BEAM TRANSPORT LINES OF THE KEKB

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Abstract

KEKB is a double ring collider of 3.5 GeV positrons (LER) and 8 GeV electrons (HER), each filled with current of 2.6 A for LER and 1.1 A for HER in the design. The transport lines convey the positron and the electron beams separately from the injector linac to the rings, each having length of about 500 m. In order to make maximum use of existing tunnels and also to avoid interference with AR, an existing ring for the synchrotron light source, the beam lines took a course that snakes its way right and left, resulting rather large curvature. The consequences were that (a) large number of bends with high field are necessary and (b) large dispersion function thus large R_{56} component. The latter issue is crucial for KEKB rings since it results in longer bunch length at the injection. We adopted a special optics that reduces the R_{56} coefficient sufficiently, which, in turn, necessitates large number of high-field quads powered independently. The present paper describes the design and the current status of the beam lines.

1 OVERVIEW OF THE BEAM LINES

Specifications of beam parameters are given in Table 1. The energy spread of the positron beam at the end of linac is 2.5×10^{-3} and is compressed half with the energy compression system, which comprises six 1.5 T chicane bends and two 2 m-long accelerating structures.

Table 1: Beam parameters

	positrons	electrons
Energy	3.5 GeV	8.0 GeV
Emittance(Linac)	2.2×10^{-7} m	1.6×10^{-8} m
Acceptance(BT)	3.6×10^{-7} m	4.6×10^{-7} m
Energy spread(Li)	1.25×10^{-3}	1.25×10^{-3}
Energy acceptance(BT)	2.5×10^{-3}	2.5×10^{-3}
Bunch length(Li)	3.4 mm	1.7 mm
Bunch length(BT:end)	7.0 mm	7.1 mm

1.1 Layout of the Beam Lines

Layout of the beam line is shown in Fig. 1. The positron and electron beams are separated at the exit of the linac and guided to each line, which is stacked vertically each other. The layout of the beam lines were decided under the guideline that maximum use should be made of the existing AR- and MR-injection tunnel and as large as separation must be made as possible from Accumulator Ring(AR), which has been planed to serve as a photon source. From these external conditions only way was to build a new tunnel that connects the AR-injection tunnel and the MR-injection tunnel, bypassing the South Hall of AR.

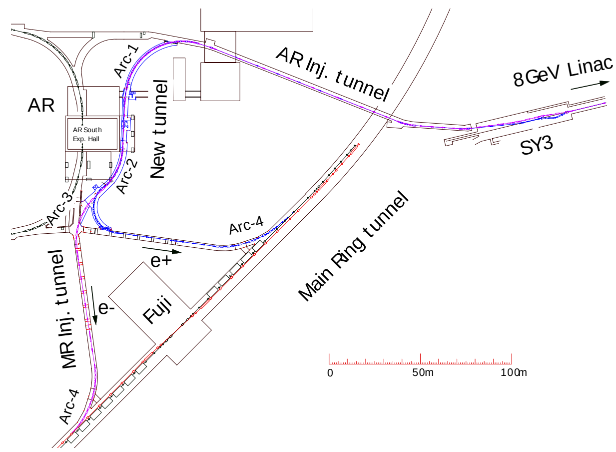

Figure 1: Layout of beam lines.

1.2 Optics

Tight constraints on the geometric conditions led large curvature of the new tunnel. Repeat of identical FODO cell would produce large dispersion function at the arcs, resulting large R_{56} component, which in turn generates longer bunch length at the end of BT due to a drift in the longitudinal phase space($\sigma_\epsilon R_{56}$). We adopted special optics that reduces dispersion function at the arcs, paying a cost that almost all quads should be powered independently. Nevertheless bunch length is still dominated by the longitudinal drift effect: bunch length at the end of BT becomes 7.0 mm and 7.1 mm for positrons and for electrons while at the end of linac they are 3.4 mm and 1.7 mm, respectively. Fig. 2 shows the optics function of the beam lines. Dispersion function are kept relatively small and closed within each region. In order to get R_{56} as small as possible the dispersion function is reversed in the middle of the arcs. R_{56} is -4.9 m for positrons and -5.5 m for electrons at the end of the beam lines.

1.3 Beam Halo Collimation

Beam halo collimation is vitally important to protect the fragile detectors of Belle from lost particles. Although KEKB rings have their own collimators or masks it is preferable to cut tail part of the beams before the injection. The collimation system is also necessary to reduce the beam loss in the transport lines. We installed 12 pair of collimators, among them two are for energy collimation of positrons and the others are for emittance collimation of

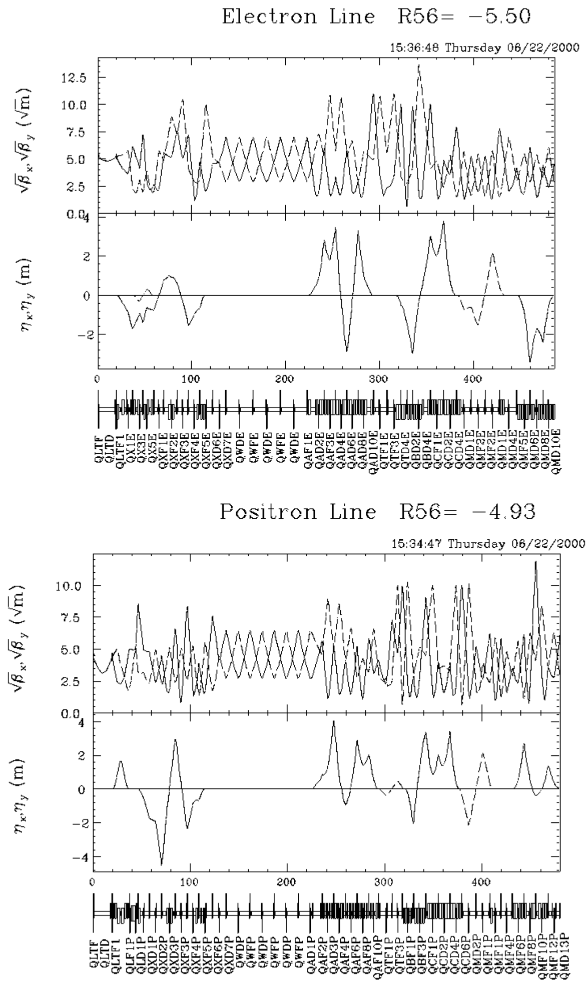

Figure 2: Optics functions.

both beams. Two sections are prepared for energy collimation: SY3, which is located just downstream of the linac, and the Arc-1. The dispersion function becomes as large as 4 m for both location. Since ceiling of the tunnel is only 1.5 m under the surface(1 m soil + 0.5 m concrete) in the upstream of the Arc-1 a possible increase in radiation level on the surface due to the collimation was another concern: although main part of the tail can be stopped completely at the body of collimator some quantity of particles scattered at the jaw of the collimators may be sprayed out and make the radiation level on the surface higher than the regulation. Simulation using EGS4 code showed that scattered particles are within safe level if tail particles are less than 5 %.

1.4 Installation

Fig. 3 shows typical view at the Arc-1 of the new BT tunnel, 3 m in width and 2.5 m in height. Positron line magnets are overlaid on top of the electron line magnets. Since the tunnel is not equipped with cranes except for the MR-injection tunnel, magnets were stacked vertically in the assembly area and then moved using a "Air Caster" which floats with compressed air. The weight of pre-assembled magnet was 7 ton at maximum.

Figure 3: Typical view from upstream at the Arc-1.

2 MAGNETS AND POWER SUPPLIES

Table 2 shows a summary of magnets. Magnetic field is

Table 2: Number of magnets

	reused	new	total	kind
Bend	19	102	121	18
Quad	79	54	133	3
Corrector	38	73	111	4

1.35 T for most of bends. Magnetic gap is 40 mm. Quads are air-cooled type except for 15 strong quads for the electron line that was necessary to produce negative dispersion in the arcs. Bore radius is 52 mm. Table 3 shows specifications on the stability of power supplies. All the specifications in Table 3 are defined as the deviation in peak-to-peak. Power supplies for bends are transistor-dropper type and those for quads and orbit correctors are switching regulator type utilizing IGBT or MOSFET switch. The specifications for correctors are unnecessarily tight because they are common to the rings.

Table 3: Stability of power supplies

	stability (T=10∼40°C)	ripple (f>0.2 Hz)
Bend	5×10^{-5}/day	1×10^{-5}
Quad	5×10^{-4}/day	1×10^{-4}
Corrector	1×10^{-4}/day and 5×10^{-4}/year	5×10^{-5}

3 INSTRUMENTATION

3.1 Beam Position Monitor

Both of the positron and electron line are equipped with beam position monitors(BPM), 61 and 56 respectively, attached to each quadrupole magnet. The BPM comprises four strip-line type pickup electrodes. Length of the electrode is 175 mm. Each electrode span 45° to the beam center and forms a part of a cylinder whose diameter is 52 mm. In order to avoid adverse effect of synchrotron light configuration of electrodes is set as a normal quad. Signals of four BPMs are combined in a single cable in the tunnel, and moreover those four combined signals are combined in the local control room, so that 16 signals are combined in a single cable. Those signals are fed into a VXI-based waveform analyzer. Coaxial switch selects signal from the two beam lines, thus a single channel of waveform analyzer covers 32 BPMs for both of the beam line. We used coaxial cable of 8D type(8 mm in diameter) which has corrugated outer conductor. Total cable length is 100 m at minimum and 300 m at maximum. Fig. 5 shows an example of combined signal. Position resolution of 100 μm has been achieved, which is dominated by digitizing resolution of 8-bit of the waveform analyzer.

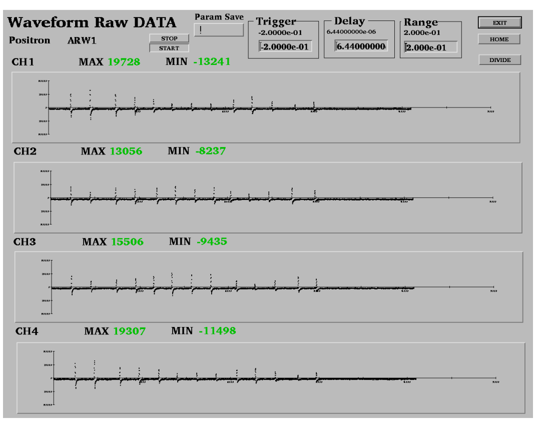

Figure 4: Example of combined signal.

3.2 Wire Scanner etc

In order to make optics matching from linac to BT four wire scanners are installed in the long straight section in between Arc-1 and SY3 for each beam line. Another wire scanner is also installed at the entrance of Arc-4 section in order to measure residual mismatch and to correct it before injection. Details are given elsewhere[1].

Screen monitors of 40 in total and 23 beam-loss monitors utilizing air-filled coaxial cables have been installed for the lines.

4 OPERATION STATUS

Figure 5 shows an example of the beam orbit display. In the commissioning we firstly made relative calibration of quad strength to bend strength. This procedure was necessary because we made field measurement using different coils for quads and bends and did not made a calibration between coils. Unknown factor is thus common to all quads. We measured a leakage of the dispersion function at downstream of one arc as a function of common factor for the quads that are included in that arc. After quad calibration all the arcs in the beam lines had dispersion function locally closed, except for the arc-1 of the electron line. We found water leakage in a coil of one quadrupole coil in the Arc-1. After we applied an optics for arc-1 that does not use the malfunctioning quad the dispersion function locally closed.

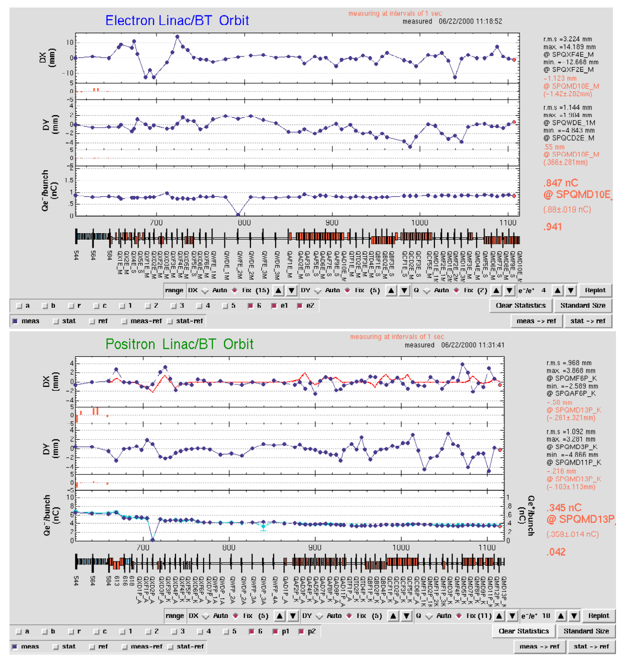

Figure 5: typical measured orbit.

Secondly we made optics matching between linac and the BT using wire scanners[1]. Optics matching was very effective especially after shutdown of the linac.

Since we could not made an intensity calibration between BPMs the transmission efficiency has an ambiguous factor. Precise calibration was difficult because the cable length of BPMs differs significantly. In the Fig. 5 empirical calibration was made. Transmission efficiency from linac to ring is more than 80% at maximum and strongly dependent on the aperture condition of rings(masks etc.).

Collimators did not show any clear effect to the beam noise to the Belle.

REFERENCES

[1] N. Iida *et al*, *"Recent Progress of Wire Scanner Systems for the KEKB Injector Linac and Beam Transport Lines", this conference.*