COMMISSIONING STATUS AND PLAN OF SUPERKEKB INJECTOR LINAC

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Abstract

The SuperKEKB main ring is currently being constructed for aiming at the peak luminosity of 8 x 10^{35} $cm^{-2}s^{-1}$. The electron/positron injector linac upgrade is also going on for increasing the intensity of bunch charge with keeping the small emittance. The key upgrade issues are the construction of positron damping ring, a new positron capture system, and a low emittance photo-cathode rf electron source. The injector linac beam commissioning started in the October of 2013. In this paper, we report the present status and future plan of SuperKEKB injector commissioning.

INTRODUCTION

The KEKB project has successfully completed its decade operation in the June of 2010. During the KEKB operation, the injector linac provided the different flavors of electron and positron beams to four independent storage rings; KEKB e-, e+, PF, and PF-AR rings. The linac beam is injected into each storage ring in every time interval of 20 ms since the linac parameters of timing and low level rf phase can be arbitrary controlled up to 50 Hz for the simultaneous top-up injection of three rings except PF-AR. For the simultaneous top-up injection, an event based timing control system has been implemented to the injector linac control system in the October of 2008 [1]. The achievement of simultaneous top-up injection made a strong impact on the triumph of KEKB project. It improve the KEKB and PF stored current stabilities up to 0.05% and 0.01%, respectively.

Figure 1 and Table 1 show the layout and the main parameters of SuperKEKB injector linac, respectively. Toward SuperKEKB project [2], the main issue is the high bunch charge transportation with keeping small emittance. For increasing the positron intensity, the flux concentrator and 10 large aperture S-band accelerating structures have been successfully manufactured and installed into the beam line [3, 4]. As a low emittance and high intensity electron source, we have designed and installed a photo-cathode rf gun cavity based on a noble new scheme in the summer of 2013 [5]. For the new rf gun system, a new laser system has been also built for aiming at the temporal modulation to obtain the longitudinal square shape beam which can help to reduce the energy spread [6, 7].

Figure 1: Layout of SuperKEKB injector linac.

Table 1: Main parameters of SuperKEKB injector linac.

	KEKB		SuperKEKB	
	e-	e+	e-	e+
Beam energy (GeV)	8	3.5	7	4
Bunch charge (nC)	1	1 (10^*)	5	4 (10^*)
Normalized vertical emittance (mm·mrad)	100	2100	20	20
Normalized horizontal emittance (mm·mrad)	100	2100	50	100
Energy spread (%)	0.05	0.125	0.08	0.07
Bunch length (mm)	1.3	2.6	1.3	0.7
# of bunch with interval of 96 ns	2			
Maximum beam repetition (Hz)	50			

*: Primary electron beam for positron production.

BEAM COMMISSIONING

Overview

The beam commissioning started in the October of 2013. At the beginning phase of beam commissioning, we mainly devoted the tuning of rf gun laser system for aiming at the high intensity bunch charge generation.

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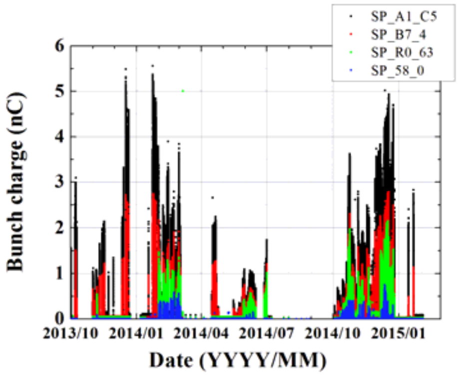
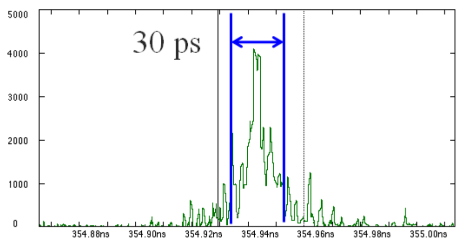


Figure 2: Bunch charge history at the several locations of SuperKEKB injector linac.

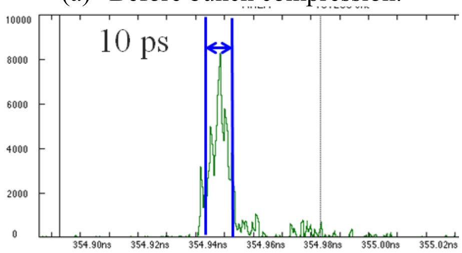
Figure 2 shows the bunch charge history during the whole beam commissioning period. In this figure, SP_A1_C5 means the bunch charge measured by the first beam position monitor (BPM). SP_B7_4 and SP_R0_63 are the bunch charges measured at the entrance and exit of J-ARC, respectively. The bunch charge at the end of linac corresponds to SP_58_0 in the same figure. We have already archived the peak electron bunch charge of 5.6 nC and 0.75 nC at the first BPM location and end of linac, respectively. The bunch charge stability is about 2.5% during KEKB operation, however, the typical one obtained by the current beam commissioning is approximately 10%. It should be improve by stabilizing the pulse-to-pulse fluctuation of laser system. Though the final goal is the bunch charge of 5 nC at the end of linac, the bunch charge of 1 nC is enough for the Phase 1 operation. In the next beam commissioning starting in this June, we will aim to obtain the stable bunch charge of around 1 nC together with the stable beam orbit control.

Bunch compression

The bunch length of electron beam emitted from the rf gun is around 30 ps to mitigate the longitudinal wakefield effect. The chicane has been constructed at the injector section for the bunch compression from 30 ps to 10 ps.



(a) Before bunch compression.



(b) After bunch compression.

Figure 3: Bunch length measured by a streak camera before (a) and after (b) bunch compression at the chicane of injector section.

Figures 3 (a) and (b) show the electron bunch lengths measured by a streak camera before and after bunch compression, respectively. The bunch length of 30 ps before bunch compression is consistent with the laser duration applied to the photocathode of rf gun. Figure 3 (b) shows the measured bunch length with the optimized bunch compression parameters of the magnetic field strength and rf phase in the upstream of chicane. These results show that the bunch compression is successfully carried out by the chicane. Furthermore, the bunch length will be compressed down to around 5 ps at the J-ARC for mitigating the transvers wakefield generated in the sector C to 5 though the isochronous optics was applied at the KEKB operation. We will evaluate the effectiveness of the bunch compression in reducing the emittance growth. Its result will be reported elsewhere in the near future.

Low emittance preservation of electron beam

The final requirement of injection beam charge of electron and positron are 5 nC and 4 nC, respectively. The low emittance preservation of electron beam is a crucial issue because the high intensity electron beam should be transported to the end of linac without a damping ring. Toward the emittance preservation at the end of linac, a lot of simulation works are now going on [8]. For our target emittances, as listed in Table 1, the target values of component alignment are less than 0.3 mm and 0.1 mm in the standard deviations for the whole linac and each sector of 100 m long, respectively. These values have been almost achieved. The result of emittance growth simulation shows that the suitable beam orbit manipulation can satisfy the target emittance of 20 mm·mrad at the end of linac [8], however the high precision BPM is inevitably required. For this purpose, a new BPM readout system based on VME bus has been successfully designed [9]. The mass production of around 100 modules was already completed in this March. They will be installed soon for the fine beam orbit control.

Figure 4 shows the results of emittance preservation study at the end of sector B. The emittance was measured

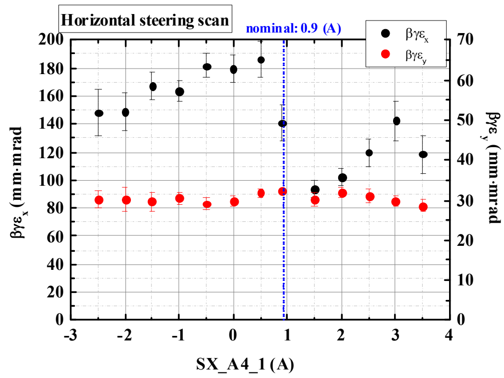


Figure 4: Results of emittance preservation study at the end of sector B. The black and red filled circles are the horizontal and vertical emittances, respectively.

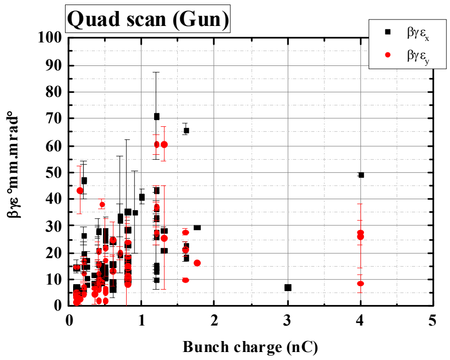


Figure 5: Emittance measurement results at the injector section by using the quadrupole scan method.

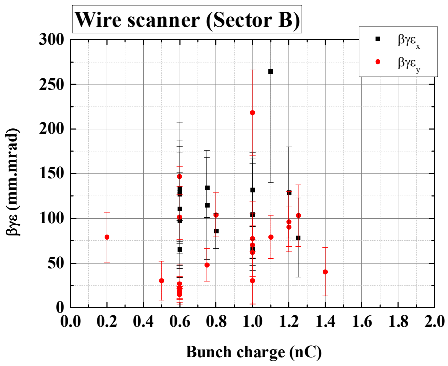


Figure 6: Emittance measurement results at the end of sector B by using the multiple wire scanners.

by the multiple wire scanners. In this figure, the black and red filled circles are the horizontal and vertical emittances as a function of excitation current to the steering magnet, respectively. We obtained also the similar results in the case of changing the vertical steering value. From these results, the emittance preservation with the fine beam orbit manipulation is feasible in the realistic beam operation.

Figures 5 and 6 show the emittances measured at the injector section and the end of sector B as a function of bunch charge, respectively. The former and latter measurements were conducted by the quadrupole scan method and multiple wire scanners, respectively. The emittance measured at the end of sector B is larger than that at the injector section since the measured beam size can be enlarged in the wire scanner measurement due to the beam position jitter. We are going to establish the method of emittance preservation at the end of sector B prior to one at the end of linac.

Positron beam commissioning

The positron beam with the bunch charge of 1 nC is required for the Phase 1 operation starting the beginning of next year. We successfully observed the first positron beam produced by the flux concentrator in the June of 2014. The positron beam of 0.18 nC was produce by the primary electron beam of 0.6 nC tough the operation current of flux concentrator was limited by 6.4 kA due to the shortage of electricity and cooling water. In this autumn, the positron bam commissioning will be conducted by using the flux concentrator full current operation of 12 kA with the upgraded electricity and cooling water system. In addition, the safety assurance of flux concentrator operation is an important because we have already experienced the cable burning and overheated modulator problem.

CONLUSIONS

Toward SuperKEKB operation, the injector linac beam commissioning is now in progress since the October of 2013. We have already measured the required electron bunch charge of 5 nC at the first BPM, positron generation, and bunch compression from 30 ps to 10 ps at the injector section. Currently, the commissioning team is devoting to increase the bunch charge at the end of linac and improve the beam charge and position stability. After these efforts, the low emittance preservation scheme will be studied in detail for aiming at the beam injection to SuperKEKB main ring in the next year.

REFERENCES

[1] Mitsuo Akemoto et al., “The KEKB injector linac”, Prog. Theor. Exp. Phys. (2013) 03A002.

[2] T. Miura et al., “Progress of SuperKEKB”, TUYB1, these proceedings, IPAC’15, Richmond, VA, USA (2015).

[3] S. Matsumoto et al., "LARGE-APERTURE TRAVELLING-WAVE ACCELERATOR STRUCTURE FOR POSITRON CAPTURE OF SuperKEKB INJECTOR LINAC", in Proceedings of IPAC2014, Dresden, Germany, May 15–20, pp.3872-3874 (2014).

[4] T. Kamitani et al., "SuperKEKB POSITRON SOURCE CONSTRUCTION STATUS", in Proceedings of IPAC2014, Dresden, Germany, May 15–20, pp.579-581 (2014).

[5] T. Natsui et al., "Quasi-Traveling Wave RF Gun and Beam Commissioning for SuperKEKB", TUPJE003, these proceedings, IPAC’15, Richmond, VA, USA (2015).

[6] R. Zhang et al., "Improvements of the Laser System for RF-Gun at SuperKEKB Injector", TUPWA071, ibidem.

[7] R. Zhang et al., "25 Hz, Sub-mJ Ytterbium Laser Source of RF Gun for SuperKEKB Linac", WEPMA044, ibidem.

[8] S. Kazama et al., “Emittance Preservation in SuperKEKB Injector”, MOPWA053, ibidem.

[9] R. Ichimiya et al., “DEVELOPMENT OF HIGH PRECISION BEAM POSITION MONITOR READOUT SYSTEM WITH NARROW BANDPASS FILTERS FOR THE KEKB INJECTOR LINAC TOWARDS THE SUPERKEKB”, in Proceedings of IBIC2013, Shanghai, China, September 16-19, pp.698-701 (2013).