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PRELIMINARY DESIGNS OF 1.54GeV DAMPING RING AND BUNCH COMPRESSOR FOR THE JLC

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ABSTRACT

We describe preliminary designs of 1.54GeV damping ring and bunch compressor for the JLC(Japan Linear Collider). The design of the damping ring is changed into feasible one by introducing a pre-damping ring for the positron beam. Parameters of the bunch compressor are adapted to parameters of the damping ring and the JLC requirements. The normalized emittances of the extracted beam from the pre-damping ring are $\gamma\epsilon_x = 220\mu$radm horizontally and $\gamma\epsilon_y = 7.5\mu$radm vertically. The damping time of the pre-damping ring is τ =3.16msec. The main-damping ring has normalized emittance of $\gamma\epsilon_x = 2.9\mu$radm and $\gamma\epsilon_y$ = 28.9nradm. The damping time is τ =6.23msec. The main parameters of the compressor as well as results of some simulations are presented. It produces bunch trains with a bunch length of the order of 60μm and a momentum spread of $\Delta p/p \sim 2\%$.

Introduction

In order to realize the JLC project, we have been discussing for several years on possible parameter sets of the JLC. We were requested to increase the normalized emittance of the injected positron beam into the DR(damping ring) about six months ago. So we designed a pre-damping ring(PDR) for the JLC because the normalized emittance more than $3.0 \times 10^{-3} radm$ gives very severe requirements for the aperture, the jitter tolerance of the extraction kickers and the damping time. Fig.1 shows the layout of the JLC according to the parameter set so far obtained.[1,2,3]

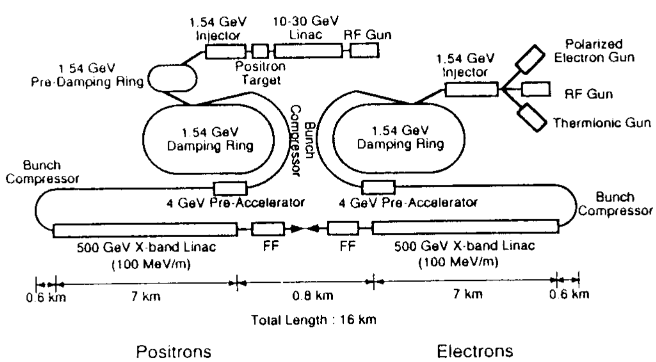

Fig.1 Layout of the JLC

The design parameters of the MDR(main-DR) and the BC(bunch compressor) which are required from the design of the JLC are as follows:

1) 1.0×10^{10}particles/bunch,

2) 10 bunches/train with the bunch spacing of 1.4 nsec,

3) repetition frequency 200Hz,

4) the normalized emittances of the extracted beam from the DR are less than $\gamma\epsilon_x/\gamma\epsilon_y = 3.0 \times 10^{-6}/3.0 \times 10^{-8}$ radm,

5) the bunch length from the BC is less than 76μm.

One of the characteristics of the present design of the JLC is to operate in a multi-bunch mode. The linac accelerates bunch trains where the bunches contained in a train are separated by about 42cm and the number of particles per bunch is 1×10^{10}. We assume that the total time duration for the kickers to turn on, extract/inject a train, and turn off is less than 130nsec. Thus the trains must be separated by at least 60nsec. We have decided to introduce damping wigglers in zero-dispersion region and also selected a racetrack configuration as a ring style for the reduction of dispersion suppression and matching regions. The type of lattice in the arc is a separated fuction FODO since simple lattice are favored for operation simplicity.[4] In the following sections, we present preliminary designs of the PDR, the MDR and the BC. Also we discuss the merits of introducing the PDR and results of some simulations are presented.

Pre-Damping Ring

A lattice design of the PDR is illustrated in Fig.2. The ring has a circumference of 50.2m and a superperiodicity of two. The optical functions β_x and β_y and the dispersion function η_x for a quarter of the ring are plotted in Fig.3. Basic parameters of the PDR are as follows: beam energy 1.54GeV, Circumferrence 50.2m, damping time 3.16msec, equilibrium natural nornalized emittance 2.18×10^{-4}radm.

The normalized emittance of the injected beam was increased from 1.0×10^{-3}radm to 3.0×10^{-3}radm. The energy acceptance was also increased from 0.7% to 1.0%. In order to accept the beam with 2.0% energy spread, energy compressor before the PDR is necessary. The PDR has mainly four merits.

1. Normalized emittance of the injected beam is easily increased because the PDR has not damping wigglers.

2. Jitter tolerance of the extraction kickers of the MDR is relaxed.
3. Requirement of the damping time for the MDR is loosened.
4. Requirement of the dynamic aperture for the MDR is relaxed.

Design of Damping Ring

A lattice design of the MDR is illustrated in Fig.4. The ring has a circumference of 172.8m. The optical functions β_x and β_y and the dispersion function η_x for the ring are plotted in Fig.5. Basic parameters of the MDR are as follows: beam energy 1.54GeV, Circumferrence 172.8m, damping time 6.2msec, equilibrium natural nornalized emittance 2.92×10^{-6}radm, bunch length 5mm.

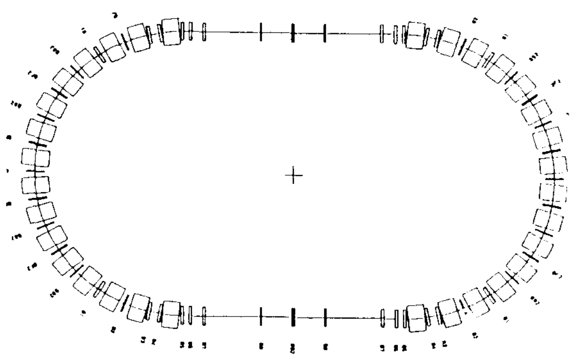

Fig.2 Schematic of the PDR.

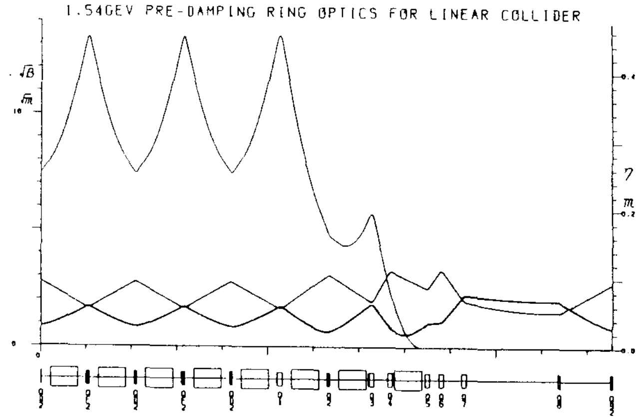

Fig.3 Optical functions for a quarter of the PDR

It is extremely important that the extraction kicker have very small jitter.[5,6] We would like to achieve a jitter tolerance of one tenth of the beam size $\sigma_{x,y}$ at the IP. This specifies a tolerance on the kicker.

$$\frac{\Delta\theta}{\theta} \leq \frac{\sigma_{jit}}{x_{kick}}$$

where

$$\sigma_{jit} \leq \frac{1}{10}\sigma_x$$

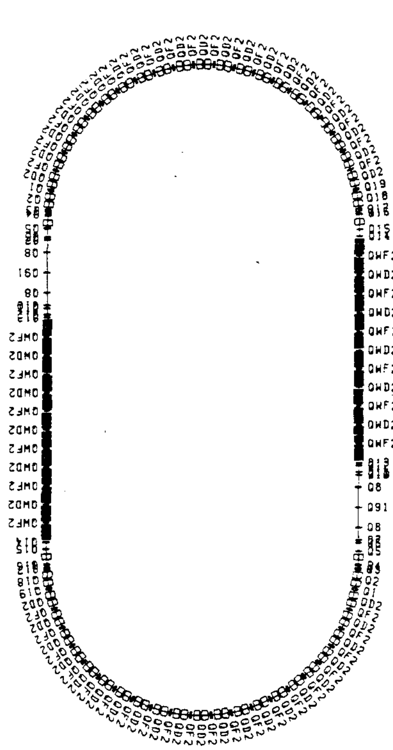

Fig.4 Schematic of the MDR.

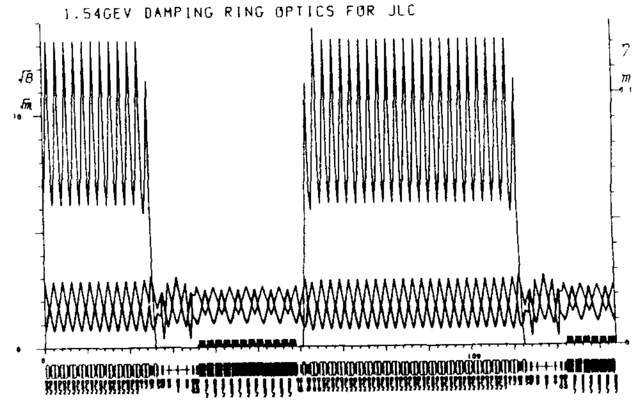

Fig.5 Optical functions for the MDR

, where x_{kick} is the transverse displacement of the kicked beam at the septum. This tolerance can be written in a more transparent form:

$$\frac{\Delta\theta}{\theta} \leq \frac{1}{10}\frac{\sqrt{\epsilon_{ext}\beta_{xsept}}}{x_{septplat} + 1mm + N_s\sqrt{\epsilon_{inj}\beta_{xsept}}}$$

where $\gamma\epsilon_{ext}$ and $\gamma\epsilon_{inj}$ are injected and extracted beam emittances. N_s is the distance between the closed orbit and the septum plate in units of the injected beam size. we assumed $N_s = 3$ and, since damping the bunch for $\sim 10msec$ reduces the emittance of the injected beam by two orders of magnitude, this value gives sufficient beam life time. The septum plate in a DC septum with strong fields cannot be made much thinner than 3mm. Assuming $\gamma\epsilon_{inj} = 3 \times 10^{-3} radm$ and $\beta_{xsept} = 7.5m$, the jitter tolerance on the kicker is

$$\frac{\Delta\theta}{\theta} \leq 7.08 \times 10^{-4}$$

The jitter tolerance of the extraction kickers $\frac{\Delta\theta}{\theta}$ is increased from 7.08×10^{-4} to 1.4×10^{-3} by using the PDR. The stored time of each train is reduced from 7τ to 5τ. This result reduces the number of the damping wigglers from 44 to 24. The required aperture of the MDR is reduced from $80\sigma_0$ to $40\sigma_0$, where σ_0 is maximum equilibrium beam size in the MDR. But the physical aperture is limited to the inner diameter more than $30\phi mm$ because the condition of the vertical emittance growth rate due to the Rutherford scattering with residual gas requires the pressure less than $\sim 10^{-7}Pa$. The results of sumilation(SAD(KEK original code)) indicate that the dynamic aperture is more than $100\sigma_0$ and that the tolerances of the quadrupole misalignment and rotational misalignment, the sextupole misalignment, the magnetic field error and the monitor setting error are less than $30\mu m$ vertically, $60\mu m$ horizontally, 0.5mrad rotationally, 0.1% and 0.1mm to obtain the required emittance, respectively.

Design of Bunch Compressor

JLC requires the bunch length of $\sim 60\mu m$ for controlling the adverse effects caused by the transverse wake field and for obtaining high luminosity . A bunch of this length is not readily obtainable from a damping ring and, hence, a compressor will be needed to transform a long bunch with small momentum spread $\Delta p/p$ into a short bunch with a larger momentum spread. For the bunch extracted from the MDR the momentum spread will be typically $\Delta p/p \approx 0.08\%$ with a bunch length of $l \approx 5mm$. Compression of this bunch length to $\sim 60\mu m$ would then require increasing the momentum spread to 7%. That is clearly unacceptable when chromatic aberrations and practical aperture limitations are considered. Therefore, a two-stage compressor with an intermediate acceleration is assumed in the present design.[7] Fig.6 shows the layout of the BC for the JLC.[8]

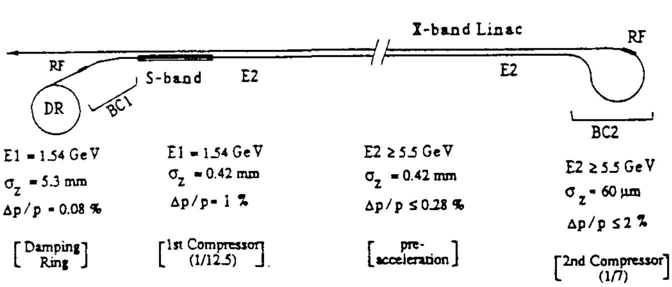

Fig.6 Layout of the BC for the JLC

The second compressor accomodates 180° bend before the injection to the main linac which make it easy to upgrade the energy and to handle the beam from control center. Transport line must have spin rotator without any degradation of spin polarization. Sextupoles were incorporated near the quadrupoles to form achromatic cells that relax the alignment tolerance as well as chromatic effects. The results of tracking simulation with 1000 particles input beam in the second BC are plotted in Fig.7. The second compressor with 2% energy spread does work and shrink the beam up to $66\mu m$ although 5% particles spread out beyond $2\sigma_z$.

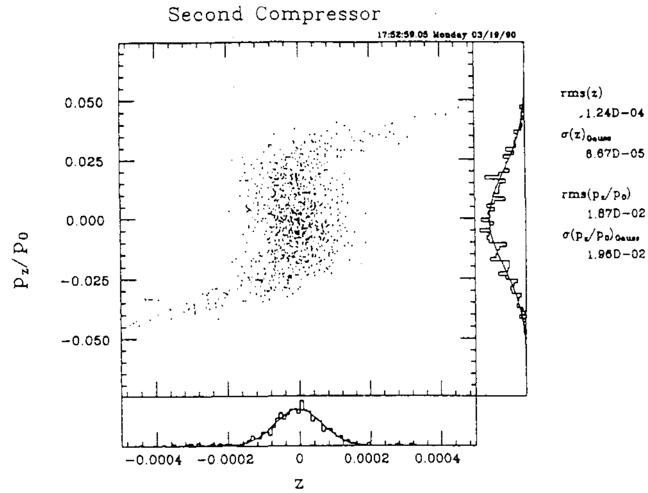

Fig.7 Results of tracking 1000 particles in the second BC

Acknowledgement

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