SUPERKEKB INJECTOR UPGRADE FOR HIGH CHARGE AND LOW EMITTANCE ELECTRON BEAM*

M. Yoshida, N.Iida, T. Natsui, M.Sato, Y. Ogawa, L. Zang, KEK, Ibaraki, Japan

Abstract

The design strategy of SuperKEKB is based on the. nano-beam scheme. The dynamic aperture decreases due to the very small beta function at the interaction point. Thus the injector upgrade is required to obtain the low emittance and high charge beam corresponding to the short beam life and small injection acceptance. The required beam parameters are 5 nC, 20 mm mrad and 4 nC, 6 mm mrad for the electron and positron respectively. For the electron beam, new photocathode RF-Gun with the focusing electric field was installed. Further the emittance growth in the LINAC is an important issue for the low emittance injection. We will report the machine study of the RF-Gun and the emittance growth through the LINAC.

INTRODUCTION

The required beam parameters are 5 nC of the bunch charge and 20 mm mrad of the normalized projected emittance for the SuperKEKB injection. The RF-Gun is the key component to obtain the low emittance electron beam. Also the beam transportation is another important issue to preserve the projected emittance.

PHOTOCATHODE RF-GUN

The photocathode DAW-type RF-Gun was already tested at the 3-2 unit and the side coupled quasi-travelling wave type RF-Gun will be installed at the A-1 unit in this summer. The RF-Gun cavity, cathode and laser system will be described [1].

Cavity

The photocathode RF-Gun is a good candidate to obtain the low emittance electron beam. However the space charge effect becomes dominant in the high charge RF-Gun. The beam diameter of the 5 nC electron beam becomes too large to transport using the world standard S-band RF-Gun which was almost designed using the coupled cavity. Thus we adopt the annular coupled cavity called as disk and washer (DAW) or the side coupled structure. It can generate the electric focussing field between the cavity nose. The cavity

Cathode

There are many candidates for the cathode material. The easiest choice for the high charge RF-Gun is the alkaline cathode like Cs_2Te to obtain the high quantum efficiency. However the lifetime of the alkaline cathode is not enough long for the long time continuous operation. Further the cathode must be replaced if the cavity will be purged into the air. On the other side the metal cathode has too low quantum efficiency. Thus the metal composition material is a good candidate for the enough life time and quantum efficiency.

Laser

The metal composition material was chosen for the long time operation. Thus the laser energy of around 1 mJ is required to obtain the charge of 5 nC. The chirped pulse amplification is not required for this laser energy. Thus the Nd:YVO4 and Nd:YAG laser system was used for the 3-2 RF-Gun test stand. The maximum laser energy is determined by the saturation power of the gain medium. The Nd:YAG rod diameter of 8 mm is used to obtain the 2 mJ

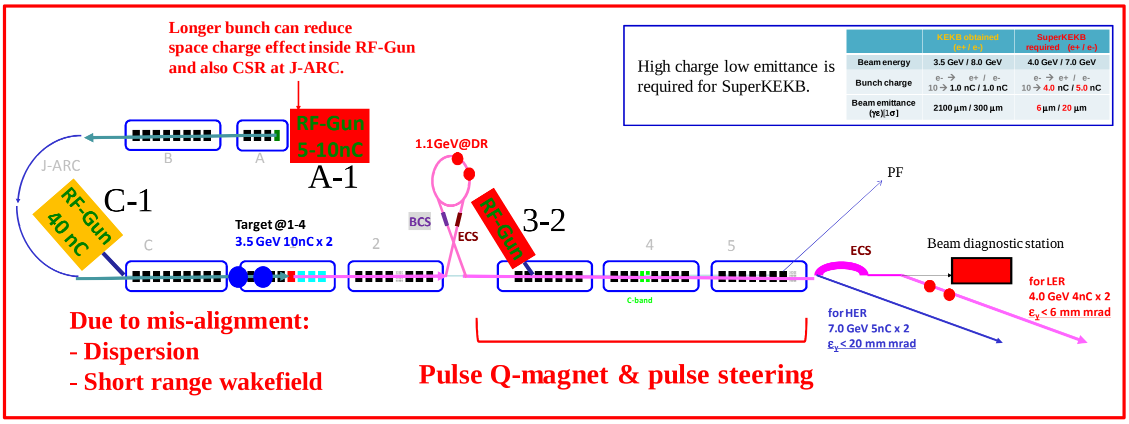

Figure 1: Layout and scheme for the low emittance electron beam of the 7 GeV LINAC.

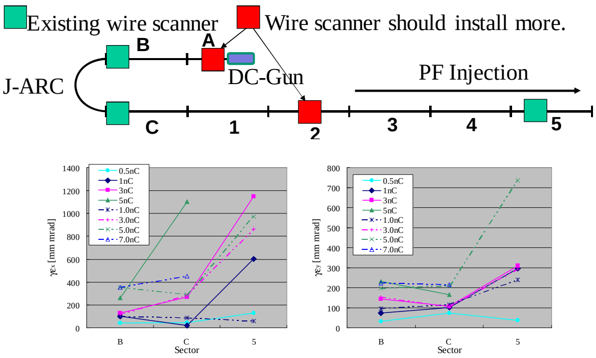

Figure 2: Present projected emittance measurement.

EMITTANCE PRESERVATION

The projected emittance becomes larger mainly due to the mis-alignment of the Q-magnets and the accelerating structures. The alignment tolerance to obtain the required projected emittance of 20 mm mrad is around a few ten micrometer for the Q-magnet and one hundred micrometer for the accelerating structure. However, since the beam position monitor is placed beside of the Q-magnet, the emittance dilution due to the mis-alignment of the Q-magnet can be minimized using the new precise beam position monitor and the beam based alignment.

The alignment tolerance of the accelerating structure must be around one hundred micrometer. This value is not easy to reach because the alignment mechanics of our LINAC have not been designed for such accuracy. Thus the additional projected emittance compensation will be required. The BNS damping, the initial offset and the bunch compression are those candidates.

We try to test all of these compensation schemes using the beam tracking simulation.

In the current result, the required projected emittance cannot be obtained using the BNS damping due to the chromatic effect of the Q-magnets. Thus the initial offset and the bunch compression is the candidate to compensate the projected emittance dilution due to the transverse wakefield.

Initial offset

The initial offset using the steering magnet around the injection region is one candidate to compensate the emittance dilution due to the transverse wakefield. We confirm the effect of the initial offset by both of the experimental beam measurement and the simulation.

The effect of the initial offset was confirmed by the experimental beam measurement using the straight beam line of the A-B sector. Figure 3 shows the projected transverse emittance versus the initial offset of the steering magnet which is called as the SX_A2_1 and is near from the injection region. The large emittance growth was observed at the high charge injection at the original beam orbit. However the initial offset adjustment effected to reduce the projected transverse emittance.

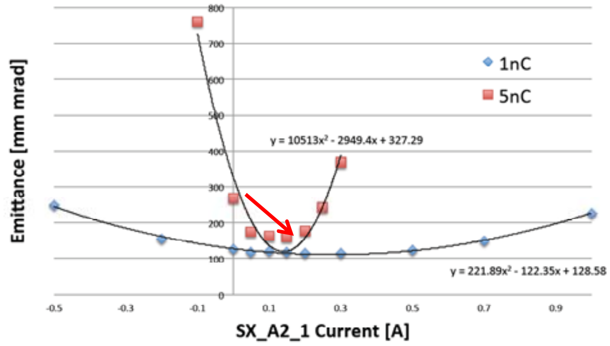

Figure 3: Initial offset scan to compensate transverse wakefiels .

The effectiveness of the initial offset is also confirmed by the beam tracking simulation. Figure 4 shows the projected transverse emittance corresponding the RF phase and the initial offset. The RF phase of 80 degree is chosen to obtain the minimum energy spread. The right figure is the initial offset effect at the RF phase of 80 degree.

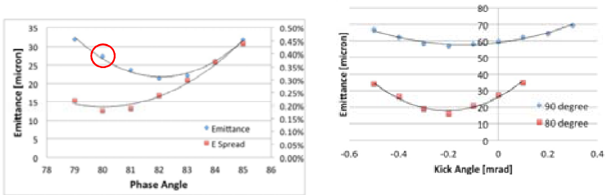

Figure 4: RF phase vs energy spread and projected transverse emittance (left), Initial offset vs projected transverse emittance (right).

Bunch compression

The transverse wakefield strength is strongly affected by .the bunch length. Thus the shorter bunch leads the smaller projected transverse emittance growth due to the transverse wakefield. However the accelerating gradient becomes less at the optimum phase to obtain the minimum energy spread due to the longitudinal wakefield.

Figure 5 shows the minimum energy spread and the optimum phase versus the bunch length in case of the gaussian bunch shape and the square bunch shape respectively. The bunch length of the 4 ps is allowable for the square bunch shape.

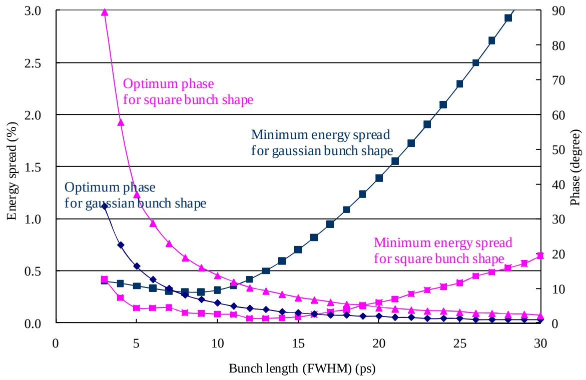

Figure 5: Minimum energy spread and optimum phase.

Figure 6 shows the analytic calculation of the emittance growth due to the transverse wakefield for the bunch length of the 0.75 mm and 2 mm with the alignment error of the 0.1 mm and 0.3 mm respectively. The alignment error of 0.1 mm is required for the bunch length of 2 mm. However the alignment error of 0.3 mm is capable at the compressed bunch length of 0.75 mm.

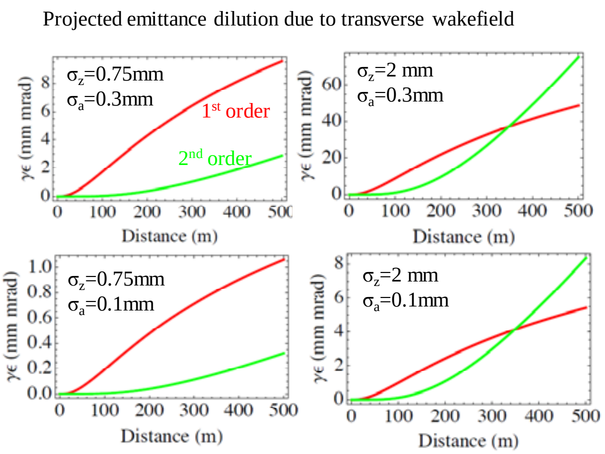

Figure 6: Consideration of bunch compression using J-ARC.

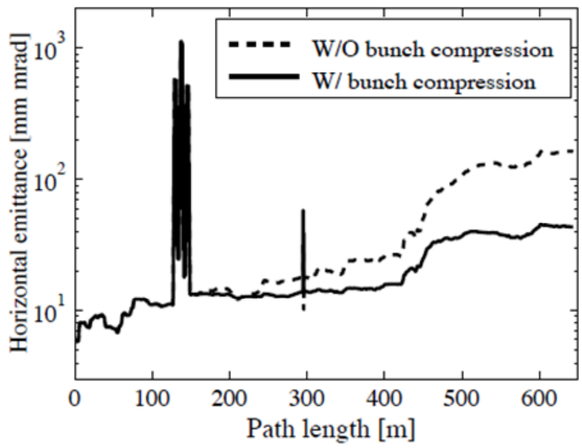

Figure 7: Beam tracking simulation with and without bunch compression in the J-ARC.

The J-ARC section has originally designed for the isochronous optics. However it can be configured as the achromatic arc to compress the bunch length. Figure 7 shows the beam tracking simulation of the transverse emittance growth with the alignment error of 0.3 mm with and without the bunch compression in the J-ARC [2]. The compressed bunch length of 4 ps leads to suppress the emittance growth.

BEAM DIAGNOSTICS

The sliced bunch shape monitor is important to distinguish the origin of the emittance growth. The X-band RF-deflector will be installed to measure the longitudinal sliced transverse emittance in the third switch yard as shown in Figure 8.

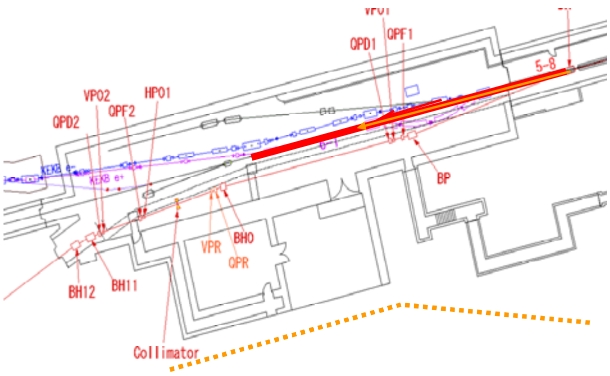

Figure 8: Beam diagnostic station In third switch yard.

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REFERENCES

[1] T. Natsui et al, “High charge low emittance RF Gun for SuperKEKB” , IPAC2012, these proceedings

[2] H. Sugimoto et al, “Design study on KEK injector linac upgrade for high-current and low-emittance beams”, IPAC2012, these proceedings.