SIMULTANEOUS TOP-UP INJECTION FOR THREE DIFFERENT RINGS IN KEK INJECTOR LINAC

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Abstract

The KEK injector linac provides the beams of different quality sequentially with four storage rings: Low Energy Ring (LER) of KEKB, High Energy Ring (HER) of KEKB, Photon Factory (PF) and Advanced Ring for Pulse X-rays (PF-AR). For the simultaneous top-up injection to KEKB LER, HER and PF, the linac upgrade has been successfully completed in March of 2009. In this upgrade, a new beam transport line of PF is constructed. A pulsed bend and twelve pulsed steering magnets are installed for fast beam orbit control. A positron generation target with a hole is adopted for the fast switching between the electron and positron beams.

Toward the simultaneous top-up operation, an operation strategy based on the multi-energy linac scheme is adopted so that the common DC magnet settings are used to accelerate the beams with different energies. In addition, an event-based fast control system is installed for the fast beam energy switching. We report the details of simultaneous top-up injection for three different rings in KEK.

INTRODUCTION

The KEK injector linac has been originally constructed as PF injector, whereas it works recently as a injector for four independent storage rings. Table 1 lists the main parameters of KEK injector linac before linac upgrade. The beam with different property is required for the beam injection of each storage ring. In order to deliver the beams with different energy and charge to desired ring as small beam loss as possible, the linac parameter (beam mode) should be changed to the optimized one for each beam property. The beam mode switching includes many settings of magnets, timing, rf phase, data acquisition and other subsystems.

The beam injections for PF and PF-AR were typically twice a day except there machine study days. On the other hand, the injection for the KEKB rings was carried out in every 90 minutes interval as shown in Fig. 1-(a). After Feb. 2005, we started the continuous injection mode (CIM) operation for KEKB for keeping the stored current almost constant as shown in Fig. 1-(b). In this operation mode, the parameters for KEKB LER and HER injection were frequently changed in several minutes interval, and each beam-mode switching required typically half a minute.

After a success of the CIM operation, more high stability of stored current was still strongly required for enhancing the luminosity tuning efficiency and avoiding the beam abort caused by the unbalanced between LER and HER stored currents [1]. In addition, the PF top-up operation was also strongly required from experimental user community [2]. For these reasons, the linac upgrade has been started to realize the simultaneous top-up among different three ring.

LINAC UPGRADE

Overview

For the KEK injector linac upgrade aiming simultaneous top-up injection for different energy beams, we adopt the multi-energy linac scheme. In this beam operation scheme, we use the common settings of DC magnets for accelerating and transporting the different energy beams along the 600-m-long injector linac [3], whereas the klystron phases are switched quickly in every 20 ms for the fine energy adjustment.

Figure 2 shows the schematic drawing of the beam-mode switching. In this figure, the CIM and simultaneous top-up operations are shown by (a) and (b), respectively. In the scheme (a), the beam injection for LER (HER) lasts usually about a few minutes. After the linac beam

Table 1: Main parameters of KEK injector linac for a typical daily operation before upgrade

Beam mode	KEKB HER	KEKB LER	PF	PF-AR
Beam energy	8 GeV e-	3.5 GeV e+	2.5 GeV e-	3 GeV (*) e-
Number of bunch	2	2	1	3 - 4
Bunch charge	1 nC	1 nC (primary e-: 10 nC)	0.1 nC	0.2 nC
Maximum beam repetition	50 Hz	50 Hz	25 Hz	25 Hz
Injection per day	> 250	> 500	2	2
Electron gun	A1	A1	A1	CT

(*) Main ring of PF-AR accelerates the beam up to 6.5 GeV. A1 and CT gun are placed most upstream and 200-m location of injector linac.

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mode switched into HER (LER), the beam injection for HER (LER) continues about a few minutes. In this operation mode, the total consumed time for the beam-mode switching is more than two hours daily since the parameter switching more than several hundred is required daily. For the simultaneous top-up operation, the linac beam mode should be changed in every 20 ms of maximum beam repetition as shown in Fig. 2-(b). In order to achieve such beam operation scheme, the linac upgrade project was started in 2004.

New PF-BT construction and pulsed switch bend

For upgrade, we constructed a new beam transport line for PF (PF-BT) in 2005 [4]. The original switch bending magnet was placed downstream of the ECS bend magnets. In order to bypass the ECS magnets, a new DC bend has been installed. The many spare components were reused to save the const. After the construction of new PF-BT, the beam-mode switching between KEKB HER and PF does not need to change the ECS parameters for standardization, and the round trip mode switching time including PF injection is decreased to 2.5 min. from 5.5 min. in a typical case. Towards the simultaneous top-up, a DC switch bend was replaced by the pulsed bending magnet [5, 6].

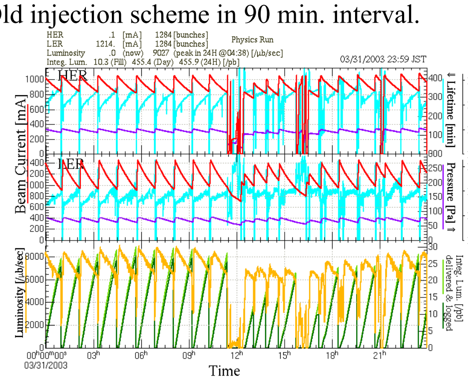
Beam operation parameter for simultaneous top-up

For the fast beam-mode switching, we use the common setting of DC magnets even for different beam mode. The developed operation parameter is not optimized one for each beam mode, but the moderated one for three beam modes (LER, HER and PF). Though the PF injection requires the electron beam with 2.5 GeV, the beam is accelerated up to around 5 GeV in the multi-energy linac scheme. After then, the beam energy is adjusted to 2.5 GeV by using the deceleration phases. This method is effective for enlarging the common optics region.

Event-based fast timing system

Towards the simultaneous top-up, it is also indispensable to upgrade the timing system. In the old timing system, approximately 150 time delay modules based on a VME bus (TD4V) and CAMAC (TD4) were used for controlling the timing signals distributed to different types of local controllers at different locations. An event generator and receiver (EVG/EVR) system based on a VME64x bus is adopted as a new timing system [7]. One EVG and 17 EVRs have been installed as shown in Fig. 3. Using this system, event information (beam mode), rf clock (114 MHz), timestamp values, and data buffers can be rapidly transferred from the EVG to the EVR via optical fibers. Some of the VME crates include DAC/ADC boards for controlling and monitoring the low-level rf (LLRF) phase fed to sub-booster klystron. We have developed an operation software based on the EPICS system.

(a) Old injection scheme in 90 min. interval.



(b) Continuous injection mode (Feb. 2005-).

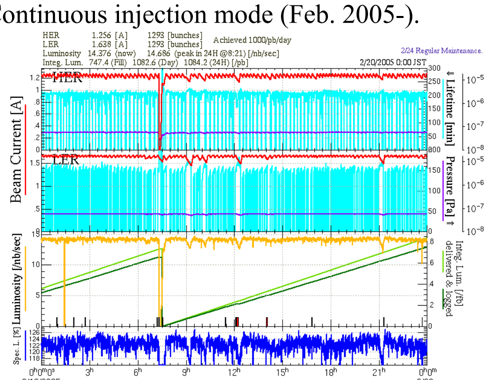
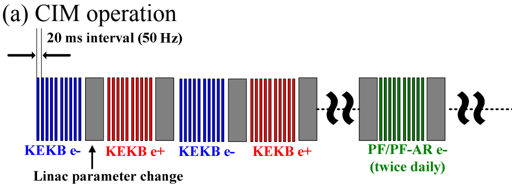


Figure 1: Typical KEKB operation in one day. Each graph shows the stored current of HER (top), LER (middle) and luminosity (bottom), respectively.

(a) CIM operation



(b) Simultaneous top-up operation

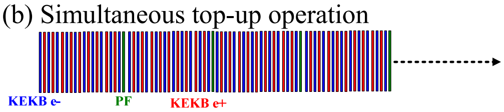


Figure 2: Schematic drawing of the beam-mode switch scheme (a) in the CIM and (b) simultaneous top-up operation, respectively.

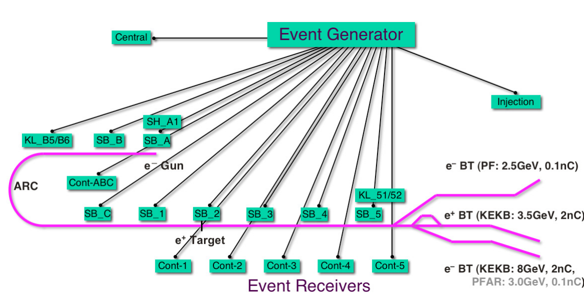


Figure 3: Installed location of the fast event-based timing systems. Cont, KL, SB and SH mean local control room, klystron, sub-booster klystron and sub-harmonic buncher, respectively.

Fast beam-mode switching between e-/e+ beams

In the old operation scheme, the positron target is controlled by a mechanical movement. For a fast beam-mode switching, the positron target with a hole is adopted [8]. A centre of a hole is placed 4.5 mm apart from that of an crystalline tungsten target as shown in Fig. 4. The diameter of a hole is about 3 mm. The electron beam passes the inside a hole for the electron mode, whereas the primary electron beam hits the target for the positron production mode. Eight pulsed steering magnets are utilized for a fast bump orbit control.

Using this scheme, the electron beam more than 95% can traverse the inside a target hole and can be successfully delivered along the linac in comparison with the old operation scheme in which the target is removed from the center of beam line.

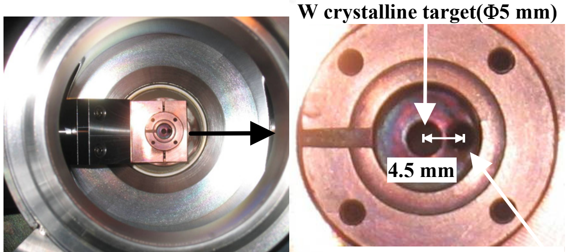
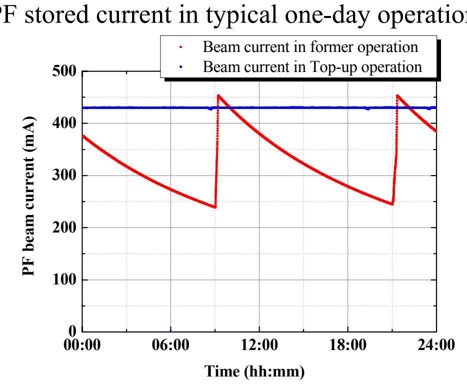


Figure 4: Photograph of positron target with a hole.

(a) PF stored current in typical one-day operation.



(b) KEKB stored current in typical one-day operation.

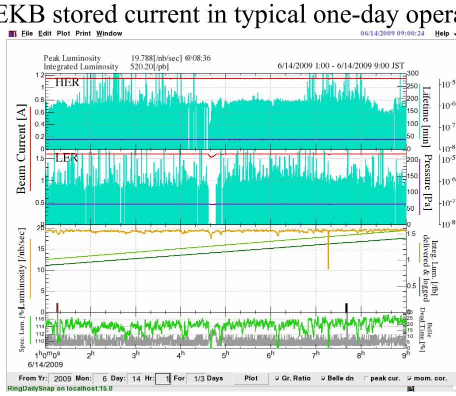


Figure 5: Typical one-day stored current variation of PF and KEKB rings during the simultaneous top-up operation.

Results

In Apr. 2009, the simultaneous top-up operation for KEKB and PF rings was started for a daily operation. Figure 5 shows the typical one-day variation of stored current in PF and KEKB rings during the simultaneous top-up operation. In Fig. 5-(a), the stored current stability (blue) of PF is drastically improved in comparison with that of previous injection scheme (red). The variation of PF stored current can be achieved less than 0.01% (0.05 mA). In addition, the stored current stability of KEKB can be successfully achieved about 0.05% (1 mA) as shown in Fig. 5-(b).

SUMMARY AND FUTURE PLAN

The KEK injector upgrade aiming the simultaneous top-up injection for three different rings is successfully completed. It is based on the multi-energy scheme for accelerating the beams with different energy and charge. In this scheme, we use a common DC magnet parameters and a fast control of LLRF phase. For the fast beam-mode switching between the electron and positron beams, the usage of a positron target with a hole is adopted. Towards next generation B-factory upgrade, we are planning for the fast beam-mode switching including the PF-AR injection. Its detailed design will be presented elsewhere in the future.

REFERENCES

[1] N. Iida, "Simultaneous Injections of Various Energy Particles into Two Rings in KEK Injector LINAC", in Proceedings of PAC09, Vancouver, Canada, 2009.

[2] T. M. Mitsuhashi et al., "Top-Up Operation of the Photon Factory", ibid.

[3] Y. Ohnishi et al., "Design and performance of optics for multi-energy injector linac", in Proceeding of LINAC 2006, Knoxville, Tennessee, USA, 2006, p. 46.

[4] N. Iida et al., "New Beam Transport Line from LINAC to Photon Factory in KEK", in Proceedings of EPAC 2006, Edinburgh, Scotland, UK, 2006, p. 1505.

[5] T. Mimashi et al., "The Pulsed Magnet System for the Simultaneous Injection of KEK-PF and KEKB Ring", in Proceedings of PAC09, Vancouver, Canada, 2009.

[6] M. Tawada et al.," Development of Pulsed Bending Magnet for Simultaneous Top-Up Injection to KEKB and PF", ibid.

[7] K. Furukawa et al., "Pulse-to-pulse Beam Modulation and Event-based Beam Feedback Systems at KEKB Linac", in these proceedings.

[8] T. Kamitani et al., "PULSE-TO-PULSE MODE SWITCHING OF KEKB INJECTOR LINAC", in Proceedings of LINAC08, Victoria, BC, Canada, 2008, p. 407.