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UPGRADE STATUS OF INJECTOR LINAC FOR SuperKEKB

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Abstract

KEK injector linac is being upgraded towards the SuperKEKB which is an asymmetric collider of 7-GeV electron and 4-GeV positron. Full-energy, high-charge and low-emittance beams are necessary in order to achieve a design luminosity of 8×10^{35} $cm^{-2}s^{-1}$ for the study of the flavour physics of elementary particles. New components such as a photocathode RF gun and a positron capture system with a flux concentrator were already integrated. Electron and positron beams are commissioned to confirm the beam properties.

INTRODUCTION

The KEK injector linac is currently being upgraded in order to deliver the high-charge and low-emittance beams to SuperKEKB. The SuperKEKB is an electron-positron collider, and aims 8×10^{35} $cm^{-2}s^{-1}$, which is 40 times larger than KEKB based on the nano-beam scheme. The requirements of the injection beam are 7-GeV electrons of 5 nC and 4-GeV positrons of positrons of 4 nC. Low emittance (less than 20 mm-mrad), and two-bunch injection of pulses with 50 Hz repetition rate as shown in Table 1. A photocathode RF gun has been installed in order to produce low-emittance and high-charge electron beams. Commissioning has begun, and in parallel, the development of high-intensity laser system has been continued. A new positron-capture section with a flux-concentrator (FC), large aperture S-band accelerating structures (LAS) and solenoid focusing coils has been constructed. The construction of the positron damping ring (DR) for achieving low emittance is in progress. The alignment of the components for emittance preservation has been performed within a tolerance of 0.1 mm in sigma locally and 0.3 mm in sigma globally [1,2]. It should also perform simultaneous top-up injections into four storage rings of High Energy Ring (HER), Low Energy Ring (LER) of SuperKEKB, Photon Factory (PF), and Photon Factory Advanced Ring (PF-AR) by pulse-to-pulse beam modulations at 50 Hz. The RF system was also developed to correspond such a pulse modulation. Commissioning of electron and positron beams has begun to confirm the beam properties [3]. This paper describes the recent upgrade status of injector linac.

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Table 1: KEKB / SuperKEKB Linac Parameters

Parameters	Electron	Positron
Beam Energy [GeV]	8.0 / 7.0	3.5 / 4.0
Bunch charge [nC]	1 / 5	1* / 4*
Emittance [mm mrad]	100 / 20	2100 / 10
Energy spread [%]	0.05 / 0.1	0.125 / 0.1
Number of bunch	2 / 2	2 / 2

(*) bunch charge of primary electron =10 nC

PHYSICAL CONFIGURATION OF THE INJECTOR LINAC

The injector linac should deliver beams with variable quantities of charge and energy to four different rings. The beam mode is switched with a 50-Hz repetition rate of the linac. That is termed simultaneous injection. The layout of the injector linac is shown in Fig. 1.

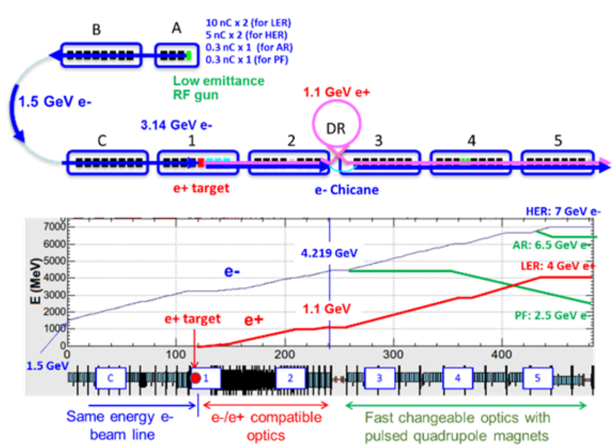

Figure 1: Layout and beam energy patterns of KEK injector linac.

Upstream of the positron target, electrons are accelerated with a common energy for each beam mode. The electron beam from the RF gun reaches an energy of 3.3 GeV at the positron target.

The section of the beam line between the target and the DR is designed to include compatible optics for low-energy positron and high-energy electron. The optics are

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mainly designed for the transport of large-emittance positrons. Hence, the focusing force for high-energy electrons is very weak in this section.

Downstream of the DR, the acceleration energy depends on the beam mode. Therefore, pulsed-quads and pulsed-steering magnets will be installed in order to optimize the optics for different beam energies and to simplify the beam handling.

PHOTOCATHODE RF GUN

A photocathode S-band quasi traveling-wave side-couple RF gun [4, 5] was installed as a low-emittance electron-beam source in September 2013 (see Fig. 3). This RF gun consists of seven acceleration cavities and coupling cavities as shown in Fig. 2. It has two side-coupled standing wave field. Thus, the quasi traveling-wave side-couple RF gun has a strong focusing force and a high accelerating gradient. The material of the photocathode is Ir_5Ce [6], which has a long life time and a quantum efficiency larger than 10^{-4}.

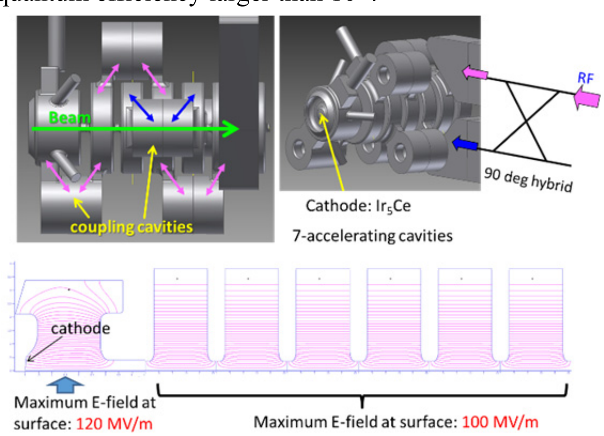

Figure 2: Quasi travelling-wave side-couple RF gun.

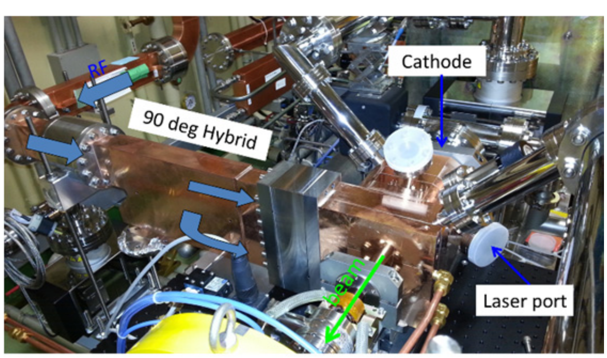

Figure 3: Photo of installed photocathode RF gun.

Beam commissioning with the RF gun is in progress. A maximum beam charge of 5.1 nC has been confirmed with Yb:YAG thin-disk laser system [7] at the low repetition rate of 5 Hz. As a result of a quad-scan for the beam of 1 nC with 2 Hz repetition rate, the normalized horizontal and vertical emittance were obtained 32.7 ± 3.1 and 10.7 ± 1.4 mm mrad, respectively[5]. Currently, commissioning of 25-Hz operation is proceeding.

POSITRON CAPTURE SECTION

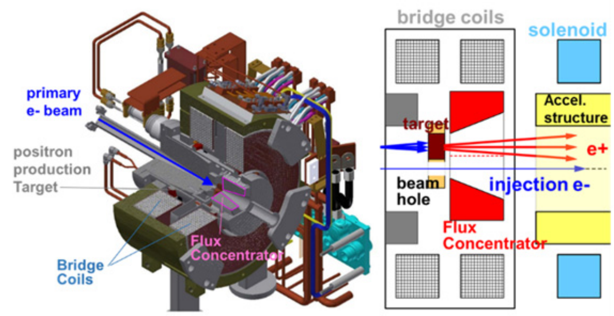

Figure 4: Schematic drawing around the positron target.

For SuperKEKB, four times greater bunch charge compared with the KEKB positron beams is necessary, but the bunch charge of the primary electron beam for positron production is the same in KEKB and SuperKEKB. Therefore, in order to increase positron yield, a new positron-capture system is developed using FC [8], and RF capture system using six LAS [9]. Figure 4 shows the positron target. In the case of electrons, beam passes through a hole (ϕ2mm) in the target located at the center of the beam line in order to preserve low emittance. On the other hand, the positron target made of tungsten (ϕ 4 mm, 14 mm in length) is placed with a horizontal offset of 3.5-mm from the beam line axis. Therefore injection orbits of the electron beam and of the primary electron beam for positron production are switched using two-pulse steering upstream of the target.

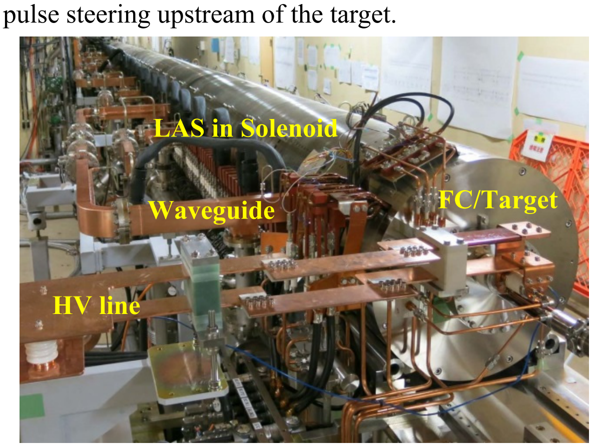

Figure 5: Positron production system.

The positron capture section is one of the most important upgrades of the injector linac. The positrons are collected by a FC of 3.5 T followed by the RF accelerator capture system with a 5kG solenoid magnetic field. The LAS, which have a large physical aperture of 30 mm in comparison with typical 20 mm are employed as the positron-capture RF system. The construction of the

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positron production system was already installed as shown in Fig. 5. In addition, a spoiler [10] was also installed upstream of the target to protect damage to the target caused by the large intensity and focussed beam.

As shown in Fig. 6, many quadrupole magnets were installed in a dense arrangement in order to accept and transport large-emittance positrons downstream of the solenoid section. Since the quadrupole magnets are overlapping with the accelerating structures, DC-type is employed. Both of low-energy positron and high-energy electron beams must be transported in the same magnetic condition.

Figure 6: Densely placed quadrupole magnets for transportation of large emittance positrons. They are overlapping with the accelerating structures.

RF DRIVE UNIT AND MONITOR

The RF system has also been upgraded in order to support RF modulation for four-ring simultaneous top-up injection. The RF monitor in operation during KEKB could not distinguish the beam modes. Therefore, in three-ring simultaneous injection at the time of KEKB operation, we could not monitor the stabilities of the RF outputs of the klystron and SLED which is an RF pulse compressor. A new RF drive unit and RF monitor using IQ digital conversion have been developed. The IQ digital technique makes possible the simple amplitude and phase modulations. Phase-inversion timing of the SLED input RF is important in order to reduce the beam acceleration energy jitter. Thus, the RF system should synchronize with the clock of an "event timing system" of 114.24 MHz, which is synchronized with the RF frequency (2856 MHz). A common design was adopted for the RF driver and monitor. A combination of 14-bit DAC/ADC and IQ modulator/demodulator is employed for the RF drive unit and RF monitor as shown in Fig. 7. The event mode and phase information from "event generator" is received by a SFP and FPGA directly through an optical fiber. The digitized IQ waveform data are sent through a Gb-Ethernet to the EPICS-IOC server at the 50-Hz repetition rate of the injector linac.

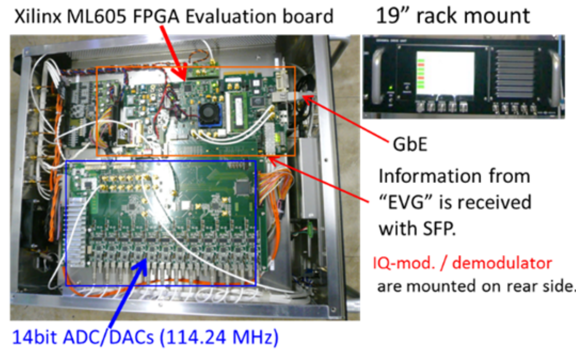

Figure 7: Commonly designed digital RF drive unit and RF monitor.

SUMMARY

The upgrade of injector linac towards SuperKEKB is ongoing. A photocathode RF gun as a high bunch charge and a low-emittance electron-beam source was installed. A positron capture section using FC and LAS with solenoid magnets was installed in order to increase positron-capture efficiency. The RF system has also been developed for four-ring top-up simultaneous injection. Currently, beam commissioning has been started during ongoing construction.

REFERENCES

[1] T. Higo et al., "Linac Alignment for SuperKEKB Injector", TUPRI090, these proceedings.
[2] M. Tanaka et al., "Refinement of Arc-alignment between Two Straight Linacs for Injector of SuperKEKB", TUPRI091, these proceedings.
[3] M. Satoh et al., "Commissioning Status and Plan of SuperKEKB Injector Linac", MOPRO026, these proceedings.
[4] T. Natsui et al., "Quasi traveling Wave Side Couple RF Gun for SuperKEKB", TUOCB103, IPAC 2013.
[5] T. Natsui et al., "Quasi-traveling Wave Side Couple RF Gun Commissioning for SuperKEKB", MOPRI033, these proceedings.
[6] D. Satoh et al., "Development of Iridium Cerium Cathode Material for High Charge and High Current", MOPRI037, these proceedings.
[7] X. Zhou et al., "Ytterbium Fiber and Disk Laser of RF Gun for SuperKEKB", WEPME061, these proceedings.
[8] L. Zang et al., "Positron Yield Optimization by Adjusting the Components Offset and Orientation", MOPRI003, these proceedings.
[9] S. Matsumoto et al., "Large-Aperture Travelling-wave Accelerator Structure for Positron Capture of SuperKEKB Injector LINAC", THPRI047, these proceedings.
[10] L. Zang et al., "Design, Manufacture and Operation of the Beam Spoiler for Positron Target Protection", MOPRI002, these proceedings.