# THE KEK INJECTOR UPGRADE FOR THE FAST BEAM-MODE SWITCH

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*Abstact*

The KEK electron/ positron linac is a 600-m-long linear accelerator with the maximum energy of 8-GeV electron and 3.5-GeV positron. It injects four different beams into four different rings. In order to enhance the operation efficiency, we have an injector upgrade plan aiming a quasi-simultaneous injection. In this paper, we will present the upgrade plan in detail.

## INTRODUCTION

The KEK injector linac has been operated since 1982, and its total operation time has been surpassed more than 120,000 hours. The operation time per year has reached 7,000 hours with a quite low failure rate [1]. The KEK linac provides the beams of the different modes sequentially with four storage rings; Low Energy Ring (LER) of KEKB (3.5-GeV/ positron), High Energy Ring (HER) of KEKB (8-GeV/ electron), Photon Factory (PF; 2.5-GeV/ electron) and Advanced Ring for pulse X-rays (PF-AR; 3-GeV/ electron). Table 1 lists the main parameters for each beam mode. For a higher operation efficiency of the linac beam, many kinds of feedback loops have been developed to stabilize the beam orbit, energy and energy spread [2, 3, 4]. In order to double the positron intensity, the two-bunch operation has been developed [5]. In addition, the three-bunch acceleration has been also tested successfully [6].

For a typical operation, PF and PF-AR need the beam injection twice a day. On the other hand, the KEKB rings are operated under the continuous injection mode (CIM) for keeping the stored current almost constant. Figure 1 shows the linac beam mode statistics in FY2005. During the CIM operation, the linac beam modes are frequently switched so that all settings of magnets, rf phases and timings are changed according to the HER and LER beam properties. Most parts of the linac beam operations are devoted to the LER injection as shown in Fig. 1. In the cases of PF/ PF-AR machine study also need the continuous beam injection, which strongly interrupt the CIM operation of KEKB. In the future, PF ring will start a top-up injection to keep the brilliance high. The injector upgrade is strongly required so that one injection mode does not interrupt the other injection operations.

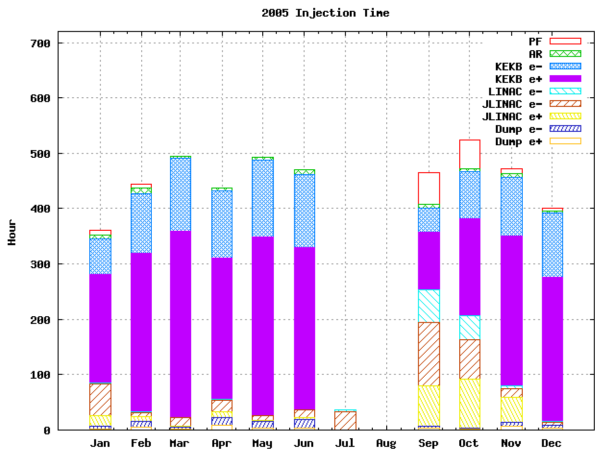


Fig. 1: Beam operation statistics of KEK injector linac.

## UPGRADE PLAN

### *Overview*

For a quasi-simultaneous injection, the consumed time for the beam mode switch should be drastically decreased. Figure 2 shows the schematic drawings of the beam-mode switch. In the case of CIM, the beam-mode switch takes around 30 seconds as shown in Fig.2-(a). Here, the parameters of the magnets, the rf phases and the timing are changed for the optimum conditions of each mode. On the other hand, the beam-mode switch between KEKB and PF/ PF-AR needs several minutes since the ECS magnet setting also should be changed as shown in Fig.2-(b). In any beam-mode switches, most parts of the consumed time are devoted to change the magnet

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

| Beam mode | KEKB e- (HER) | KEKB e+ (LER) | PF | PF-AR |
|---|---|---|---|---|
| Intensity | 1-nC | 1-nC (source e-: 10-nC) | 0.1-nC | 0.1-nC |
| Beam energy | 8-GeV | 3.5-GeV | 2.5-GeV | 3-GeV (*) |
| Maximum beam repetition | 50-Hz | 50-Hz | 25-Hz | 25-Hz |
| Number of bunch | 2 | 2 | 3 – 4 | 3 – 4 |
| Injection per day | > 250 | > 500 | 2 | 2 |
| Electron gun | A1 | A1 | CT | CT |
| ECS magnet mode | ON (KEKB mode) | ON (KEKB mode) | OFF | ON (AR mode) |

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

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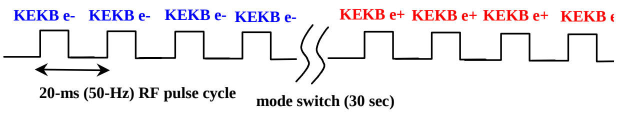
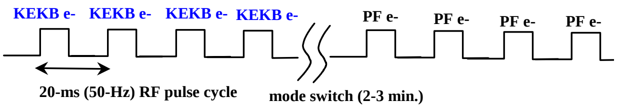
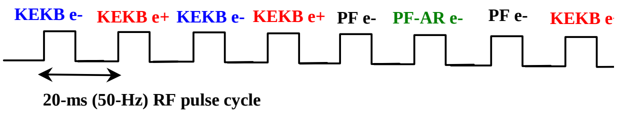



(a) CIM operation for KEKB rings




(b) Beam-mode switch between KEKB and PF mode




(c) Fast beam mode switch (After upgrade)

Fig. 2: Schematic drawing of beam-mode switch

parameters. In our upgrade plan, we will use the common magnetic parameters for any beam modes, and the energy adjustment will be carried out by changing the low-level rf phases quickly. The KEK injector linac upgrade will be progressed by the following three phases. In the final stage of the upgrade, the linac beam-mode will be changed up to 50-Hz as shown in Fig.2-(c).

## *Phase-I*

The purpose of the phase-I is constructing the new PF-BT line to shorten the beam-mode switch time between KEKB and PF. The original switch bending magnet was placed downstream of the ECS magnets as shown in Fig. 3. In order to bypass the ECS, a new DC bend (BM_58) has been installed by removing one accelerating unit, and a new PF-BT line of 60-m-long has been constructed in the last summer [7]. For a compensation of the energy margin, the C-band accelerator unit can be available [8]. The many spare components were reused to save the const.

After the phase-I, the beam-mode switch between KEKB and PF does not need to change the ECS parameters, and the round trip mode switch time including PF injection is decreased to 2.5 min. from 5.5 min. in a typical case. In addition, the beam injection efficiency is increased as shown in Fig. 4. It is convinced that the radiation level caused by the beam losses is decreased.

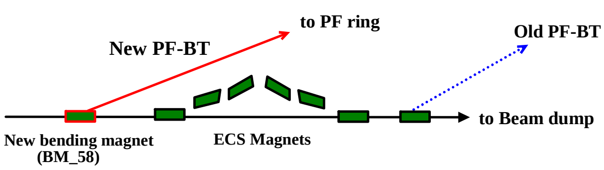



Fig. 3: Arrangement of a new PF-BT line and ECS

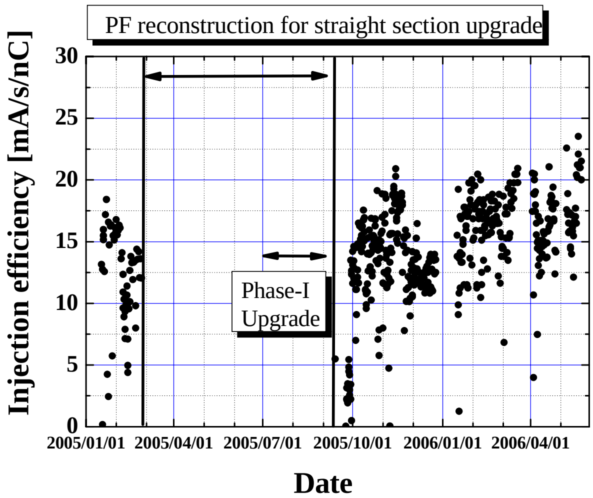



Fig. 4: Beam injection efficiency [mA/sec/nC]

## *Phase-II*

The phase-II aims to perform the fast beam-mode switch between KEKB electron and PF modes up to 50-Hz. Here, we will use the characteristic scheme called "Multi-Energy Linac" [9]. In this scheme, the common magnet settings for KEKB e- and PF modes are used instead of installing the pulsed magnets. The fast change of the beam energy is done by changing the low-level rf phases quickly. Though PF ring needs the 2.5-GeV electron, the beam is accelerated up to around 5-GeV in the multi-energy 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. In this method, PF mode will also use the A1 gun instead of the CT gun. The result of a preliminary machine study using the multi-energy scheme has been already carried out, and its result shows that this scheme is feasible for a realistic operation.

The DC switch bend (BM_58) magnet will be replaced by the pulsed magnet in this summer. The new pulsed bend and power supply are under tested. After the phase-II, the PF top-up operation will be available during the KEKB HER mode. For handling the complicated timing, the timing system will be upgraded in this summer [10]. A new BPM system also will be installed for a fast data acquisition up to 50-Hz [11].

## *Phase-III*

In the phase-III, the fast beam-mode switch will include the positron beam operation. In the current operation, the positron target is controlled by a mechanical movement. For a fast mode switch, one solution is to build a target bypass line with the pulsed magnets. However, it seems to be difficult because of a space and a cost limit. In our plan, the positron target with a hole will be used, and the fast mode change between electron and positron will be performed with a fast control of the electron beam orbit.

For a feasibility study, a test target was installed as shown in Fig. 5. A centre of a hole is placed 4.5-mm apart from that of an amorphous tungsten target. The

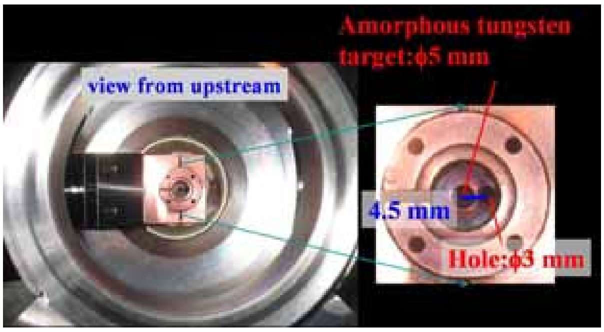



Fig. 5: Photograph of positron target with a hole

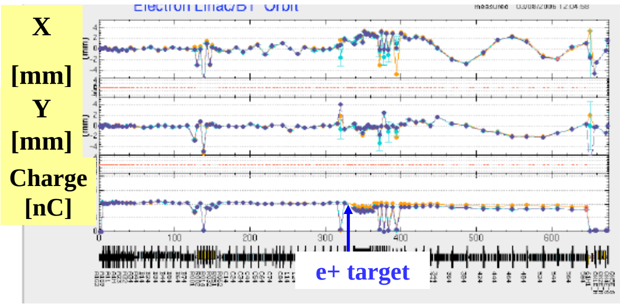



Fig. 6: Preliminary machine study result of positron target with a hole. The horizontal (upper), vertical (middle) beam orbit and beam charge (bottom) are shown along the linac.

diameter of a hole is about 3-mm. The electron beam passes the inside a hole for the electron mode, whereas the electron beam hits the target for the positron mode.

A preliminary study result is shown in Fig. 6. The orange dots show the beam orbit and charge along the linac when a target is removed. The blue dots show the result with a target, here, the electron beam goes through inside a hole. Around 90% of the electron beam can traverse the inside a target hole in comparison with a normal operation. This scheme seems to be feasible, although the more detailed study should be continued. In addition, an amorphous tungsten target will be replaced by a crystalline one to enhance the positron production efficiency [12].

In this phase, the fast beam-mode switch should include PF-AR mode. One solution is to use the 3.5-GeV positron beam of LER mode for a 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. The detailed design study is now in progress, and its result will be reported elsewhere.

## SUMMARY AND FUTURE PLAN

The KEK injector upgrade aiming the fast beam-mode switch is outlined. We propose the multi-energy linac scheme using a common magnet parameter and a fast control of rf phase. For the fast beam-mode switch between electron and positron, the usage of a positron target with a hole is proposed. The preliminary study results show the feasibility for a practical beam operation. However, the more detailed machine studies and design works should be continued. This upgrade will be a grate effective to increase the beam operation efficiency of the injector linac. Eventually, the operational availability of each ring will be greatly enhanced.

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