HIGH CHARGE LOW EMITTANCE RF GUN FOR SUPERKEKB

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Abstract

We are developing a new RF gun for SuperKEKB. We are upgrading KEKB to SuperKEKB now. 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. Now, we are testing a Disk and Washer (DAW) type RF gun. Its photo cathode material is LaB_6 or Ir_5Ce. Normally, LaB_6 or Ir_5Ce are used as a thermionic cathode, but they are suitable for long-life photo cathode operation. This gun has a strong focusing field at the cathode and the acceleration field distribution also has a focusing effect. We obtained 3.0 nC beam charge with the RF gun.

INTRODUCTION

We are currently upgrading whole system of accelerator for SuperKEKB. 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

	Charge [nC]	Emittance [mm-mrad]
e-	1 to 5	300 to 20
e+	1 to 4	2100 to 6

We are developing a RF gun for high charge (5 nC) low emittance (20 mm-mrad) beam generation. This RF gun is not typical 1.6 cell RF gun but Disk and Washer (DAW) type RF gun. This gun has strong focusing RF electric field to cancel space charge effect from 5 nC high beam charge. Fig.1 is a schematic view of KEK accelerator system. The gun will be installed at start point of J-linac. First, we construct a test beam line at middle of J-linac (3-2 section). This beam line is constructed on the angle.

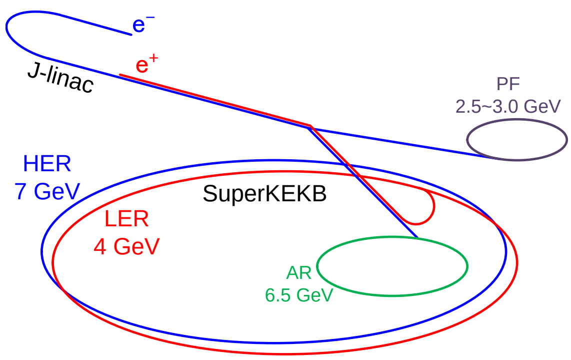

Figure 1: schematic view of KEK accelerator system

DAW TYPE RF GUN

Cavity design

The idea of DAW type accelerating cavity is older method of accelerator. However, DAW type cavity was off from practical use, since it has complicate structure. Fortunately, the machining and calculation technical improvement of these days makes it possible to develop a DAW type accelerating cavity. We adopt DAW type RF gun to achieve high charge low emittance beam generation.

The RF gun has four cavities. These cavities have strong coupling value. It has cathode rod, 3 disks and coaxial coupler as shown Fig.2. The cathode diameter is 6 mm. The accelerating field distribution is generated as shown Fig.3 which is resonant mode calculation by using SUPERFISH. Fig.4 is calculation result of electric field on axis. This field distribution makes Alternative Phase Focus (APF). Beam is focused by this APF effect.

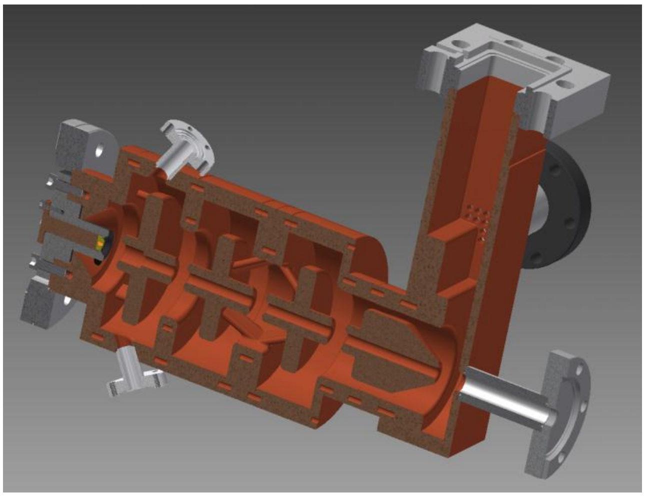

Figure 2: Cut view of DAW type RF gun

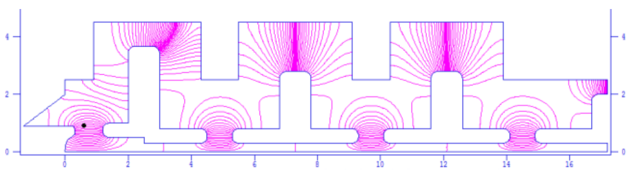

Figure 3: 2D resonant mode calculation (E-field)

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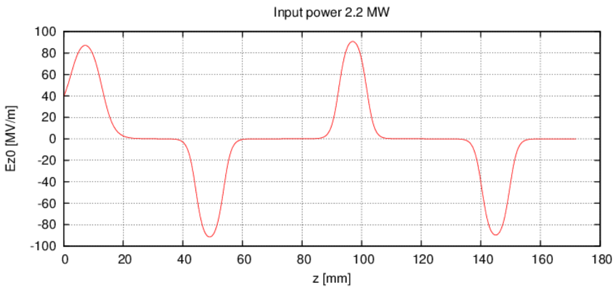

Figure 4: E-field distribution on-axis

Beam tracking simulation

Beam tracking simulation was run with General Particle Tracer (BPT). Emission beam parameter is 30 ps bunch length and 6 mm diameter. The simulation result is shown as Fig.5 and Fig.6. Beam energy is 3.4 MeV. Fig.5 shows that the beam focused at nearby cathode. This gun has very thin beam pipe, however 5 nC high charge beam was transmitted without external magnet. Emittance is 6 mm-mrad in this simulation. Target value of end of linac is 20 mm-mrad. Thus less than 10 mm-mrad of beam emittance is required in the RF gun. This simulation result shown that this gun has sufficient performance.

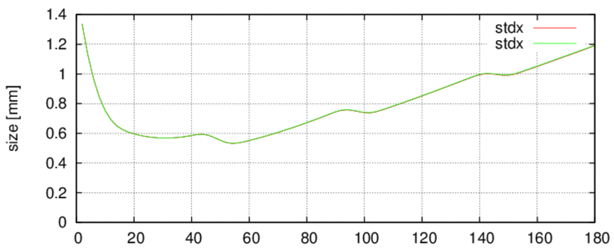

Figure 5: Beam size in the RF gun

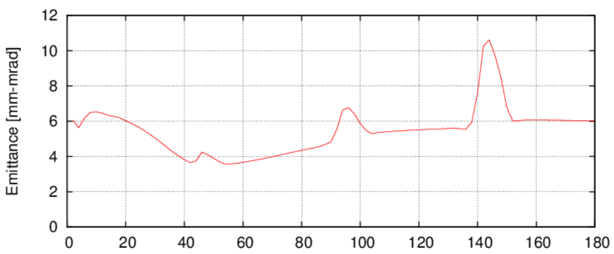

Figure 6: Beam emittance in the RF gun

Photo cathode

We select LaB_6 or Ir_5Ce as photo cathode. Normally, LaB6 is used as thermionic cathode. However work function of LaB_6 is lower than metal. Thus quantum efficiency (QE) is suitable and it can be used as photo cathode with high power laser system. An advance point of LaB_6 is long life time. For SuperKEKB, stable beam generation is necessary. Therefore solid type long lifetime photo cathode is suitable.

Additionally, Ir_5Ce has work function that is lower than LaB6 and longer lifetime. There are few actual performances of Ir_5Ce. We are testing these cathodes.

RF GUN BEAM LINE

The RF gun is installed at middle of linac beam line. Thus we designed an injection beam line on the angle. This beam line has the gun, solenoid, chicane, 1 m traveling wave accelerating structure, doublet and bend magnet as shown fig.7. The output beam from gun is defocusing beam. A solenoid is needed nearby RF gun. Next component is chicane. It can perform bunch compression. Since this is optional, first beam study is without bunch compression. After chicane, beam is accelerated to 10 MeV with 1 m S-band traveling wave accelerating structure. Because 3.4 MeV beam is not suitable to transport. The angle is 26.56 degree (arctan1/2). Next of bend magnet is an existing beam line. This gun will be used as PF injection electron source after high charge beam study.

The RF gun photo is shown as Fig.8. Fig.9 is photo of constructed injection beam line. In this line, there is two waveguides. These waveguides lead to different klystrons.

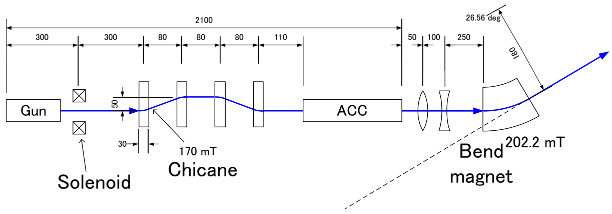

Figure 7: Injection beam line

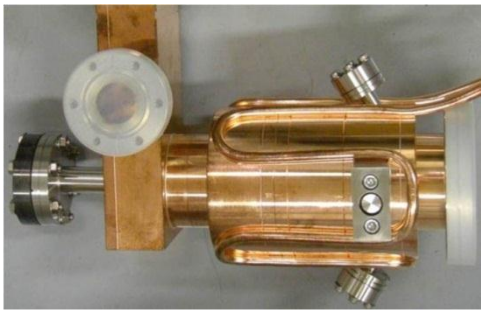
Figure 8: Photo of RF gun


Figure 9: Photo of Injection beam line

BEAM STUDY

We were starting beam study from September 2011. First, we use LaB_6 cathode. We achieve 1.2 nC beam charge with LaB_6. We performed a laser cleaning with 532 nm laser. However, QE of LaB_6 cathode is not enough. It was under 1.0e-5. Laser cleaning was effective. However the QE is reduced immediately. Furthermore we faced breakdown problem. When we input over 0.5 mJ laser pulse, breakdown rate at cathode was too high to continue beam study.

The cathode was replaced to new Ir_5Ce cathode as shown Fig.10. In this cathode, breakdown problem came good.

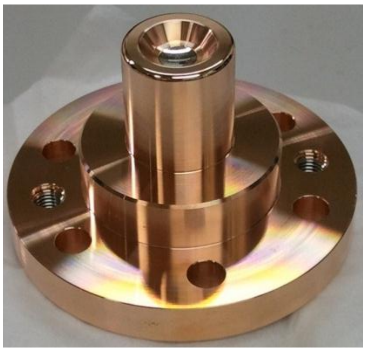

Figure 10: Ir5Ce cathode

We were testing a two way laser injection angle which is 0 degree injection and 60 degree injection. The angled injection was expected to improve QE by schottky effect.

As a result of RF gun beam measurement, 60 degree injection is effective for Q.E. increase. The measured QE of this cathode is 4e-5 without laser cleaning. We achieved 3.0 nC beam generation from the gun. This beam can be transported to end of J-linac. Fig.11 is BPM measurement data of beam transport. Beam energy from RF gun is 3.4 MeV with 4.0 MW RF at 2 pps. 1.5 mJ laser pulse energy is generate at 266 nm wave length. On the other hand, the energy is 0.5 mJ at cathode. There is big power loss at laser transportation. It should be improved.

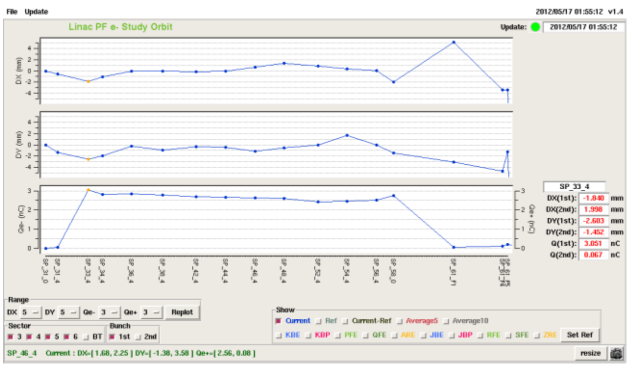

Figure 11: Operation log of 3.0 nC beam generation

CONCLUSION

We are developing a photo cathode RF gun for SuperKEKB. Final goal of electron beam parameters is 5 nC 20 mm-mrad. The RF gun has DAW type cavities. Since 5 nC beam has strong space charge effect, we designed the gun which has a strong focusing RF electric field. As a result of simulation of this gun, 5 nC 6 mm-mrad beam generation was achieved.

We tested LaB_6 and Ir_5Ce as photo cathode. Finally, we choose Ir5Ce cathode. Its QE is 4e-5. Laser system was constructed for photo cathode. Its pulse length is 30 psec and pulse energy is 1.5 mJ at 5pps.

We achieve a 3.0 nC beam generation with RF gun. Beam study is continued. We aim increase a beam charge and measurement of beam emittance.

REFERENCES

[1] Takuya Natsui, Mitsuhiro Yoshida, Xiangyu Zhou, Yujiro Ogawa, "DEVELOPMENT OF HIGH CHARGE LOW EMITTANCE DAW TYPE RF GUN FOR SUPERKEKB" *Proceedings of the 8th Annual Meeting of Particle Accelerator Society of Japan 2010*

[2] Mitsuhiro Yoshida et al., "SuperKEKB Injector Upgrade for High Charge and Low Emittance Electron Beam" TUPPD035, these proceedings.