NEW BEAM TRANSPORT LINE FROM LINAC TO PHOTON FACTORY IN KEK

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Abstract

The 8-GeV electron LINAC in KEK injects the electron and positron beams sequentially into four storage; Low Energy Ring(LER) of KEKB (3.5 GeV/e^+), High Energy Ring (HER) of KEKB (8.0 GeV/e^-), Photon Factory(PF) (2.5 GeV/e^-) and Advanced Ring for pulse X-rays(PF-AR) (3.0 GeV/e^-). The LINAC continuously injects beams into LER and HER alternately every about five minutes, and both of KEKB rings maintain almost full operating currents. The PF or PF-AR needed about 20 minutes for topping off the current, including 5 minutes for switching time of Linac, several times in a day. During this, the stored currents in KEKB rings significantly decreased and the optimum points of luminosity tuning was lost. It had taken more than two hours to recover the luminosity. It is therefore important for maximizing luminosity of KEKB to shorten the switch-time of LINAC from KEKB to PF or PF-AR, and vice versa. In summer of 2005, the transport line from LINAC to PF were renewed, in which a new DC bend deflects the electron beam from the end of LINAC to the new line. We succeeded in reducing the occupancy time of PF injection to about five minutes. In this paper design of the new PF beam transport (PF/BT) line and its performance are described.

INTRODUCTION

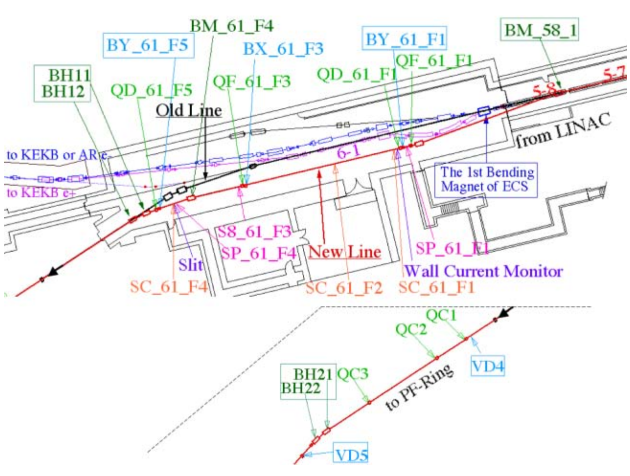

Figure 1: Layout of Beam Transport Lines from LINAC

The layout of the beam-switch yard (BSY) at the end of LINAC is shown in Fig. 1. Changing sequentially its operation mode, the Linac supplies each ring with requested beam having specific energy, charge, and bunch structure. The thick black(red) line designates the old(new) line to PF. In the old system all beams pass through the first bend of Energy Compression System (ECS) for KEKB/e^+ and it plays a role of switch-bend. Two KEKB beams are guided to their own transport lines without changing ECS bend owing to different charge and energy. Mode-change between KEKB and PF, however, needs to turn off/on the ECS, simply because charge and energy are different and the PF line is initiated at the downstream of ECS. Since the ECS bends are heavily saturated it takes about three minutes for the magnetic field to be recovered. We decided to construct a new line for PF where the PF beam is extracted through the new switch-bend (BM_58_1) dedicated for PF at the upstream of ECS and guided to the existing line at downstream of BSY. The new switch-bend is able to be set up the magnetic condition within about a half a minute. The new line rejoins the existing PF line at a bend, BH12.

OPTICS DESIGN

Optics parameters (β-functions, dispersion-functions and beam sizes) from the end of LINAC to the entrance of PF ring are shown in Fig. 2. Solid and broken lines correspond to the horizontal and vertical parameters, respectively. Fig 2-(a) and (b) show the old and new optics respectively. The horizontal and vertical emitttances are assumed to be 1.5×10^{-8} m and 1.0×10^{-8} m respectively, based on the measurements using wire scanners at the end of LINAC. Energy spread is assumed to be 1.25×10^{-3}. In the new optics, β-functions are matched to those of the old optics at the lower PF/BT point where is the exit of a bend (BH22), which is placed at the downstream of existing PF/BT line. The horizontal dispersion is also made matched to zero here. It is highly desirable to cut energy tail and beam halo at upstream of the PF/BT line. A horizontal slit is installed at a point where dispersion is larger and β-function is smaller. Ratio of the horizontal beam sizes originated only from dispersion to that from emittance is 5.77.

COMPONENTS

Magnets and Power Supplies

All magnets installed in the new PF/BT line can be available to 3.0 GeV beam. Bending magnets are reused from those of the old TRISTAN-AR beam transport (AR/BT) line [1]. They are H-type conventional block magnets. It

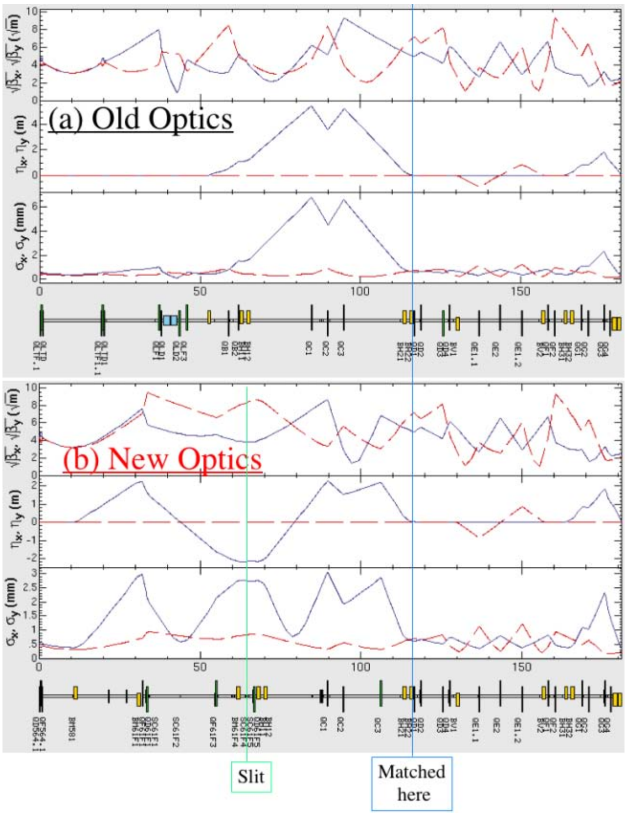

Figure 2: Optics from the end of LINAC to the injection point of PF.

takes about a half of minute to rise up/down magnetic field from zero to operation field (∼0.92 T). There is, however, a remanent field of 33 Gauss. At KEKB mode, main current of BM_58_1 is turned off and the correction coil of this magnet is excited to 0.78 A in order to cancel the remanent field. There are two types of quadrupole magnets. Two of upstream quads are reused from the old AR/BT line, whose bore diameter is 52 mm. The poles of these magnets were remade to fit the bore diameter of quads of PF line, which is 63 mm. The two quads at downstream and all the steering magnets are moved from the old PF/BT line.

Stabilities of the power supplies are less than 100 ppm in peak to peak (p-p), and the ripples of them less than 50 ppm(p-p). We estimated effective growth of emittance due to strength jitter of power supplies as below;

$$\left(\frac{\varepsilon'}{\varepsilon}\right)^2 \sim 1 + \frac{\beta^* < d\theta^2 >}{\varepsilon},$$

where ε and ε' are emittances at the entrance and exit of an bend, respectively. β^* is a β-function at the center of the bend. $< d\theta^2 >$ is a mean squared jitter of deflection angle of a power supply. The estimated values of emittance growths are summarized in Table 1, where jitters of power supplies are assumed to be 100 ppm and $\Delta\varepsilon = \varepsilon' - \varepsilon$. BMAG is emittance growth from beta-mismatch. There is no problem for PF/BT operation for the stabilities of bends with 100 ppm(p-p).

Table 1: Emittance growths due to jitter of bending magnets

Bend	θ (rad)	$d\theta/\theta$	$\Delta\varepsilon/\varepsilon$	BMAG
BM_58_1	0.114	10^{-4}	4×10^{-3}	$1{+}8\times10^{-6}$
BM_61_F1	-0.114	10^{-4}	2.2×10^{-2}	$1{+}2\times10^{-4}$
BM_61_F4	0.0874	10^{-4}	3×10^{-3}	$1{+}6\times10^{-6}$
BH11	0.131	10^{-4}	8×10^{-3}	$1{+}3\times10^{-5}$
BH12	0.131	10^{-4}	1.0×10^{-2}	$1{+}5\times10^{-5}$

Monitors

As shown in Fig. 1, there are three screen monitors (SC_61_F∗), three BPMs [2] (SP_61_F∗) and one OctoPos monitor[3] [4] (S8_61_F3). BPMs and steering magnets are located near to quadrupole magnets for making an efficient orbit correction. For getting more S/N, only electrodes of the first BPM (SP_61_F1) do not rotate by 45°. The screen monitors, SC_61_F1 and F4 are designed to observe beam size mainly from energy spreads and energy deviation. Whereas the screen SC_61_F2 is located at the position where dispersion is designed to be zero and used for observing emittance profiles (See Fig. 2-(b)). OctoPos is a non-destructive monitor which is sensitive to quadrupole component of the beam profile. A wall current monitor [5] is installed, which measures the beam current at the end of LINAC.

ALIGNMENTS

Magnets installed in the new line were aligned making use of a laser tracker that measures the magnet position with precision of 1 μm. The magnets were divided into two groups; The upstream magnets from QD_61_F1 are defined as "Group 1" and the other magnets as "Group 2". We define a right-handed coordinate system as indicated in Fig. 1. The x-axis coincides with the direction of LINAC. The measured data were least-square-fitted to the design value by using three free parameters; translation in x and y coordinate and rotation in the xy plane. The results of measurements are summarized in Table 2.

Table 2: Results of the measurements

(mm)	X	ΔX	Y	ΔY	Z	ΔZ
Group 1	0.443	0.023	-0.025	0.178	-0.02	0.03
Group 2†	-0.354	0.096	0.020	0.033	0.03	0.04

(† Group 2′ for the level measurements)

In the X-direction, it was found that Group 1 is 0.8mm away from Group 2. This interval is so small that we corrected design values of magnet strengths. Each magnets are settled with an error of about 100 μ m. These values are small enough to correct beam orbit with the steering magnets. Levels of the magnets were measured with a leveling telescope. It was found that the floor level around the end of LINAC to BSY has a slant of 20.15 μm/m as shown in Fig. 3.

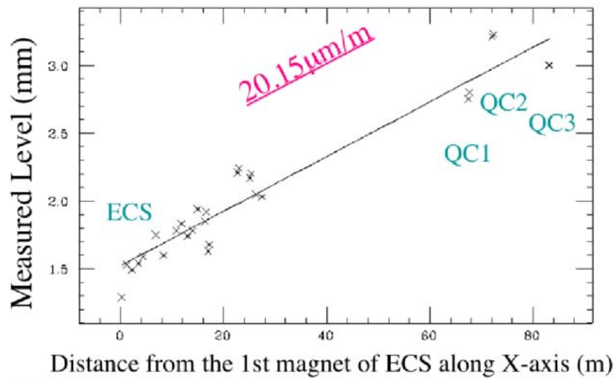

Figure 3: Level measurements along the X-axis in BSY

Figure 4: Adjusted levels of magnets

To reconcile with this slanted floor we adjusted the levels of magnets as Fig. 4; the level of Group 1 is fit to the level of LINAC while the downstream magnets from BY_61_F, defined as Group 2′, are fit to an average of QC1 and QC2 levels. The resultant orbit from this alignment is able to be corrected with BY_61_F1, BY_61_F5, VD4 and VD5. Results of the level measurements are shown in Table 2 as Z and Δ Z.

OPERATION

On 24/Sep/2005, injection mode was switched from KEKB to PF and returned to KEKB again [6]. The time summed for both ways were 2.6 minutes. It had taken 5.3 minutes in the old system. Thus the mode-switch time is successfully made almost half of that of old system. The horizontal/vertical orbits and transmission from CT gun of LINAC to the entrance of PR ring are shown in Fig. 5. The differences of the horizontal orbits from the center of beam pipes keep within 4 mm, and those of the vertical orbits within 2 mm, which have no problem to transport the beam. Possible beam loss may attributed to an energy tail. The injection rate for PF ring surpassed more than 2 mA/sec as shown in Fig. 6, which is very good values compared to that in the old beam line.

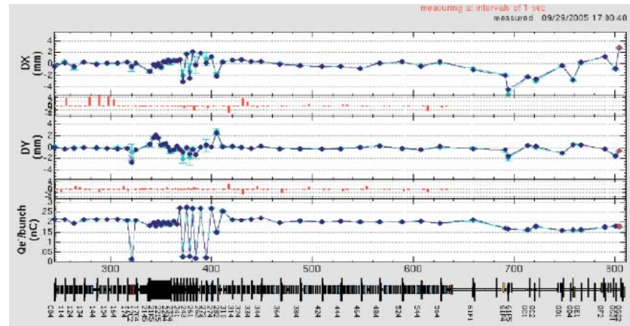

Figure 5: Measurements of beam positions and charges from LINAC to the entrance of PF ring

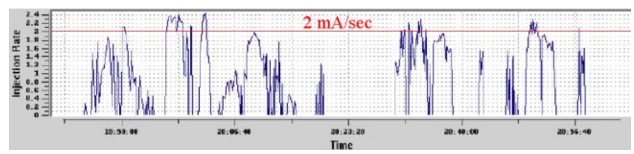

Figure 6: Trend graph of injection ratio for PF ring

CONCLUSION AND FUTURE

We reconstructed a half part of transport line from LINAC to PF. The switch-magnet for PF/BT were installed at the upstream of ECS for faster change of the magnetic field. Mode-switch time between KEKB and PF was made almost half of that in original system. At the first operation the injection ratio was more than 2 mA/s. In the near future, we will make a correction of optics-dispersion function.

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