch length. Therefore, several institutes which study FEL [1], early response of a radiochemical processes [2, 3], and/or advanced accelerator technologies specially for International Linear Collider (ILC) [4] adopted the photo-cathode RF gun as their injector.

In this paper, we present a modified RF gun with new compact tuners and show results of a conditioning study using high power RF field. A starting point of this study is an design of the S-band Cs_2Te-cathode RF gun used in the Accelerator Test Facility of KEK (KEK-ATF).[4]

INTRODUCTION

The RF gun operated in KEK-ATF has 1.6 cells structure. It consist of three copper body called full cell, half cell and end plate. RF coupler and two RF tuners are on full cell. On the half cell, two slanting ports are mounted. A laser making the photo-electrons is injected from electron port to the cathode with about 90 degrees, as the so-called normal incident configuration, or from the slanting ports with about 22 degrees. The Figure 1a shows a schematic illustration for the ATF's gun, but the tuners, the RF coupler and the slanting laser ports are not written. The full and half cells are brazed. On the other hand, the end plate is attached to the half cell using SUS plates and the Helicoflex seal, which allows a person to change a length of half cavity.

Complicated structure of the edges and gaps around the Helicoflex seal is one of the major cause for electrical discharge limiting the impressed RF power. To avoid that downside of the existing gun, we design the gun cavity using the brazing attachment for the end plate, here the Helicoflex seal is not used. (see Fig. 1b) Fabrication procedure is also reviewed and simplified. The change of the design requires several relating developments, mainly for new tuners that can fit even on the half cell. In the next section, we present the new tuner structure.

* Work supported by Promotion of Collaborative Research Programs in Universities of High Energy Accelerator Research Organization (KEK), and High-Tech Research Center Project of Ministry of Education, Culture, Sports, Science and Technology (MECSST) 707, Japan

† Present address: University of Tokyo, Tokyo 113-0033, Japan. (email: kamiya@icepp.s.u-tokyo.ac.jp)

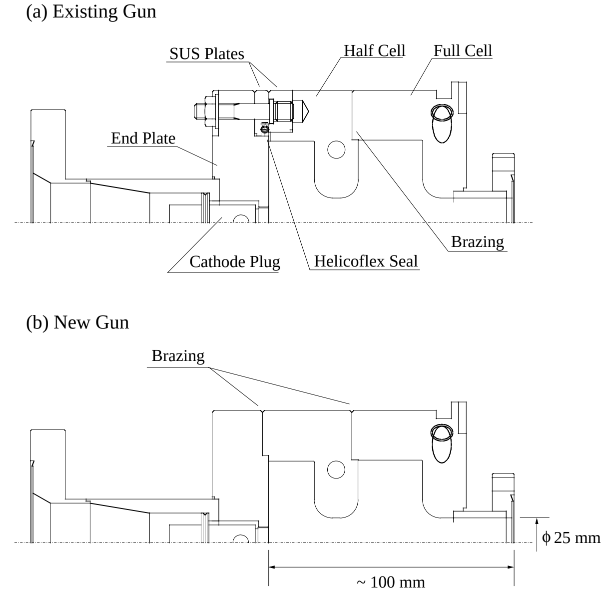

Figure 1: Cross-section drawing of the existing ATF's gun (a) and New gun (b).

NEW TUNER STRUCTURE

Design

The figure 2a shows tuner structure for the existing gun. The existing ATF's cavity has holes (only on the full cell) with 10 mm diameter and RF tuning is done by moving tuning rods inside the holes. Considering the cavity quality, holes with 10 mm diameter do not fit on the half cell with about 20 mm length. The structure is not preferred from a point of view as its vacuum property.

We developed the new tuning structure that is applied the plastic deformation of the inner cavity wall by moving outside pole (Fig. 2b). Tuner with this kind of structure has been developed in other RF cavity of different RF frequency like cavity BPM[5] and accelerator tube for X-band. This study is the first application for the S-band RF gun.

Test for an Adjustable Range

To understand an adjustable range of the tuner and acceptable wall thickness, we made a test cavity that has one cell structure.

The outside pole moves up and down by turning outside screw, and deform the inner wall. One turn of the screw

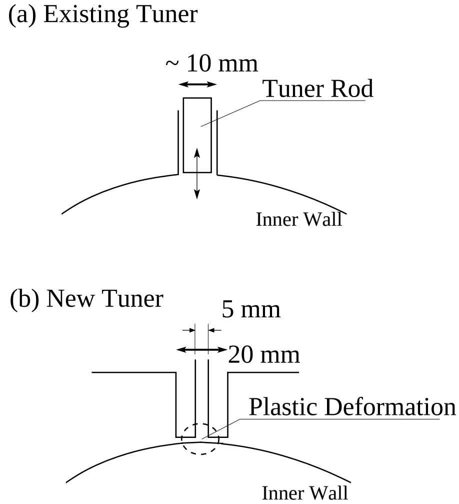

Figure 2: Schematic drawing for the existing tuner (a) and the new tuner (b).

correspond to 0.25 mm movement. The figure 3 shows a frequency shift for tuner turns. The results show adjustable rate is 220 kHz/turn. A backlash from the screw, corresponding half turn, is observed seeing the difference between the clockwise and counterclockwise move. Linearity is verified through the ±1.5 turns corresponding to ±330 kHz. Four tuners can be make on the each cells because of this compactness. Therefore, the adjustable range is ±1320 kHz for both cells. It is enough for the roles of the tuner, frequency readjustment after brazing and fine tuning for an RF field balance between the full and half cells. This results are compared with a SuperFish simulations. They are consistent within factor two. The figure 4 shows the cells with the new tuners before brazing.

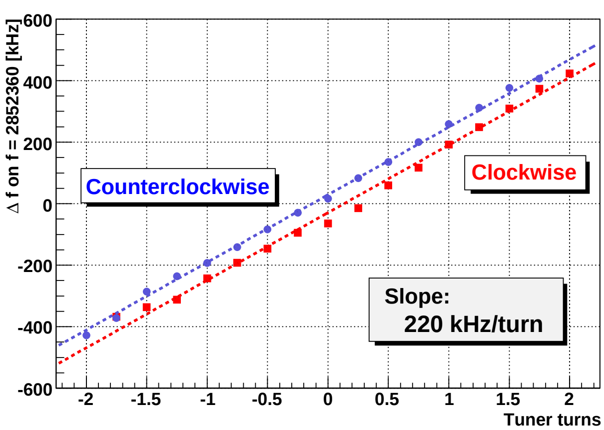

Figure 3: Results of the tuner test. Slope of this figure shows an adjustable rate for one turn.

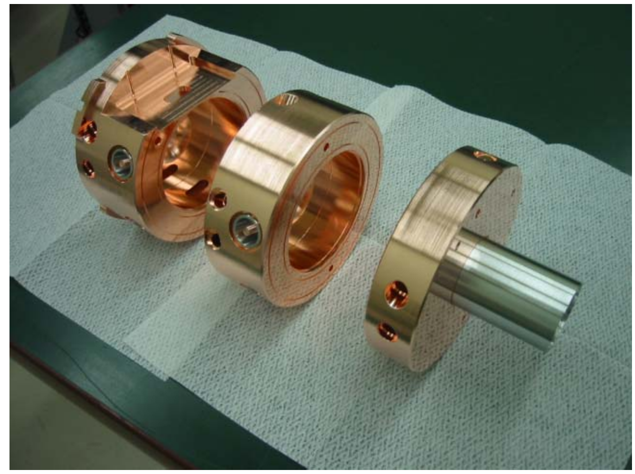

Figure 4: The cells with the new tuners before brazing.

CONDITIONING STUDY

Conditioning Process

Gun conditioning study using high power RF field was done at an ATF's injector section. We start the conditioning with RF field with 1 MW/pulse and 0.5 μsec duration. Finally, RF field of 12 MW/pulse and 2.0 μsec duration is impressed to the gun during about 100-hour conditioning, but electrical discharges occasionally happen in this power. On the RF of the 10 to 11 MW/pulse power and 2.0 μsec duration, the gun can be stably operated. Gun temperature is set to 28 ℃.

Dark Current Measurement

During the Conditioning, dark currents from the gun cavity is measured using a Faraday cup that is located 70 cm downstream from the cavity exit. The figure 5 shows a setup of the measurement. A solenoid coil is just after the gun. Current of the solenoid coil is set to 110 A, which is the optimum current for the operation of the existing gun. There are a set of BPM and laser injection mirrors for the normal incident configuration. A gate valve is used to check the zero point of a Faraday cup signal. The signal from the Faraday cup is evaluated using charge-integrating ADC.

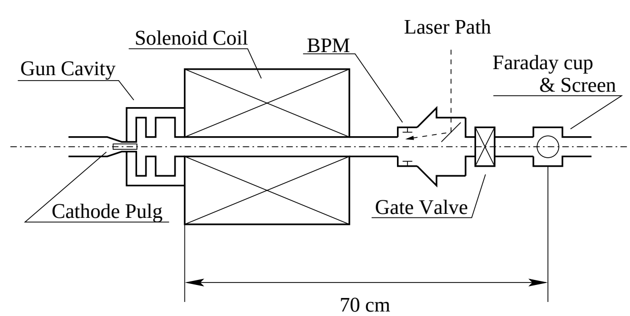

Figure 5: Setup for gun conditioning study.

The figure 6 shows results of dark current measurements. Those plots are taken during the RF duration of 1.8 μsec is used. Open circle plots shows the result taken 5 hours later than the RF duration changed. Dark current is already low like on old well-conditioned gun even it is just 30 hours later than the start of the conditioning. Triangle plots shows for 10 hours, and it looks that the dark current is decreased somewhat during this time. Open square plots shows for 20 hours. There is no significant improvement in this 10 hours.

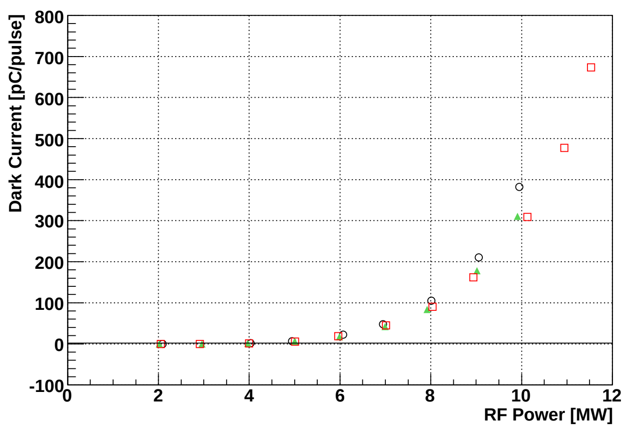

Figure 6: Results of dark current measurements with RF duration of 1.8 μsec. Horizontal axis shows RF power going to the gun cavity. Open circle plots shows the result after going through 5 hours after changing the RF duration to 1.8 μsec. Triangle plots shows for 10 hours, and open square plots shows for 20 hours.

After changing the RF duration to 2.0 μsec and conditioning for 5 hours using around 11 MW power, a Cs_2Te photo-cathode is made on the molybdenum plug by vacuum deposition. The vacuum chamber is located just after the gun in the ATF gun section and connected though the vacuum pipe to the gun cavity. Therefore, there is no contamination of the photo-cathode from the air, especially from oxygen. A measured quantum efficiency after the deposition is 6%.

The figure 7 shows results of dark current measurements before/after the cathode deposition. Triangle plots shows the results before making cathode, that is to say, for the molybdenum cathode. Circle plots shows the results after making cathode, for Cs_2Te cathode. Dark current increase about 4 times. We have a plan to study for the dark current source, whether this dark current growth is came only from the cathode surface or not.

SUMMARY

We have been developing a new S-band Cs_2Te-cathode RF gun. The gun with new compact tunes was made and installed to the ATF injector section for the conditioning study. It takes about 100 hours to impress the high power

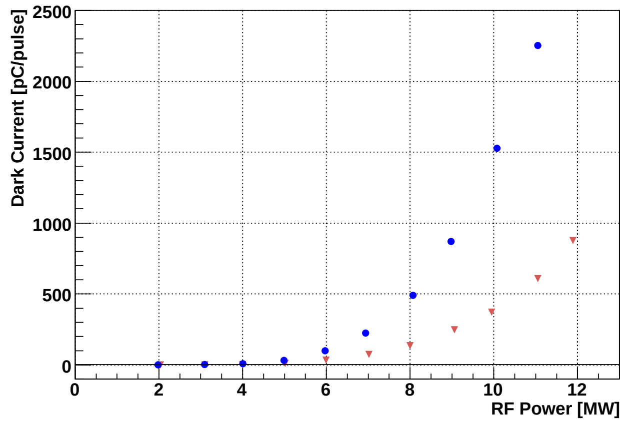

Figure 7: Results of dark current measurements before/after the cathode deposition. RF duration of 2.0 μsec. Horizontal axis shows RF power going to the gun cavity. Triangle plots shows the dark current before making cathode. Circle plots shows the dark current after making cathode.

RF with 12 MW power and 2.0 μsec. Spent time for conditioning to get this parameter is remarkably shot compare to the other existing guns. The amount of dark current is comparable to the old well-conditioned gun. The dark current growth when we change the cathode is still puzzling. At the moment, the study for the dark current and electron dynamics in the cavity by electron bunches are going on.

ACKNOWLEDGMENT

I would like to thank to Professor Toshiyasu Higo for measurement of the low level RF, to Dr Yousuke Honda for discussion about the new tuner sturcture, and to Dr Hokuto Iijima for discussion about cavity tuning.

REFERENCES

[1] http://wonda.iae.kyoto-u.ac.jp/index-e.html

[2] http://www.sanken.osaka-u.ac.jp/labs/bsn/index.htm

[3] http://www.f.waseda.jp/washiom/top-e.html

[4] http://atf.kek.jp/

[5] Y. Honda, (private communication, 2006)

