THE SLS BOOSTER SYNCHROTRON

C. Gough, G. Irminger, W. Joho, P. Marchand, M. Munoz, V. Schlott, L. Schulz, A. Streun, V. Vrankovic, P. Wiegand, J.A. Zichy, Paul Scherrer Institute, CH5232 Villigen, Switzerland

Abstract

The full energy booster synchrotron for the Swiss Light Source (SLS) will be located in the same tunnel as the 2.4 GeV storage ring. This concept saves building and shielding costs. A FODO lattice with 3 dispersion-free straight sections produces a low emittance beam. The compact magnets can be cycled with a flexible ramping procedure up to 3 Hz, making top-up injection very attractive.

1 INTRODUCTION

For the 2.4 GeV electron storage ring of the Swiss Light Source (SLS) [1] we will build a booster synchrotron as an efficient full energy injector. Instead of building a compact lattice with separated function magnets we will fit the booster into the same tunnel as the storage ring (see Figure 1). With the generous space available for the lattice one can now adopt the idea, originally proposed for storage rings [2] , to distribute the bending over many small combined function magnets.

This design offers a striking number of advantages, which are summarized below:

- substantial saving of building space and shielding.
- economic low field magnets with small aperture.
- simple stainless steel vacuum chamber.
- low power consumption, less than 200 kW at 3 Hz, less than 30 kW for continuous top-up injection.
- flexible repetition rates and field ramping B(time), including operation as a storage ring up to 1.7 GeV.
- low emittance beam (7 nm at extraction at 2.4 GeV) giving a clean injection into the storage ring.
- simple transfer line between booster and ring.

The chosen repetition rate of 3 Hz is:

- Fast enough to fill the storage ring in 2-3 min.
- Slow enough to have low eddy currents induced on the vacuum chamber. This allows a relatively simple construction of the vacuum chamber: a round stainless steel tube, 0.7 mm thick, is deformed into an elliptical cross-section of 30·20 mm^2, requiring no reinforcement ribs.
- Even with all combined function magnets in series the maximum induced voltage is less than 500 V versus ground.

Table 1: SLS Booster Parameters

Maximum Energy	GeV	2.4
Circumference	m	270 = 3·90
Lattice		FODO with 3 straights of 8.68 m
Harmonic number		450=15*30
RF frequency	MHz	500
Peak RF voltage	MV	0.5
Maximum current	mA	12
Maximum rep. Rate	Hz	3
Tunes Q_x, Q_y		(12.39, 8.35)
Chromaticities C_x, C_y		(-14,-12)
Momentum compation factor		0.005
Equilibrium values at 2.4 GeV		
Emittance	nm-rad	9
Radiation loss	keV/turn	233
Energy spread, rms		0.075 %
Partition numbers (x,y,ε)		(1.7, 1, 1.3)
Damping times (x,y,ε)	ms	(11, 19, 14)

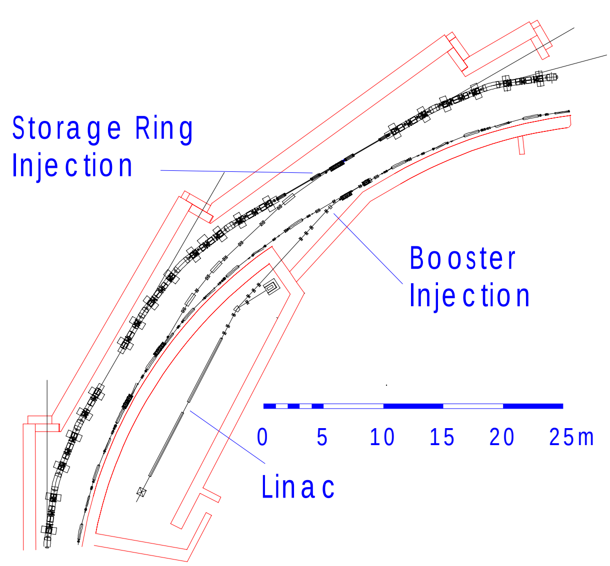

Figure 1: Layout of the tunnel, showing the storage ring, booster, linac and the transfer lines.

A summary of the relevant booster parameters is given in Table 1. The optical functions are shown in Figure 2. The ramping of the booster magnets produces time varying stray fields, which could affect the beam in the storage ring in the top-up injection mode. To avoid this we place the booster directly at the inner wall of the tunnel 2 m away from the storage ring. Access to the ring tunnel will occur from the technical area through five openings in the inner wall. However one has to duck under the vacuum chamber of the booster, placed 1.4 m above the floor.

One price we have to pay for this booster concept is the relatively large number of (small size) components:

- 93 combined function magnets.
- 18 Quadrupoles.
- 18 Sextupoles.
- 108 beam steerers.
- 97 Pumps.

The pre-injector for the booster synchrotron will be a 3 GHz Linac with a minimum energy of 100 MeV.

2 LATTICE

The basic structure of the booster lattice consists of three arcs, each with a 8.68 m long straight section. An Arc has two matching cells plus 13 FODO cells, each with two combined function magnets, BD and BF, separated by 1.44 m long drifts (see Figure 3). We have identical currents in both BD and BF conductors from a common power supply circuit for all dipoles. The magnet BF is actually a half quad with more focusing than bending (see Figure 4). A trim coil is used to compensate for possibly different residual fields between the BF and BD magnets.

Three families of quadrupoles, located in the straight sections, can be used to provide a tuning range of about 1 unit in the horizontal and vertical direction (Figure 5). Apart from a periodic solution in the FODO-structure one can get a solution with lower overall maximum values for

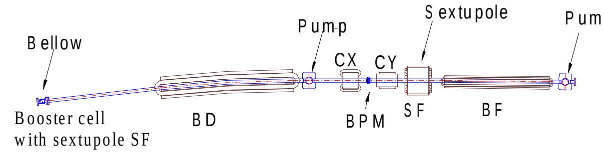

Figure 2: Layout of one FODO cell with 2 combined function magnets (BD and BF), two steerers (CX and CY) and one sample sextupole (SF).

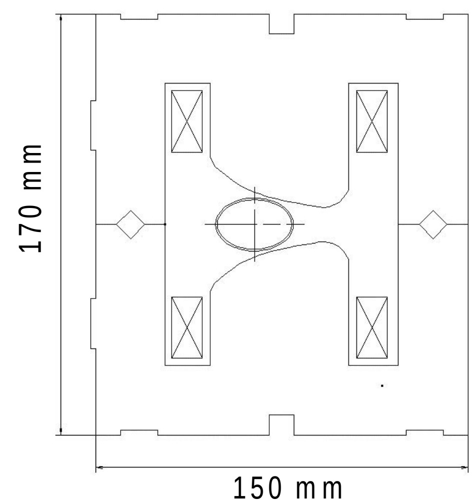

Figure 3: Cross-section of a BF magnet with the 30x20 mm^2 vacuum chamber. The pole profile provides the combined (dipole plus quadrupole plus sextupole) magnetic field.

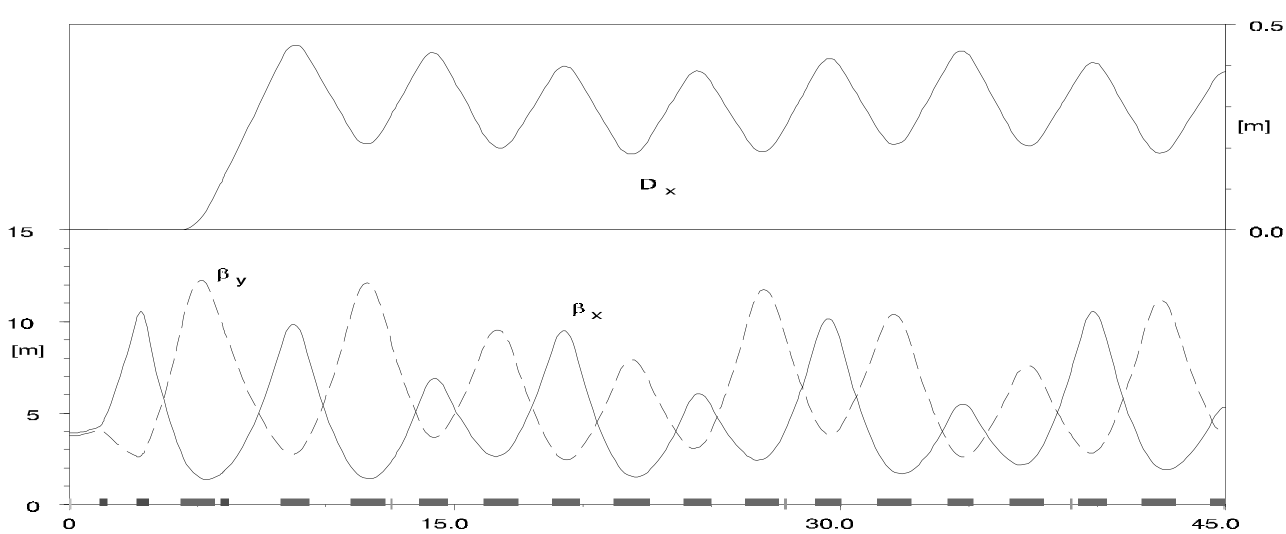

Figure 4: Optical functions for 1/6 of the booster, from center of straight to middle of arc.

the beta functions but at the expense of some beating (see Figure 2). It is advantageous to have the straight sections dispersionless, since both the RF-cavity and the injection elements are located in these straights.

A chromaticity correction is incorporated into the pole profile of the booster dipoles. However we will install two families of sextupoles (SF and SD) with three pairs of sextupoles in each arc. They will give flexibility in optimizing the chromaticity. In addition they will correct the sextupole component induced by eddy currents in the vacuum chamber, estimated to be less than 0.2 m^{-3} in the BD dipole at injection. The choice of about 90° phase advance horizontally and 60° vertically in the FODO cells of the three arcs gives a very efficient correction scheme with non-interleaved sextupoles.

The elliptical vacuum chamber has dimensions of 30*20 mm^2 given by the transversal and longitudinal beam values at injection. We assume a normalized rms emittance at the Linac exit of 50μm rad and a rms energy spread of 0.5 %. Requiring values of 3 σ_x and 3 σ_y for the beam amplitude, and an energy acceptance of 2% leaves us with 4 mm for closed orbit distortion.

This FODO-lattice has surprisingly relaxed tolerances.

The energy acceptance of the lattice would be ±7%, but is actually limited to ±2% at injection by the vacuum chamber and to ±0.43% at 2.4 GeV by the maximum RF voltage of 0.5 MV.

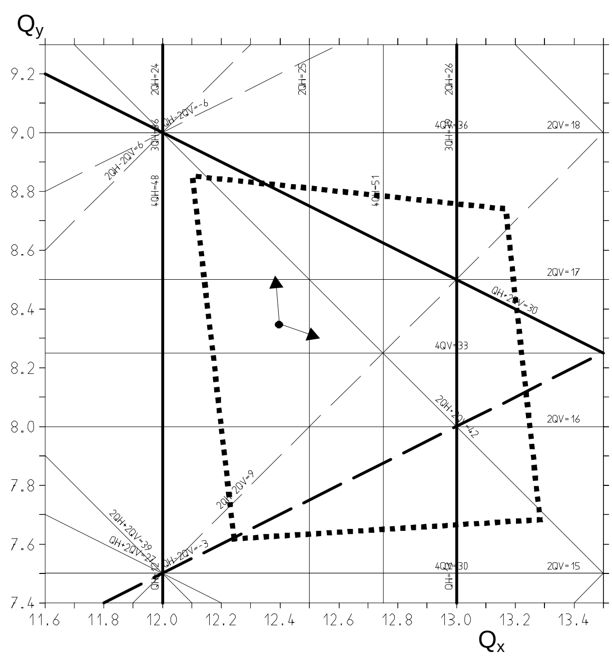

Figure 5: Tune diagram, showing the working point (12.39, 8.35), with the change produced by a 1% gradient error in BD, BF (arrows), the accessible region with the three quadrupole families (dotted line), and the four major resonances (thick lines).

The dynamical aperture is well above the geometrical limits given by the vacuum chamber.

3 VARIA

•Magnet power supply

The maximum stored energy in the BD and BF magnets is only 30 kJ. 80 electrolytic capacitors serve as an energy buffer during the magnet cycle. A switch-mode circuit controls the magnet voltage required for a given current waveform. The standard cycle will be a 3 Hz biased cosine function, but other waveforms are possible as well: A flat bottom of a few seconds between pulses is ideal for top-up injection at a very low power level. Even DC operation as a storage ring up to 1.7 GeV is feasible.

•RF

The same 500 MHz monocell cavity and the same klystron as in the storage ring will be used.

•Extraction

Extraction from the booster occurs from a drift in the regular arc section, leading to a short transfer line between booster and storage ring (see Figure 1). The large circumference of the booster gives a revolution time of 0.9 μs and allows a relaxed kicker rise time of about 0.2 μs.

•Diagnostics

A total of 54 Beam Position Monitors can register the beam during its acceleration cycle. In addition we will have 5 Optical Transition Radiation Screens and 3 Synchrotron Radiation Monitors, the latter for non-intercepting profile measurements.

CONCLUSIONS

The Booster Synchrotron for the SLS project is an economic full energy injector producing a low emittance beam at a flexible repetition rate, suitable for topping-up mode. Commissioning should start in the summer of 2000.

ACKNOWLEDGMENTS

We would like to thank G.Muelhaupt for triggering the idea of a small emittance booster and L.Rivkin and A.Wrulich for many stimulating discussions.

REFERENCES

[1] W.D. Klotz, G. Mülhaupt, “Another Lattice Model for High Brightness Synchrotron Radiation Sources” ESRF-LAT-88-07, 1988

[2] A.Streun et al, “The SLS Accelerator Complex, an Overview”, this conference.