QUASI-TRAVELING WAVE RF GUN AND BEAM COMMISSIONING FOR SUPERKEKB

Takuya Natsui#, Mitsuhiro Yoshida, Xiangyu Zhou, Yujiro Ogawa, KEK, 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 which has two side coupled standing wave field. 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. This RF gun has been installed KEK J-linac. Beam commissioning with the RF gun is in progress.

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 Parameters

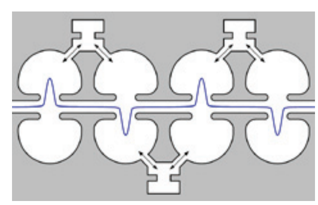
	KEKB (e+/e-)	SuperKEKB (e+/e-)
charge [nC]	1 / 1	4 / 5
Emittance [mm-mrad]	2100 / 300	10 / 20

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 DC gun. Thus RF gun must be installed to realize required electron beam parameter. 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. Since beam hole is also the coupling hole. Thus annular coupling is required.

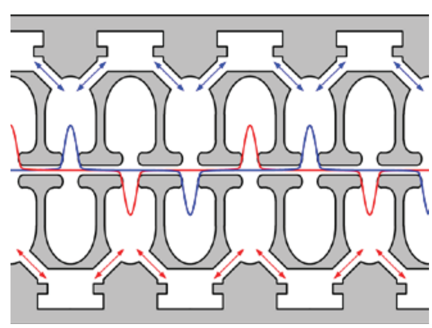
We had tested Disk and Washer (DAW) type RF gun [1]. DAW cavity is an annular coupling cavity. Using this gun, we evaluated the cathode of two types LaB_6 or Ir_5Ce. As a result, we confirm that Ir_5Ce is suitable for photo cathode in terms of quantum efficiency and lifetime. In the DAW type RF gun study,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

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.

One solution is to use two standing wave cavities. If two side coupled cavities are 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 to accelerated beam. Since two side coupled cavities are possible to place on the same axis, a quasi-traveling wave

#takuya.natsui@kek.jp

can be realized. Quasi-traveling wave can realize very efficient beam acceleration and focusing.

COMMISSIONING

The RF gun has been installed at A1 sector in J-linac. J-linac is injector of SuperKEKB [2]. Laser system for electron generation is also constructed near the RF gun. Oscillator is Yb fiber and amplifier is Yb:YAG thin disk [3,4]. Laser has broad band and center wave length is 1035 nm. Laser bunch shaping is necessary to low emittance high charge beam. Therefor broad band Yb laser was chosen. Ir_5Ce is chose for cathode. It is suitable for photo cathode in terms of quantum efficiency and lifetime [5]. Figure 2 is layout of beam line after RF gun.

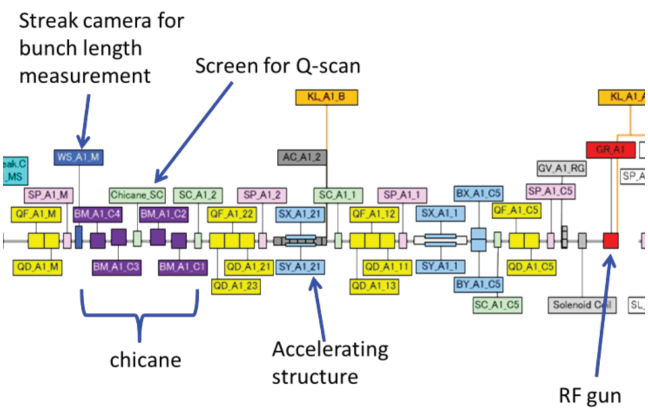


Figure 2: A1 layout.

Laser

The laser hut was constructed near the RF gun. Injected laser is fourth harmonics. First, laser pulse was converted to second harmonics at laser hat. The second harmonics was used for transportation from laser hut to RF gun. Transported second harmonics was converted to fourth harmonics at near the RF gun. BBO crystal was used for conversion. Optics for injection is shown Fig.3. Injection angle is 60 degree.

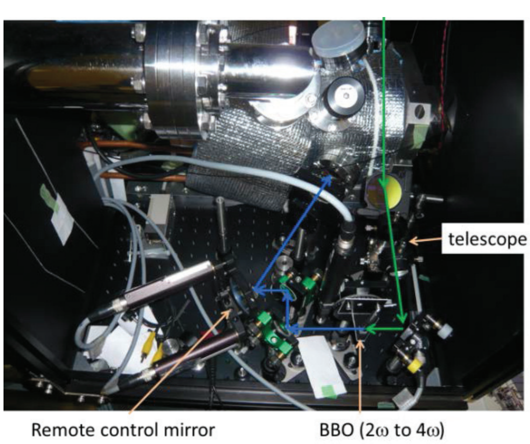


Figure 3: Optics for laser injection.

Laser profile of forth harmonics was measured with CCD camera. Figure 4 shows laser profile of consecutive 10 shot s. Profiles is not gaussian and intensity is unstable. Instability of laser was big problem for beam commissioning.

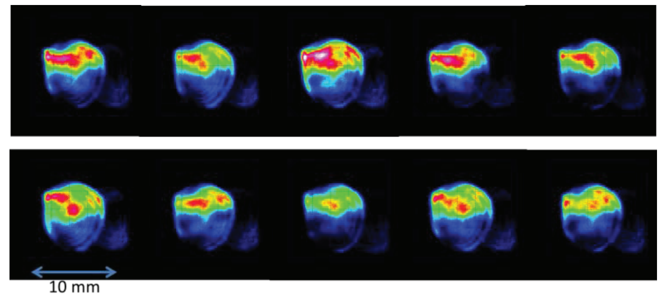


Figure 4: laser profiles of consecutive 10 shot.

Q-scan Emittance Measurement

Emittance is measured by using Q-scan method at the A1 screen. The screen is alumina fluorescent 30 μm thickness screen. Beam energy is 30 MeV and measurement beam size was a few hundreds μm at the screen. Measured normalized emittance was 13.4 +/- 5.9 in horizontal and 8.05 +/- 0.47 in vertical at beam charge of 0.6 nC. High charge beam of 5.0 nC beam measurement is required. However, high charge beam measurement was difficult due to instability of laser.

Bunch Compression on Chicane

To avoid emittance growth in RF gun cavity, first beam bunch length is long. Therefor chicane is used for bunch compression. Accelerating structure in Fig.1 makes energy slope with acceleration. Bunch length can be adjusted by using chicane and the accelerating structure. Bunch length is measured with streak camera at after the chicane. Figure 5 shows result of streak camera measurement. Bunch compression with chicane was confirmed.

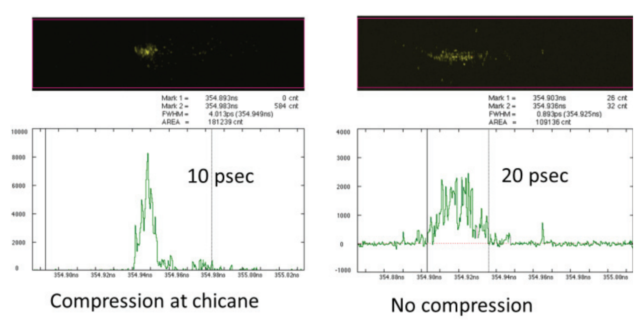


Figure 5: Results of streak camera measurements.

Charge History

From last summer, we had tried to make 25 Hz laser system. However, it was difficult compared to 5 Hz operation due to thermal problem of thin disk amplifier. Additionally, oscillator had become gradually unstable. Therefore beam charge from RF gun was not stable shown as Fig. 6.

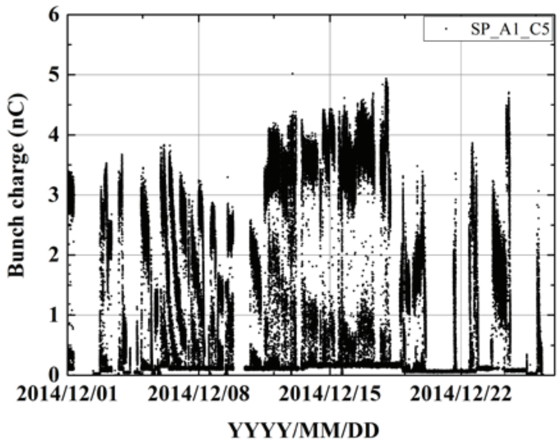


Figure 6: Beam charge of RF gun.

RF Conditioning of RF Gun Cavity

Cavity RF conditioning progress was not so good. Target RF power is 20 MW 1 μsec. On the other hand, achieved RF power is 14 MW 600 nsec. Vacuum reduction due to frequent breakdown disturbs conditioning. Two causes of breakdown were found. Laser abrasion on cathode is one of cause. Sometimes laser spot was focused on cathode by miss operation. Careful laser operation and interlock system is required. Another cause of breakdown is RF contact at cathode rod. RF was cut by metal contact. This design is risky for high power RF operation.

CAVITY INPROVEMENT

After commissioning, the cathode rod taken off was damaged at surface. The Damaged point was metal contact surface. Cathode cell was redesigned. New cavity has choke structure for RF cutoff. RF power is reduced fully at metal contact surface. Figure 7 shows electric field of designed cathode cell. This new RF gun was constructed. RF conditioning of the gun will be started in this summer.

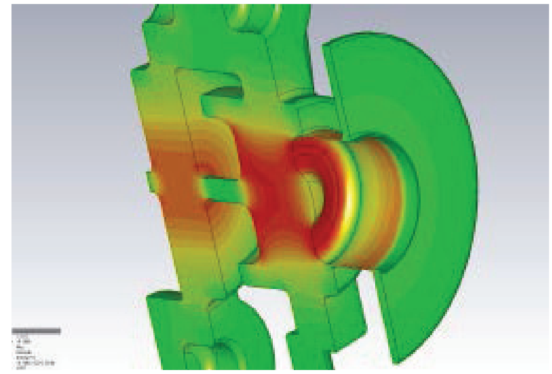


Figure 7: Choke structure of cathode rod.

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. Quasi-traveling wave RF gun was developed for SuperKEKB. The RF gun was already installed A1-sector of KEK injector.

In the SuperKEKB injector linac, beam commissioning by using the RF gun is in progress. However, instability of laser power is one of big problem. The laser system was upgraded to 25 Hz from 5 Hz operation. 25 Hz operation has thermal conductance issue.

RF conditioning progress is one of the problems. Cathode cell had a risk of breakdown. The cavity was redesigned. The new RF gun has choke structure for RF cutoff. This RF gun was already constructed. RF conditioning will be started in this summer.

RF gun commissioning will be carried out with new RF gun and stable laser system.

REFERENCES

[1] Takuya Natsui et al., “High Charge Low Emittance RF Gun for SuperKEKB” TUPPD057, IPAC’12, New Orleans, LA, USA, 2012.

[2] Takuya Natsui et al., “Quasi-traveling Wave Side Couple RF Gun Commissioning for SuperKEKB” MOPRI033, IPAC’14, Dresden, Germany, 2014.

[3] R. Zhang et al., “Improvements of The Laser System for RF-gun at SuperKEKB Injector”, TUPWA071, IPAC’15, Richmond, VA, USA, 2015, these proceedings.

[4] X. Zhou et al., “25Hz Sub-mJ Ytterbium Laser Source of RF Gun for SuperKEKB”, WEPMA044, IPAC’15, Richmond, VA, USA, these proceedings.

[5] Daisuke Satoh et al., “Development of Better Quantum Efficiency and Long Lifetime IrCe Photocathode for High Charge electron RF Gun” MOPFI023, IPAC’13, Shanghai, China, 2013.