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The Booster to Storage Ring Transport Line for SRRC

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Abstract

A 70 m long booster to storage ring (BTS) transport line has been designed for the SRRC to transport the beam extracted from the booster to the storage ring at 1.3 GeV. The booster is outside the main ring and has a vertical level difference of 4.15 m relative to the ring. The design has been optimized to reach small beam size and to reduce the effects of magnet errors. In total, two families of bending magnets and 17 quadrupoles are used in the BTS line. Diagnostic instruments and correctors are equipped to measure the beam intensity, position, emittance, energy spread and to steer the beam. A method of injection into the storage ring is also presented.

I: Introduction

The injector of SRRC is a 1.3 GeV booster synchrotron. The energy of the booster is ramped from 50 MeV to 1.3 GeV in 10 Hz. The emittance of the beam from the booster is below 3×10^{-7} m·rad and the energy spread is less than 5×10^{-4}. The BTS transport line will transfer the the beam extracted from the booster to the storage ring. The beam size in the transport line should be as small as possible in order to reduce the loss of the beam in the transport line.

II: Design of Transport Line

The layout of the storage ring[1], BTS transport line and the booster are shown in Fig.1. There is a level difference of 4.15 m between main ring and the booster. The beam is extracted from the booster, through the transport line and injected into the ring in the horizontal plane from the inside of the storage ring. The whole BTS transport line is about 70 m long which includes one 9° extraction septum (B1), four horizontal bending magnets (B2,B3,B6,B7) with length of 0.8 m and bending angle ≈10°, two vertical bending magnets (B4,B5) with length of 1.2 m and bending angle of 15°, 17 quadrupoles (Q1~Q17) with length of 0.21 m and one 10° injection septum (B8). The bending magnets are classified into two families which can be powered in series respectively. This will save the cost of construction. The BTS transport line is separated into three achromats and two dispersion free sections. The beam parameters coming from the booster can be matched by using the four quadrupoles (Q1~Q4) in the horizontal achromat between the extraction septum and B3. The beam parameters at the end of the BTS are calculated basing on Tazzari's report "Aperture for Injection" [2]. The β_x is 3 m for a three standard deviation up right elliptical injected beam (α_i=0). It is matched by using the quadrupoles Q14, Q15 and Q16, Q17 in the horizontal achromat between B6 and B8. Special care should be taken in the vertical achromat between B4 and B5 because there is a 7 m long sleeve tunnel which can not be equipped with any

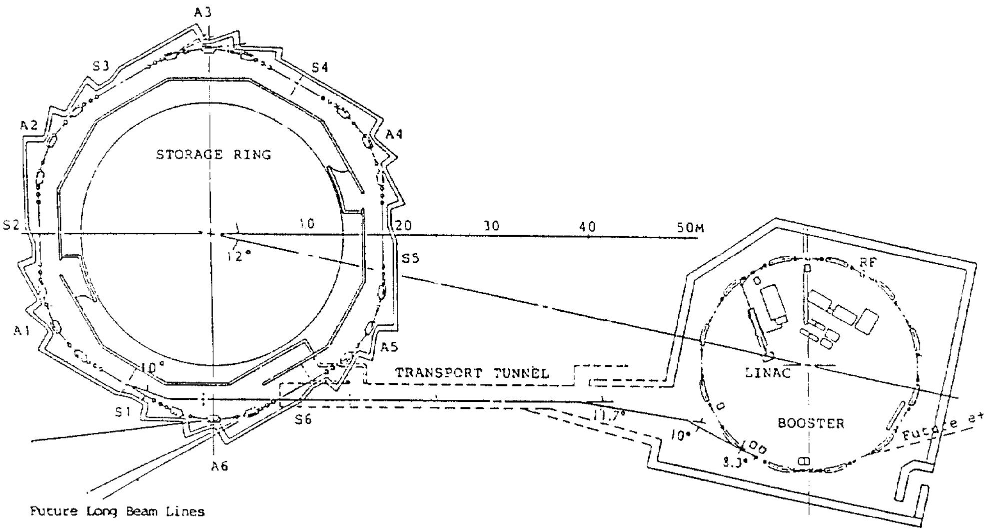

Fig. 1 SRRC Synchrotron Layout

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components. The optics of BTS transport line has been carefully managed s.t. the β function of the whole line are below 100 m. The maximum β value occurs before Q14 with value of 81 m which corresponds to the beam size of $3\sigma_x$, about 15 mm, with $\varepsilon_x = 3 \times 10^{-7}$. The β_x at the exit of B5 is 57 m which determines the minimum dipole magnet gap. The value of the half magnet gap is 16 mm by taking $3\sigma_x$ plus 3mm for the thickness of vacuum chamber and assembly error. The maximum dispersion function occurs at Q2 with η = -2 m and β = 37 m. The beam size of $3\sigma x$ is 16 mm for $\Delta p/p = 10^{-3}$. All these numbers are well accommodated with dipole gap of 36 mm and quadrupole bore radius of 30 mm. The horizontal and the vertical beam profiles of 3 $\sigma_{x,y}$ with and without dispersion function are shown in Fig.2.

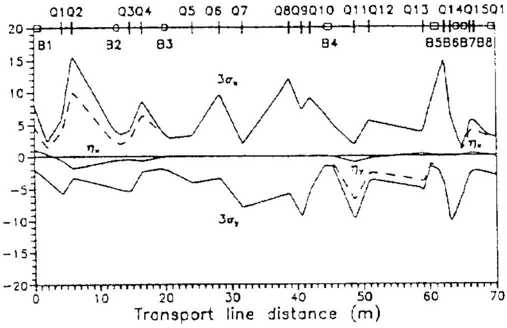

Fig. 2 The horizontal and vertical beam profile of 3 $\sigma_{x,y}$

III: Diagnostic and Correction Scheme

The main task of the diagnostic and the correction scheme in BTS transport line are:

1. Beam position measurement.
2. Energy, energy spread measurement.
3. Emittance measurement.
4. Beam steering.

There are 5 screen monitors and 6 button position monitors in this transport line for beam position measurement. The reason why we use two kinds of monitors is that there are different requirements on commissioning and routine operation and the construction cost can be reduced in this way. The screen monitor, which is a destructive monitor, is mainly used in commissioning stage. Two screen monitors are put between extraction septum and B2 to "see" the beam extracted from the booster and to measure the profile and position of the beam. For the same reason two screen monitors are put between B5 and the injection septum to adjust the beam launch condition. Using any three beam profiles read from screen monitors the emittance of the beam can be calculated. The energy of the beam is obtained by changing the strength of bending magnets and measuring the movement of the orbit. For energy spread measurement the optics are changed by tuning Q1, Q2 and Q3 to blow up the dispersion function and the slit before Q4 is used to measure the beam. The resolution of the energy spread is about 8×10^{-4}. A gap monitor is used to measure the time structure of the beam. Three current transformers are inserted after extraction septum, before Q12 and before injection septum to measure the intensity of the beam. Trim coils in the bending magnet and independent trim magnet after every bending magnet are put as a pair of horizontal and vertical correctors to steer the beam. These correctors combined with the BPM or screen monitors right before the next bending magnet work as a set to correct the orbit. The maximum strength of the corrector is 2 mrad. The location of the diagnostic and the correction elements are shown in Fig.3. A set of typical errors with dipole field error $\Delta B/B = 10^{-3}$,quadrupole displacement error $\Delta x,y = 0.3$ mm and dipole rotation error $\alpha = 0.5$ mrad are put into simulation using application code O.C. developed by ourselves. The results of the beam with these errors before and after corrections are shown in Fig.4.

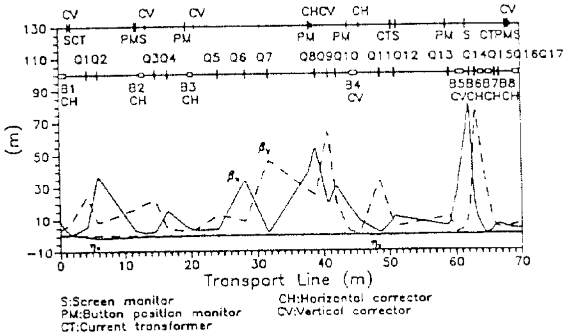

Fig. 3 The diagnostic and corrective scheme

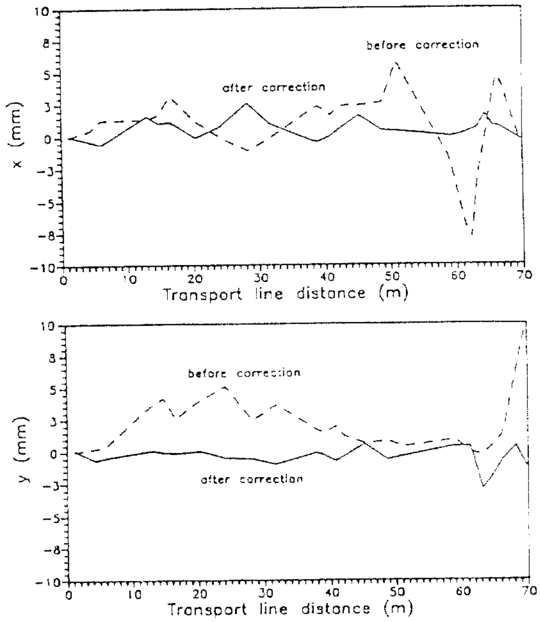

Fig. 4 Orbit distortion before and after correction

A beam dump are reserved after B4. The beam will go straight to the beam dump by turning off the power of the dipole B4. With the screen monitor, BPM and CT placed in the beam dump the beam properties can be studied without interacting with the main storage ring.

IV: Injection Scheme

The injection section is placed in one of the six long straight section of storage ring. The scheme is composed of four 40 cm long fast bumpers and a 1 meter long 2 mm thick septum magnet. The four fast bumpers are symmetrically positioned with respect to the middle point of the long straight section. In this way, all fast bumpers can be of the same strength, independent of the tune, to form a local bump. The septum is located between the two inner bumpers. A schematic layout of the scheme is shown in Fig.5. The oscillation amplitude A at injection is estimated to be A= 8 σ_0+ ES + 3 σ_i=14.2 mm[3]. Where σ_0, σ_i are the stored beam size and the injected beam size at the injection point. ES is the effective septum thickness which includes fringe field effect, vacuum chamber wall and high permeability material for leakage field shielding. It turns out that the aperture required at the injection point determines the Beam Stay Clear (BSC) of the main ring. The BSC at the injection point is 21 mm from the center. Fig.6 illustrate the horizontal phase space acceptance defined by the effective septum position, the bumped ring acceptance, the vacuum chamber wall, the stored beam, the bumped beam, and the injected beam etc. It is shown that the injected beam is accepted by inwardly bumping the stored beam by 17.3 mm. The corresponding strength and field of fast bumper are 11.93 mrad and 1.29 KGauss.

Conclusion:

The design goal of this BTS transport line is to transfer the beam at 1.3 GeV from booster to storage ring efficiently. With the design of the arrangment of the magnets and diagnostic elements this goal can be achieved easily.

Acknowledgement:

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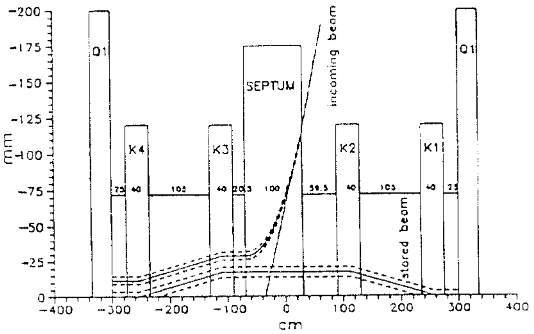

Fig. 5 Schematic layout for injection elements

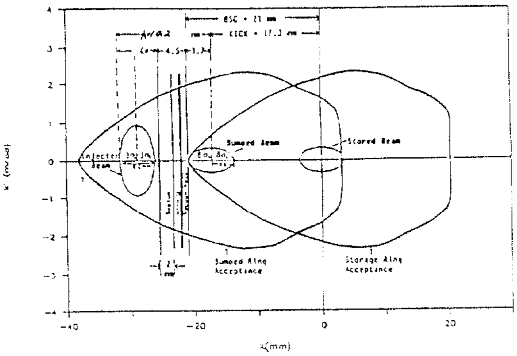

Fig. 6 Horizontal phase space acceptance at injection point

Reference:

[1]: C. S. Hsue, C. C. Kuo, J. C. Lee and M. H. Wang," Lattice Design of the SRRC 1.3 GeV Storage Ring", also presented in this conference.

[2]: S. Tazzari,"Apertures for injection", ESRF-IRM-4/83, 1983.

[3]: C. C. Kuo, S. T. Chou, M. H. Wang and C. S. Hsue," Storage Ring Injection Scheme and Booster to Storage Ring Transport Line", SRRC/BD/89-7, 1989.