QUASI TRAVELING WAVE SIDE COUPLE RF GUN FOR SUPERKEKB

Takuya Natsui#, Mitsuhiro Yoshida, Xiangyu Zhou, Yujiro Ogawa,
High Energy Accelerator Research Organization (KEK)
1-1 Oho, Tsukuba, Ibaraki Japan

Abstract

We are developing a new RF gun for SuperKEKB. High charge low emittance electron and positron beams are required for SuperKEKB. We will generate 7.0 GeV electron beam at 5 nC 20 mm-mrad by J-linac. In this linac, a photo cathode S-band RF gun will be used as the electron beam source. For this reason, we are developing an advanced RF gun. We have tested a Disk and Washer (DAW) type RF gun. Additionally, another new RF gun which has two side coupled standing wave field is developed. We call it quasi traveling wave side couple RF gun. This gun has a strong focusing field at the cathode and the acceleration field distribution also has a focusing effect.

INTRODUCTION

The upgrade of KEKB to SuperKEKB is going on. Since high luminosity is required in SuperKEKB, improvement of beam emittance and charge is necessary. Table.1 is upgrade parameter of e- and e+ beam.

Table 1□e- and e+ beam parameter

	KEKB (e+/e-)	SuperKEKB (e+/e-)
charge [nC]	1 / 1	4 / 5
Emittance [mm-mrad]	2100 / 300	6 / 20

We are developing a photo cathode S-band RF gun for high charge (5 nC) low emittance (20 mm-mrad) beam generation. A thermionic cathode DC gun was used in KEKB. However it is difficult to make a low emittance beam with the gun. Thus RF gun must be installed required for an electron beam source. However the standard on-axis coupled 1.5 cell RF gun is not suitable for this high charge beam. Because standard gun is used up to about 1 nC by ordinary. If we obtain 5 nC in the gun, beam size will be too large. We have to consider both beam focus and emittance preservation. Thus it is necessary to make a focusing field against the space charge in the cavities.?But in this on-axis coupling cavity, it is difficult to arrange the field freely on the axis because of on-axis. (Because beam hole is also coupling hole.)□ Thus annular coupling is acceptable.

We are testing Disk and Washer (DAW) type RF gun [1]. DAW cavity is an annular coupling cavity. Using this gun, we evaluated the cathode of two types LaB_6 or Ir_5Ce. As a result, we confirm that Ir_5Ce is suitable for photo cathode in terms of quantum efficiency and lifetime[2].

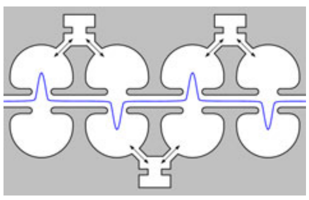
This DAW type RF gun has strong focusing electric field. In 5 nC beam charge, space charge effect is big problem for beam transport in RF gun. The designed cavity has electric field focusing. As a consequence, I have achieved a beam generation of 4.8nC without an external solenoid magnetic field in this gun.

In this study, we confirmed that electric field focus (effect) technique is effective for high charge low emittance beam generation. However, focusing is still not enough in this gun, generated beam still has divergence angle. Since 5 nC is maximum output, this gun has no margin. In addition, beam energy is still low (3 MeV). Thus we have to consider the further emittance preservation in beam transport.

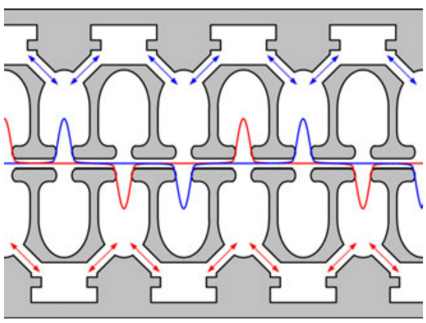
We are developing a new advanced RF gun. It has new acceleration scheme, we call it as a quasi-traveling wave. In this method, higher accelerating field and stronger focusing field are expected. It is very efficient acceleration method. This quasi traveling wave cavity is realized by using a two side couple cavities.

QUASI TRAVELING WAVE SIDE COUPLE

Annular coupled cavities as DAW or side coupled cavities are possible to make narrow acceleration gap. The narrow gap makes the focus field. Our DAW RF gun is using this focus field. Side coupled cavity also can be made the narrow gap. However, these cavities have a long drift space as Fig.1 (a) that shown normal side couple cavities. Due to the long drift space, the DAW RF gun generates beam with a divergence angle.



(a) Normal side coupled cavities



(b) Quasi traveling wave side coupled cavities

Figure 1: Structure of the quasi traveling wave cavity

takuya.natsui@kek.jp

One solution is to use two standing wave cavities. If two side coupled cavities which arranged staggered, we obtain a double standing wave field as Fig.1 (b). These two standing wave side coupled cavities are independent electromagnetically. If we feed RF power with $\pi/2$ phase difference, acceleration field is similar to traveling wave for accelerated beam. Since two side coupled cavities are possible to place on the same axis, a quasi-traveling wave can be realized. Quasi-traveling wave can realize very efficient beam acceleration and focusing.

2D CAVITY DESIGN

The first cavity of RF gun is most important for beam quality. Since beam energy of cathode cell is still low, space charge affects beam size and emittance. First cavity should be designed to have strong focus field. However nonlinear component of the strong focus field causes emittance growth. In addition, we must avoid the electric field concentration at the cavity surface.

In the 2D cathode cell cavity design, a lot of parameters shown Fig.2 were searched. The parameters were optimized through the beam tracing simulation in the cavity design. Thus we need complicated procedure for designing. We automatized this procedure by using downhill simplex method. The emittance, beam size and energy spread were minimized under the conditions that were 100% transmission at 5 nC and surface electric field strength of less than 120 MV/m. SUPREFISH and GPT (General Particle Tracer) calculation code were used for this calculation.

Fig.3 is whole cavities structure design and electric field (SUPERFISH result). This cavity shape is obtained by using automatic downhill simplex method calculation in the condition with the maximum field strength of less than 100 MV/m in the main cavity. This RF gun has total of seven acceleration cavities. These are divided into two standing wave structure of 3 and 4 side coupled cavities respectively. There are no couplings to next cavity on the axis.

Figure 5 shows the beam tracking simulation for 5 nC beam charge result; emittance is 5.5 mm-mrad: beam size is 0.4 mm (standard deviation) at exit of RF gun (z = 250 mm). In the Fig.4, we can find that the beam size becomes gradually smaller in the RF gun. This is caused by not additional magnetic field but the focusing electric field of RF gun. Beam energy will be 11.5 MeV with 20 MW RF input. The energy spread is 0.6 %. These results satisfy the requirement in our application.

In addition, we confirm that this gun can generate 10 nC beam generation by calculation; emittance is 10 mm-mrad; beam size is 1.2 mm; energy spread is 1 %. It is enough margins.

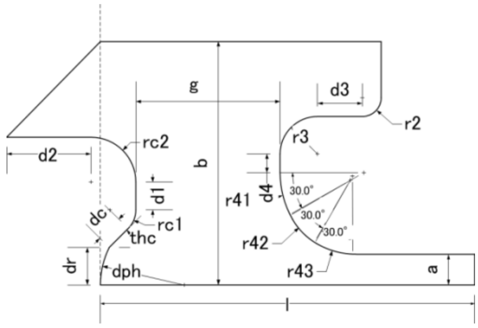


Figure 2: First cavity shape and searched parameters

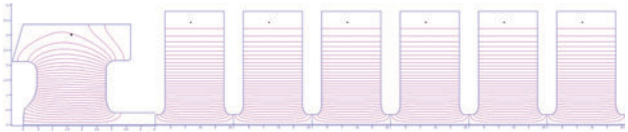


Figure 3: Designed RF gun cavities (SUPERFISH calculation result)

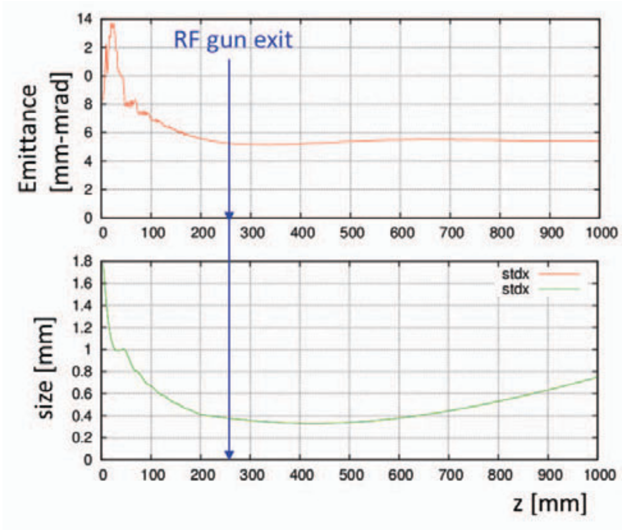
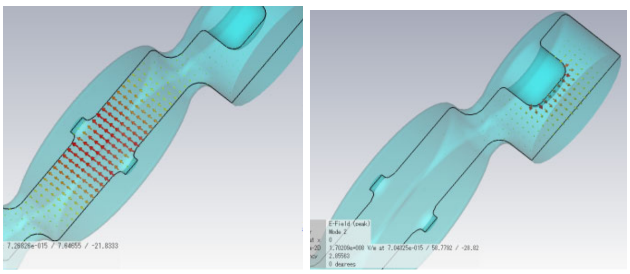


Figure 4: Beam tracking simulation result

3D CAVITY DESIGN

We used CST MICROWAVE STUDIO for 3D cavity design. Figure 5 is the calculation result of the regular cell of a side coupled cavity. The acceleration mode and coupling mode are adjusted to be same frequency. Coupling value k is 3 %. This gun has two standing wave cavities; we designed two types coupler as shown Fig.6.



(a) Accelerating made (b) Coupling mode

Figure 5: regular cell cavity calculation result

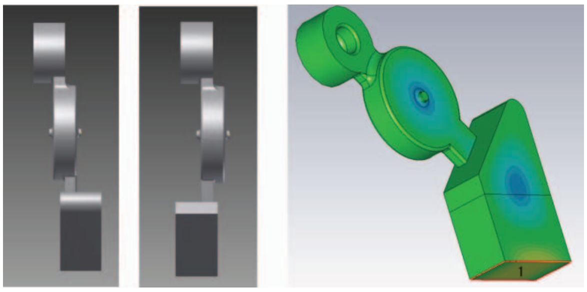


Figure 6: Two type couplers and calculation result

Figure 7 shows the whole cavity shape. The side couple cavities of the two standing wave cavities are mounted as 90 degrees in the azimuthal angle. It has two ports for RF feed. We use 90 degree hybrid for RF feed. We manufactured a compact 90 degrees hybrid. It will be mounted RF gun directly. We already finished mechanical design as shown in Fig.8.

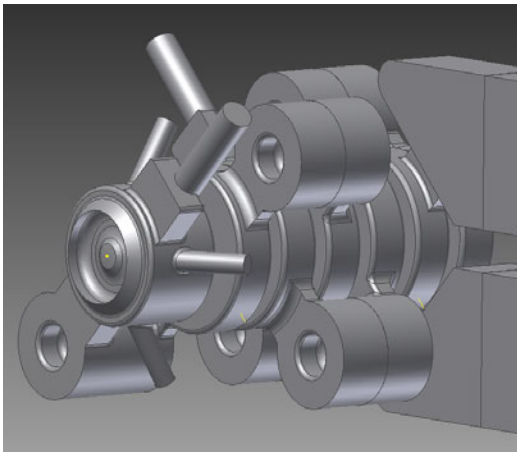


Figure 7: Whole cavity shape

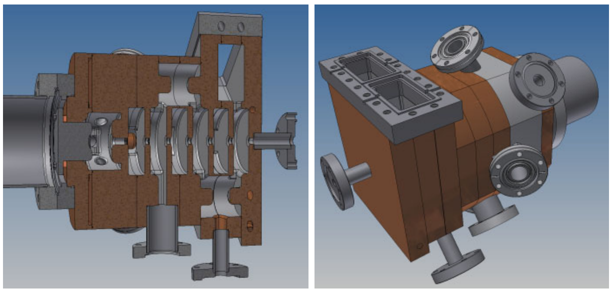


Figure 8: mechanical design

CONCLUSION

High charge and low emittance electron and positron beam are required for SuperKEKB injection. An RF gun will be used for electron beam source. Required electron beam parameter is 5 nC and 20 mm-mrad. Thus we are developing a new photo cathode S-band RF gun for high charge and low emittance beam generation. The annular coupled cavity is suitable for this beam generation. DAW type RF gun and quasi-traveling wave RF gun was developed for SuperKEKB.

A DAW type RF gun was tested. In the study of DAW type RF gun, we achieved 4.8 nC beam generation. We confirmed electronic field focusing technique in the cavity. However DAW type RF gun is still not enough to our SuperKEKB operation.

Thus the new quasi-traveling wave side coupled RF gun has developed. The quasi-traveling wave is a new acceleration scheme. We have to use two standing wave cavities for the quasi-traveling wave. Two side coupled cavities on same axis can realize it. It is suitable for the high charge and low emittance beam generation. Its mechanical design is already finished. Fig.8 is photo of manufactured cavity cell. This RF gun is ready to in ready to brazing.The quasi-traveling wave RF gun will be tested soon.

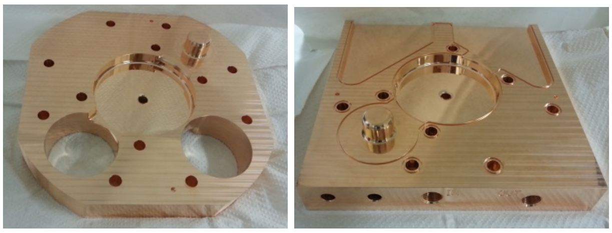


Figure 8: Photo of manufactured cavity cell

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[1] Takuya Natsui et al., TUPPD057, IPAC12, Louisiana, USA, 2012.

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[3] Xiangyu Zhou et al., “Ytterbium Laser Development of DAW RF Gun for SuperKEKB” WEPME018, IPAC13, Shanghai, China, 2013