PRESENT STATUS OF THE KEK INJECTOR UPGRADE FOR THE FAST BEAM-MODE SWITCH

M. Satoh# for the IUC* Accelerator Laboratory, High Energy Accelerator Research Organization (KEK), 1-1 Oho, Tsukuba, Ibaraki, 305-0801

Abstract

The KEK Linac provides the four different quality beams for the four independent rings. The KEK Linac upgrade aiming a fast beam-mode switch operation is now in progress so that the KEKB continuous injection and PF top-up injection can be carried out at the same time. In this paper, we will report the present status of the KEK Linac upgrade in detail.

INTRODUCTION

The KEK Linac provides the beams of the different modes sequentially with four storage rings (KEKB 3.5 GeV positron/ 8 GeV electron, Photon Factory (PF) 2.5 GeV electron and Advanced Ring for pulse X-rays (PF-AR) 3 GeV electron).

For a typical operation, the PF and PF-AR need the beam injection twice a day on scheduled time. On the other hand, the KEKB rings are operated by the continuous injection mode (CIM) for keeping the stored current almost constant. In the CIM operation, the switch time between the electron and positron modes takes about a half minute so that all settings of magnet power supplies, RF phases and timings should be changed according to the electron and positron beam properties. In the near future, the PF top-up operation will be started to enhance the integrated photon flux. For these reasons, the linac upgrade is strongly required for a fast beam-mode switch [1, 2, 3 and 4].

Figure 1 shows the schematic drawing of ultimate fast beam-mode switch operation. In this operation scheme, we will change only the minimum parameters of the timing signals and Low-Level RF (LLRF) phases, and all the rest of parameters like DC magnet settings are never changed even for the different beam-mode. In the final stage of the linac upgrade, the beam mode can be changed in every 50 Hz of an arbitrary beam-mode pattern.

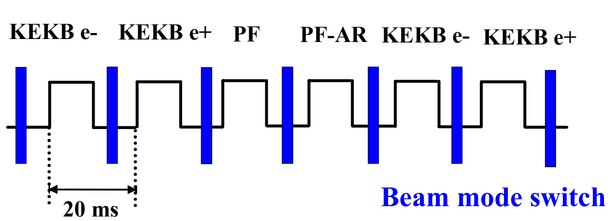

Figure 1: Schematic drawing of fast beam mode.

masanori.satoh@kek.jp

* Injector Upgrade Committee: Cross-functional team for the injector upgrade from PF/ KEKB and Linac members

UPGRADE PLAN

Outline

This project is a phased upgrade, and the phase-I has been already completed in the summer of FY2005. The detailed upgrade phases are shown in following sub-sections.

Phase-I

In the phase-I, the new PF-BT line has been constructed for shortening the beam-mode switch time between the KEKB and PF modes. Here, the initialization procedures of the energy compensation system (ECS) bends are required since the original DC switch bend was placed downstream of the ECS bends. In order to bypass the ECS, a new DC switch bend has been installed by removing four accelerating structures, and a new PF-BT line of 60-m-long has been constructed [5].

After the phase-I, the beam-mode switch between the KEKB and PF modes does not need to change the ECS parameters. The round trip mode switch time including PF injection was reduced by half from 5.5 min. to 2.5 min. In addition, the beam injection efficiency has been increased.

Phase-II

The phase-II aims to perform the fast beam-mode switch between the KEKB electron and PF modes up to 50 Hz. For the phase-II and later, we will use the new operation scheme called “Multi-Energy Linac” [6 and 7]. In this scheme, the common magnet settings are used for the different beam modes. The adjustment of the beam energy is performed by a fast control of LLRF phase. Though PF ring injection requires the 2.5 GeV electron, the beam is accelerated up to about 5 GeV in the multi-energy scheme. After then, the beam energy is adjusted to 2.5 GeV by using the deceleration RF phases. This method is effective for enlarging the common optics region. The result of a preliminary machine study shows that this scheme is feasible for a realistic beam operation. In this autumn, the more detailed machine study will be carried out to develop the daily operation parameters.

Phase-III

In the phase-III, the fast beam-mode switch will include the KEKB positron mode. In the current operation, the positron production target is controlled by a mechanical movement. For the fast beam-mode switch between the electron and positron modes, the positron target with a hole will be used. In this scheme, the fast beam-mode switch will be performed by a fast control of the electron beam orbit at upstream of the positron target.

The tungsten crystalline target with a hole has been installed as shown in Fig. 2. A centre of a hole is placed 4.5 mm apart from that of a crystalline tungsten target. The diameter of a hole is about 5 mm. The electron beam goes through the inside of a hole for the electron mode, whereas the electron beam hits the centre of target for the positron mode.

In the machine study, it was measured that almost 100% of the electron beam can traverse the inside a target hole in comparison with a normal operation (target removed). We convinced that this scheme is applicable to the practical beam operation. For a fast control of the beam orbit upstream target, the pulsed steering magnets have been installed in the winter of FY2007.

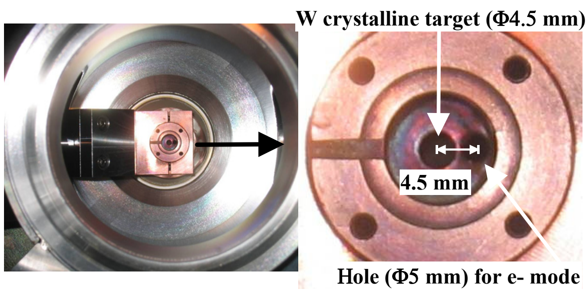

Figure 2: Photograph of tungsten crystalline positron production target with a hole.

PF-AR Injection

The full energy injection of PF-AR is very difficult since the current beam energy at AR-BT is limited up to 3.1 GeV. One solution is to use the 3.5 GeV positron beam of KEKB positron mode for the PF-AR injection, though this scheme involves the installation of a pulsed bend and the improvement of two power supplies at the AR-BT line. In addition, all quadrupole magnets and vacuum chambers should be remodelled for increasing magnetic field. The detailed design study is now in progress, and its result will be reported elsewhere.

PULSED BEND SYSTEM

For the fast beam-mode switch, the PF beam should be selectively kicked out toward the PF-BT by using the pulsed bend. The DC switch bend installed in the phase-I was replaced by the new pulsed bend system in the last winter maintenance. Table 1 shows the main parameters of the pulsed bend system. The photograph of pulsed bend is shown in Fig. 3.

Though the 2.5 GeV electron are used for the PF injection, the pulsed bend was designed for the beam operation up to 3 GeV. The maximum beam repetition is 25 Hz, and its output current has the half-sinusoidal shape of 200 µs. The both at long and short term stability of power supply output current was satisfied less than 0.1%.

The 1200-mm-long ceramic chamber has been also installed, and its cross-section is a race track-shaped. To avoid the heating, the inner wall of ceramic chamber was coated with 1-µm-thick Ti.

In the first week of February 2007, the PF top-up test operation has been successfully performed during single-bunch user operation. Figurer 4 shows the stored current stability of the PF ring. In this machine study, we can achieve the stability of 10^{-3} by using a newly installed slit at the PF-BT. The pulsed bend has worked well during the one week continuous operation without any problem.

Table 1: Main Parameters of Pulsed Bend System

Pulsed bend:		
	Beam bending angle:	7 deg. (up to 3 GeV)
	Max. magnetic field:	1.36 T
	Gap:	157 x 30 mm (W x H)
	Coil:	1 tuen
Power supply:		
	Max. current:	32 kA (12.5 Hz)
		27 kA (25 Hz)
	Pulse width:	200 µs (half-sinusoidal)
	Stability:	0.1%
Ceramic chamber:		
	Length:	1200 mm
	Coating:	Ti (1 µm)

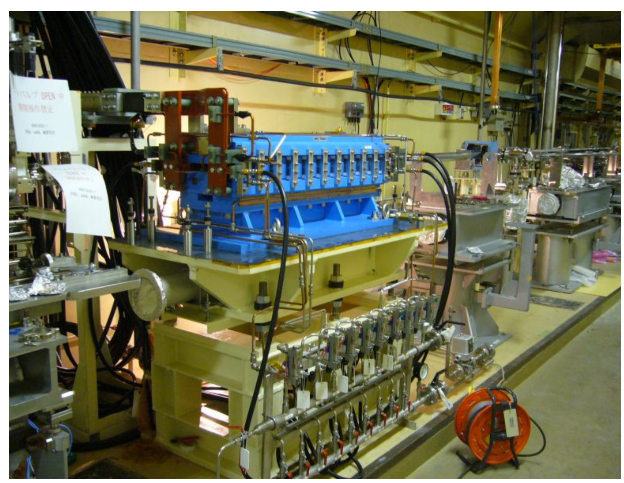

Figure 3: Photograph of pulsed bend.

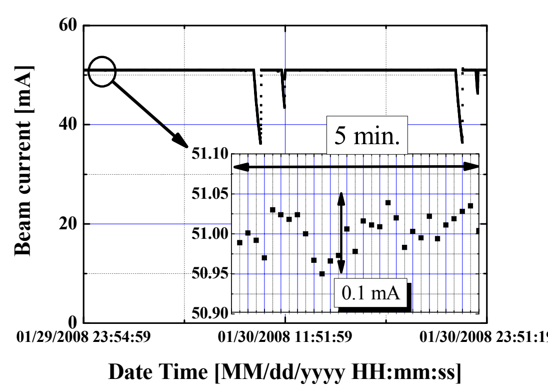

Figure 4: Stability of stored beam current at PF ring for single-bunch Top-up injection study.

OTHER NEW SUBSYSTEMS

Beam-Charge Interlock System

Toward the fast beam-mode switch operation, a new PLC-based beam-charge interlock system was developed for radiation safety [8]. This system restricts a regulated amount of integrated beam charges traversing through at several locations for machine protection, and it also monitors the amount of integrated beam charges delivered to the four different storage rings at the linac beam switchyard.

The beam charges delivered from an electron gun are measured with the beam-charge interlock system. This system consists of the wall-current monitors, beam-charge integration circuits, and a PLC-based control system. This system sends the beam abort signals directly to another radiation safety system with hard-wire cables when the amount of the integrated beam charges is beyond the prescribed threshold level. This system has been already used for a daily operation.

Timing System

In the present timing system, about 150 timing delay modules based on VME-bus and CAMAC (TD4V/ TD4) are used for controlling the timing signals distributed to the many different types of local controllers. The timing system upgrade is indispensable since it is very difficult for the current system to realize a fast timing control.

The event generator and receiver (EVG/EVR) system based on VME64x-bus was adopted as a new timing system [9, 10, 11 and 12]. In the new system, one EVG and eleven EVRs are connected via optical fibre. The event information (beam-mode), RF clock (114 MHz), timestamp and data buffer can be quickly transferred from EVG to EVR. In addition, the number of used module for the timing system can be drastically reduced by using the EVG/EVR system. This can gratefully increase the reliability of timing system and beam operation. The operation software based on EPICS system has been already developed. One EVR and nine EVRs are already utilized for the beam operation. In the near future, the overall system test will be carried out for the practical operation after the two rest EVRs will be installed.

SUMMARY AND FUTURE PLAN

The KEK injector upgrade aiming the fast beam-mode switch is in progress so that the KEKB CIM and PF top-up injection can be simultaneously performed. For this upgrade, the pulsed steering and bend system have been already installed. The almost part of new timing system works for a beam commissioning. In addition, many software development and update are going on. This upgrade will be very effective to increase the beam operation efficiency of KEK Linac. Eventually, the operational availability of each ring will be also greatly enhanced.

REFERENCES

[1] M. Sato, et al., “KEK injector linac upgrade for fast beam-mode switch (II)”, Journal of Particle Accelerator Society of Japan, Vol.5, No.2 (2008).

[2] M. Sato, et al., “KEK injector linac upgrade for fast beam-mode switch”, Journal of Particle Accelerator Society of Japan, Vol.3, No.2 (2006).

[3] M. Satoh, et al., “THE KEK INJECTOR UPGRADE FOR THE FAST BEAM-MODE SWITCH”, in Proceedings of EPAC2006, Edinburgh, UK, 26-60 June 2006, pp.855-857 (2006).

[4] M. Satoh, et al., “The KEK Linac Upgrade for the Fast Beam Mode Switch”, Proc. of EPAC 2006, Edinburgh, 26-30 June 2006, pp.855-857 (2006).

[5] N. Iida, et al., “NEW BEAM TRANSPORT LINE FROM LINAC TO PHOTON FACTORY IN KEK”, Proc. of EPAC 2006, Edinburgh, 26-30 June 2006, pp.1505-1507 (2006).

[6] Y. Ohnishi, et al., “Design and Performance of Optics for Multi-Energy Injector Linac”, Proc. of LINAC2006, Knoxville, 21-25 August 2006, pp.46-48 (2006).

[7] Y. Ohnishi, "Design and Performance of Optics for Multi-energy Injector Linac", these proceedings.

[8] T. Suwada, E. Kadokura, M. Satoh, and K. Furukawa, "New beam-charge interlock system for radiation safety at the KEKB injector linac", Review of Scientific Instruments, Vol.79, 023302 (2008).

[9] K. Furukawa, T. Suwada, M. Satoh, E. Kadokura, A. Kazakov, “TIMING SYSTEM UPGRADE FOR TOP-UP INJECTION AT KEK LINAC”, Proc. of EPAC 2006, Edinburgh, 26-30 June 2006, pp.3071-3073 (2006).

[10] K. Furukawa, et al., “Development of Timing and Control Systems for Fast Beam Switch at KEK 8 GeV Linac”, these proceedings.

[11] S. Kusano, et al., “DEVELOPMENT OF SOFTWARE FOR EVENT SYSTEM IN KEK LINAC”, Proc. of The 5th Annual Meeting of Particle Accelerator Society of Japan and the 33rd Linear Accelerator Meeting in Japan, Higashihiroshima, 6-8 August 2008.

[12] T. Kudou, et al., “Parameter management in KEK Linac”, ibid.