DEVELOPMENT OF AN S-BAND MULTI-CELL ACCELERATING CAVITY FOR RF GUN AND BOOSTER LINAC *

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Abstract

We have been developing a photocathode rf gun. The rf gun with multi cell can produce a high energy electron beam, so it may be used for numerous applications such as medicine and industry. At the Laser Undulator Compact X-ray source facility, called LUCX, we have developed a compact X-ray source based on inverse Compton scattering [1]. An S-band 3.5 cell rf electron gun which is 20 cm long can produce a high quality electron beam with energy of 8.7 MeV. According to the simulation, the emittance of 3.5 cell rf gun is as low as that of 1.6 cell rf gun. The electromagnetic design has been performed by the code SUPERFISH, and the particle tracing by PARMELA. The new rf gun is already installed and produced a high quality electron beam with energy of 8.7 MeV. As a consequence of the substantial efforts of developing rf cavity, we decide to make a compact RF accelerating structure with more cell for achieving a smaller system. The measurement results of using the 3.5 cell rf gun, the design of 12 cell booster cavity, and current status of 12 cell cavity manufacturing will be presented at the conference.

INTRODUCTION

We have successfully developed and operated a photocathode rf gun. The year before last, we already reported that we performed increasing the mode separation between operating π mode and the 0 mode to 8.6 MHz while increasing the Q and shunt impedance of our new rf gun [2]. This rf gun cavity is operating at LUCX as an injector. These efforts encouraged us to make a new rf gun with multi cell last year.We designed the new rf gun which has 3.5 cell accelerating cavity. The electromagnetic design has been performed by the code SUPERFISH, and the particle tracing by PARMELA. We carried out manufacturing with a few micron precision on the diameter of each cell and the cut was taken at KEK machine shop. Last year we successfully made 3.5 cell rf gun and tested at KEK Accelerator Test Facility (ATF). It can produce a high quality electron beam with energy of 8.7 MeV, thus it may be used for numerous applications such as medicine and industry.

As a consequence of the substantial efforts of developing rf cavity, we decide to make a compact standing wave rf accelerating structure based on rf gun structure, the design of the 12 cell booster cavity is now almost finished. In this conference, we report 3.5 cell rf gun results, design of the 12 cell booster, and present status of 12 cell booster manufacturing.

DESIGN AND TESTING OF 3.5 CELL RF GUN

The 3.5 cell rf gun was designed to operate 2856 MHz at π mode. Fig. 1 shows the cavity profile of the new rf gun designed by SUPERFISH. The cell structure is same with

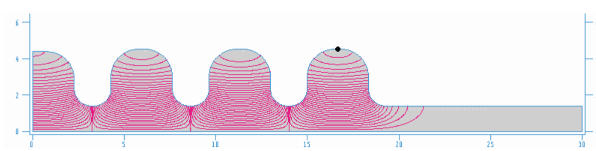
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Figure 1: 2D section of the 3.5 cell rf gun.

the mode separating rf gun designed in Ref. [2] to confirm the enough mode separation. Last year, referring to a result of the SUPERFISH simulation, we successfully made this rf gun structure in order to produce higher energy electron beam. It is used at ATF as an injector for the 1.3 GeV linac [3]. The photograph of the 3.5 cell rf gun is shown in Fig. 2. As shown in Fig. 2, 3.5 cell rf gun has, from near side, a cathode insertion port, vacuum pumping port, and rf input port. Each cell has 4 rf tuner shown as gold colored projection.

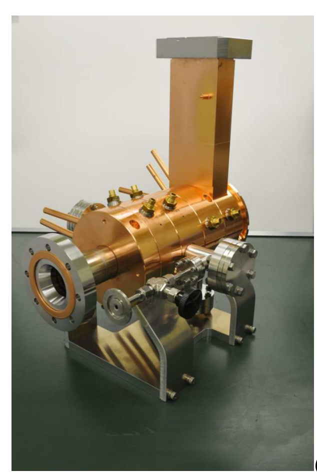
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Figure 2: The 3.5 cell rf gun structure.

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At ATF, we measured the beam parameters. The correspondent on-axis electric field is given in Fig. 3 and the resonance frequency at the 0 mode to the π mode is shown in Fig. 4. In Table 1 we listed measured parameters of the 3.5 cell rf gun. As shown in Fig. 3, the field balance is almost flat. According to Fig. 4 and Table 1, the mode separation is large enough to produce a high quality electron beam with π mode, and the resulting 3.5 cell cavity has enough Q value and the designed resonant frequency.

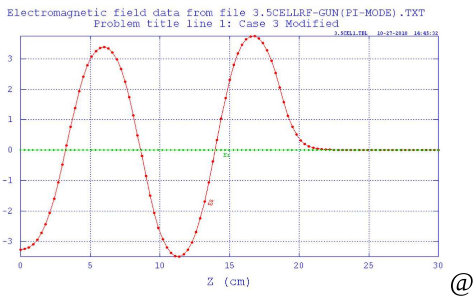

Figure 3: On-axis accelerating electric field.

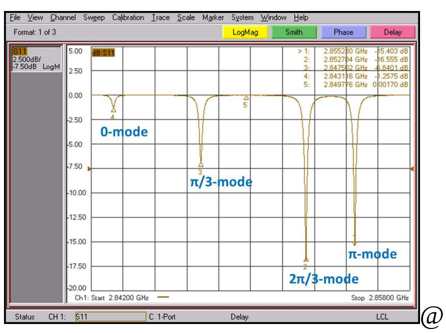

Figure 4: Frequency at the resonance mode.

Table 1: Measurement Results for 3.5 Cell RF Gun

Frequency@πmode	2855.235 MHz
@	i2856 MHz in vacuumj
Q	15456
β	0.71
Temperature	34.7
Mode Separation	12.164 MHz

BEAM PARAMETER MEASUREMENT

We tested the new rf gun, and measured the beam parameters at the injection of ATF. The peak value of the beam energy is 8.7 MeV for an input rf power of 13 MW (Fig. 5). The beam energy is limited not by a discharge breakdown but by an rf power from klystron.

We also measured rf phase vs charge relation as shown in Fig. 6, compared with the calculated results which is without Schottky effect. These results show that we have achieved good control over rf gun fabrication and we can tune the gun as desired, and successfully demonstrated more than 8 MeV beam from the rf gun.

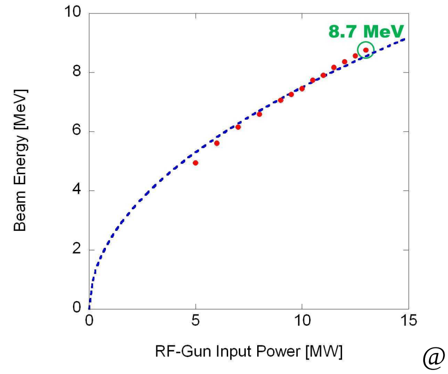

Figure 5: Beam energy for various input rf power.

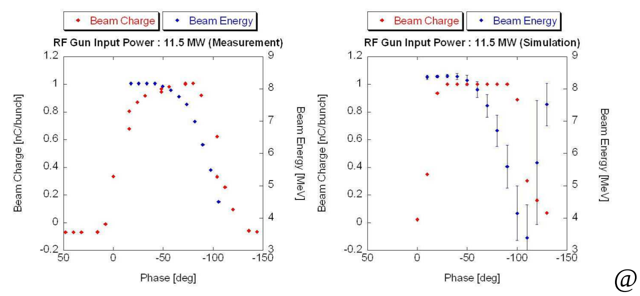

Figure 6: Measured and calculated phase versus charge and energy. The left plot is experimental results and the right plot is PARMELA simulation (without Schottky effect).

DEVELOPMENT OF 12 CELL BOOSTER LINAC

We successfully made and operated the 3.5 cell rf gun, then we started to make a new booster linac with 12 cell accelerating cavities, which is standing wave accelerator. After the machining of the booster linac has been carried out, we will replace existing traveling wave linac with the 12 cell booster linac at LUCX. According to the PARMELA simulation, the new standing wave booster linac can produce an electron beam with almost same energy and emittance. While the new 12 cell booster is only 80 cm long, our traveling wave linac has 3 meters. So we plan to use the new booster linac, and the LUCX system will be small enough for application use.

Using the code SUPERFISH, we optimize the electromagnetic design of booster linac. The 2D profile of the 12 cell cavity is shown in Fig. 7, and the correspondent on-axis electric field is given in Fig. 8. The cell radius is derived cavity resonant frequency to 2856 MHz and field balance to unity. Each cell of booster cavity is the same shape as that of the 3.5 cell gun cavity. Table 2, we list the main rf parameters of booster linac.

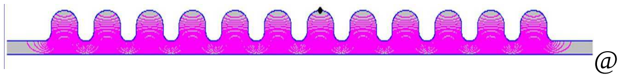

Figure 7: 2D Section of the 12 Cell Booster Linac

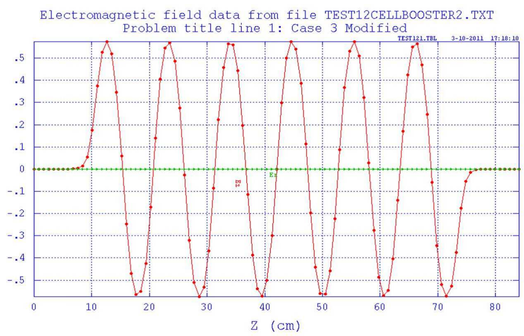

Figure 8: On-axis accelerating electric field of 12 cell booster linac.

However the 12 cell booster cavity has 12 resonance modes, thus the mode separation has to be considered for high quality beam generation. 13 MHz mode separation between the π mode to the 0 mode is not enough to accelerate a high quality beam in case that the Q value is about 15000. Then we redesign the 12 cell booster cavity, in order to increase the mode separation. We changed 11 irises in the cavity to enlarge the mode separation. In case we choice the cavity with the new inner shape which has 3 mm smaller irises, the mode separation was increased from 13.3 MHz to 51.4 MHz. Fig. 9 shows that the variation of frequency as a function of the resonance mode. For the comparison of the mode separation of normal iris cavity with that of small iris cavity are also shown. It is clearly seen that the booster cavity with small irises has a larger mode separation. The separation of the normal iris is not enough for 12 cell accelerating structure, therefore we redesigned the iris shape with SUPERFISH and PARMELA.

Table 2: Main Parameters of the 12 Cell Booster Linac

Frequency@π mode	2856 MHz
Q	15456
R_s	55.43 MΩ/m
Mode Separation	13.3 MHz
(3 mm-small iris)	51.4 MHz

In order to make sure that these simulation results are correct, we did a experiment with 4 cell cavities which are materials for booster linec (Fig. 10). We used cutting stock for the experiment. This result of the 4 cell cavity experiment proved that the current simulation results are correct and agree with the measurement results. According to these results, we will redesign the 12 cell booster cavity, considering the beam parameters by PARMELA.

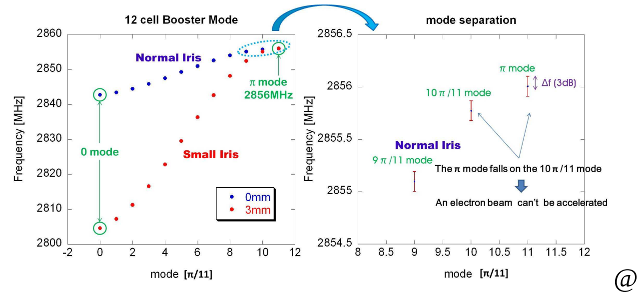

Figure 9: Frequency as a function of resonance mode. The blue plots is for the booster cavity with the normal iris which is the same shape as 3.5 cell rf gun while reds are for 3 mm-small iris. The right plot shows the frequency around the π mode. The error bar in the graph indicates the cavity bandwidth.

Figure 10: The experiment with 4 cell cavity to increase the mode separation.

CONCLUSIONS

We successfully designed and made 3.5 cell rf gun and installed in ATF. The beam energy was doubled by 3.5 cell rf gun at 13 MW rf input power. Now we plan to measure other parameters of electron beam such as emittance and bunch length. Also the machining of the 12 cell booster linac is on-progress at KEK machine shop. We will finish manufacturing and install to LUCX within this year, then operate and evaluate the beam parameters.

REFERENCES

[1] K. Sakaue et al.,Rev.Sci.Instrum.80,123304 (2009).

[2] A. Deshpande, Nucl. Instrum. and Meth. A 600 (2009), p. 361.

[3] N. Terunuma et al., Nucl. Instrum. and Meth. A 613 (2010), p. 1.