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Title :

The SESAME Booster- Storage Ring Transfer Line TL2

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Revision table

Rev #	*date*	*Done by*	*Remarks*
1	12/3/2015	Click here to enter text.	• Quadrupole k-values, optics are changed. • Some distances slightly modified to cope with engineering layout.
2	10/5/2015	Click here to enter text.	• Some distances slightly modified to cope with engineering layout, injection septum length increased from 0.5 to 0.75m. • Some Quadrupole k-values slightly modified
3	Click here to enter a date.	Click here to enter text.	Click here to enter text.

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The SESAME Booster- Storage Ring Transfer Line TL2

Introduction

The transfer line TL2 will be used to transport the 800MeV Booster electron beam into the Storage ring. The original TL2 was designed assuming that Booster and the Storage Ring will have the same beam height 120cm [1]. Increasing the Storage Ring beam height to 140cm resulted in a change in TL2 design by inserting two vertical dipoles used to create a 20cm vertical step, in addition to three strong quadrupoles used to cancel the created vertical dispersion [2]. However, later on, a decision was taken not to cancel the negligible-impact created vertical dispersion, hence no need became for the strong quadrupoles anymore. Consequently, the previous TL2 [2] structure was modified to produce the final version of TL2, presented in this note, where its elements are those of BESSY TL2 except the two vertical dipoles and their vacuum chambers which are being designed by SESAME. We tried to build TL2 using, as much as possible, BESSY old components of the lattice elements, correctors and diagnostics.

1. The booster-storage ring transfer line TL2

The new structure of TL2 taken into account the following points:

- Keeping the booster area as less crowded as possible, hence one qudarupole is used there.
- Reducing the number of magnets in the section between the two vertical dipoles (which has ~ 1.97^o slope) in order to make alignment as smooth as possible. So only a doublet of quadrupoles, that can be fixed on one girder, is used there.
- Having flexibility in matching different optics conditions at the injection point in the storage ring, so a triplet is used there, keeping a space for passage.

It is taken into account to keep the quadrupoles gradients below their maximum value 12 T/m (k = ±4.5 m^{-2} @ 800 MeV) in any optical matching condition.

The 25.3506 m structure and magnetic parameters of TL2 are listed in Table 1, with quadrupoles strengths matching the nominal optics in the storage ring. In Table 1 D, QD, QF refer to distance, defocusing quadrupole, and focusing quadrupole respectively, whereas BEND and VBEND refer to the normal horizontal bending and vertical bending respectively. The corresponding optical functions are shown in Fig. 1. The optical parameters used at the starting point of TL2 are those at the booster extraction point (i.e. starting of the extraction septum) which is 15 cm downstream the QF quadrupole in the extraction section. These parameters are β_x = 5.655 m, α_x = -0.1586, β_y = 2.857 m, α_y = -0.342, η_x = 1.603 m, and $\eta_x^/$ = 0. They correspond to the optics with working point (2.25, 1.41).

Element	**θ (^{o})**	**ρ (m)**	**Length (m)**	**k (m $^{-2}$)**	**I (A)**
Extraction septum	-10	-5.874	1.0252		
D1			1.997		
Q1 (QD1)			0.25	-1.4311	13.65
D2			3.05		
Q2 (QF1)			0.25	1.3645	13.01
D3			1		
BEND1	23.5	2.66852	1.09450		875
D4			0.59653		
VBEND1	1.9678	11.3554	0.3905		202.05
D5			2.240		
Q3 (QD2)			0.25	-2.5011	23.85
D6			0.35		
Q4 (QF2)			0.25	2.3581	22.49
D7			2.2459		
VBEND2	-1.9678	-11.3554	0.3905		202.05
D8			0.460		
BEND2	23.5	2.66852	1.0945		875
D9			0.60		
Q5 (QF3)			0.25	1.4097	13.44
D10			2.2820		
Q6 (QD3)			0.25	-2.1856	20.84
D11			1.35		
Q7 (QF4)			0.25	2.5576	24.39
D12			1.148		
Thick septum	15	2.66852	0.6986		875
D13			0.70426		
Injection septum	9	4.77466	0.75		

Table 1

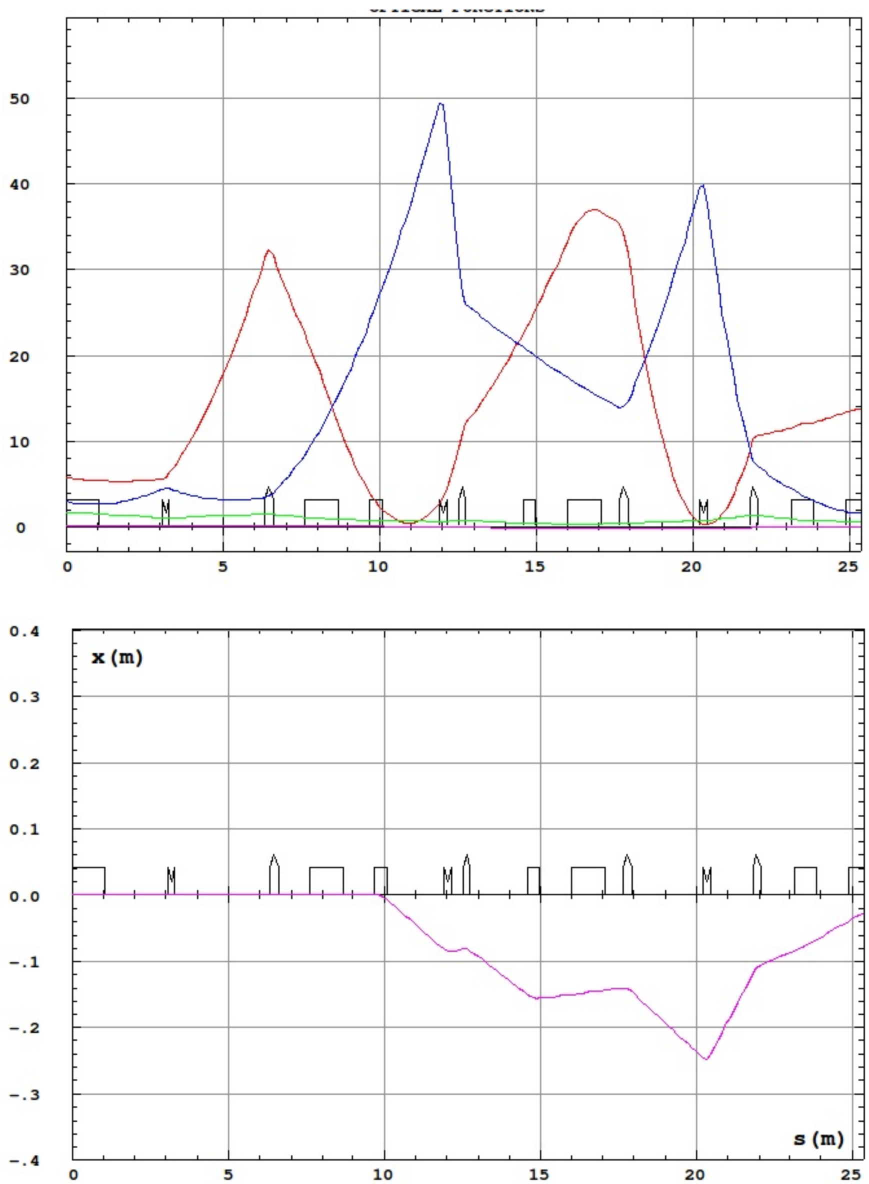

Figure1: Nominal optics of transfer line TL2 (top) with full matching to the ring optical values: β_x = 13.61m, β_y = 1.61m, η_x = 0.53 and $\alpha_x = \alpha_y = \eta_x' = 0$. (bottom) Propagation of the vertical dispersion created by the vertical dipoles.

It is worth mentioning that the TL2 quadrupoles (which are BESSY I components) have a maximum gradient of 14 T/m corresponding to current of 50 A. Moreover the gap of the water-cooled vertical dipole's has been reduced from 40 mm to 36 mm, which reduced the required nominal current from 224.5 A to 202 A.

The corresponding 3 rms beam size is shown in Fig. 2. It is calculated using booster emittance 300 nm.rad and 1rms energy spread 3e-4 as given at full energy.

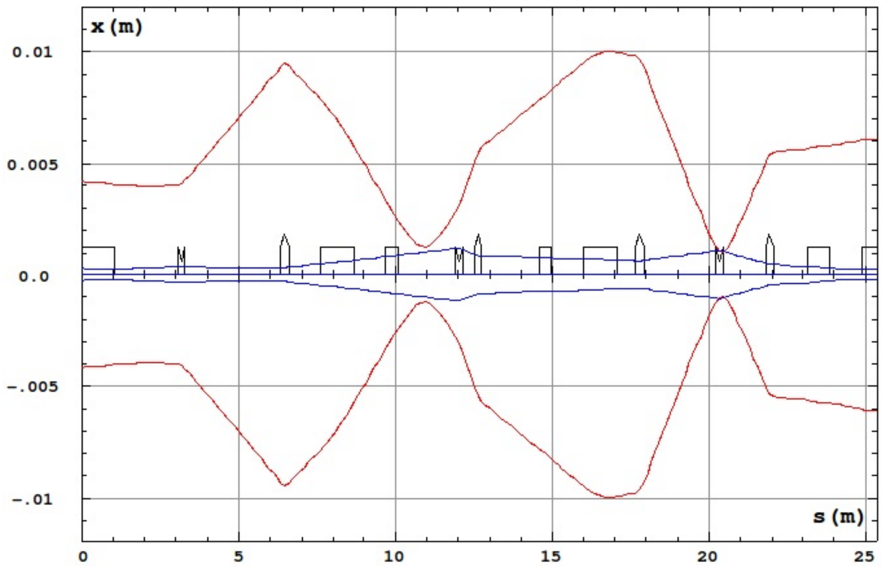

Figure 2: The 3 rms beam size along TL2. Horizontal size is in red and the vertical one is in blue.

To check flexibility of TL2 lattice in matching different optical conditions in the storage ring, many matching cases have been tried taking into account that quadrupole strengths are always within the range of the existing ones. One case is shown in Fig. 3 where the TL2 optics is matched to storage ring optics but with β_x = 3m, and the corresponding quadrupole strengths are listed in Table 2.

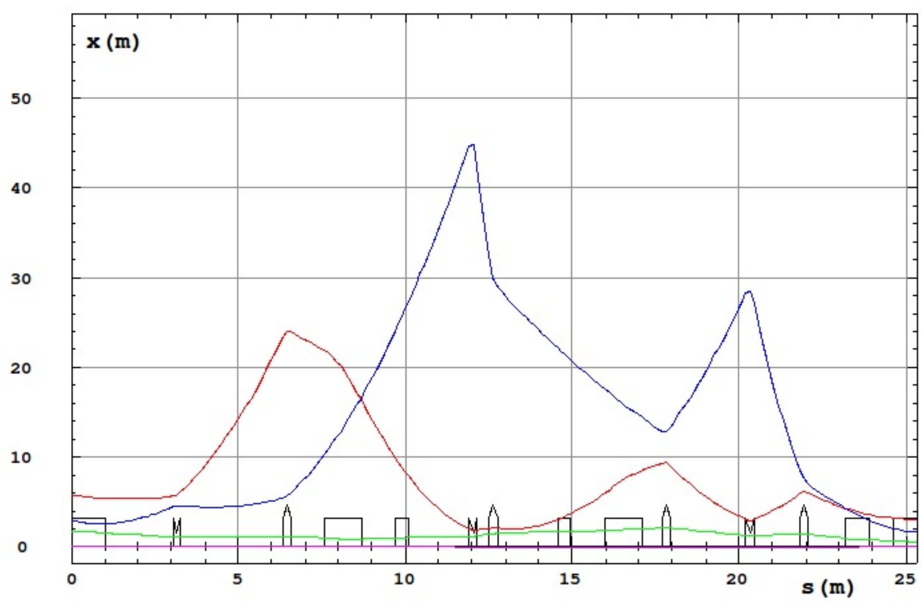

Figure 3: Optics of transfer line TL2 with matching to the optical values: β_x = 3m, β_y = 1.61m, η_x = 0.53 and $\alpha_x = \alpha_y = \eta_x' = 0$.

Quadrupole	k-value (m^{-2})
Q1	-0.996
Q2	0.853
Q3	-1.857
Q4	1.386
Q5	1.166
Q6	-1.845
Q7	1.631

Table 2

5. The TL2 dipole correctors

In order to have more efficient beam trajectory correctors, their distribution in TL2 should follow the optics such that a horizontal/ vertical corrector should be installed where the horizontal/ vertical betatron functions have as large values as possible. On the other hand, the corrector distribution is governed also by the lattice structure. Figure 4 shows the foreseen structure of TL2 dipole correctors.

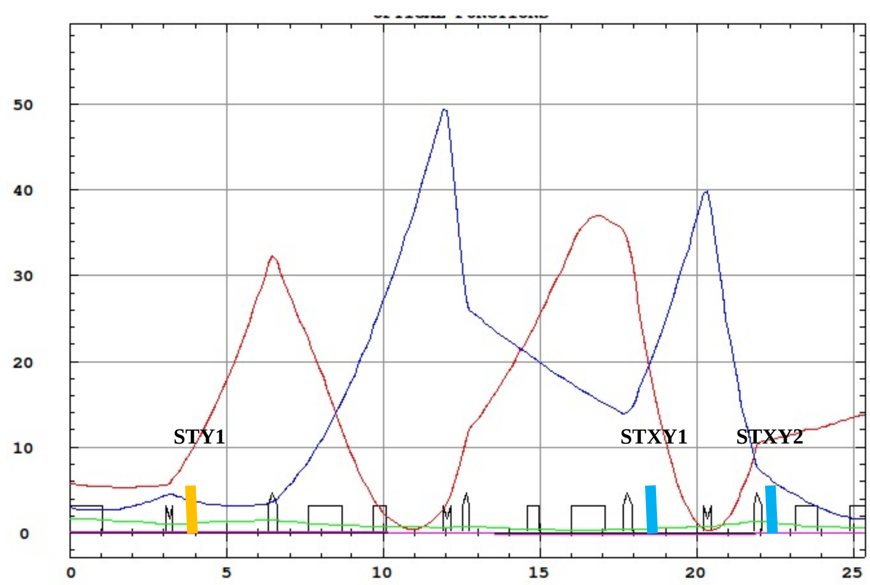

Figure 4: Corrector distribution of transfer line TL2: (Orange) Vertical corrector STY, and (light blue) horizontal-vertical corrector STXY.

This distribution is chosen based on the fact that each of the horizontal and vertical bending magnets of TL2 will have independent power supply which enables them to be used as correctors too [3]. The first corrector STY1 is foreseen to be vertical one, since the beam horizontal steering is assumed to be done by the booster extraction system. The corrector STXY1 will be used to center the beam into the next doublet and thick septum. The final corrector STXY2 will be used mainly to control the horizontal and vertical angles of the injected beam into storage ring.

6. The TL2 diagnostics

The beam diagnostics of TL2 are mainly needed to define the beam position which can be done using Florescent Screens (FS) and the beam current in the transfer line which can be defined using Fast Current Transformers. Distribution of these components [4] is shown in Fig. 4.

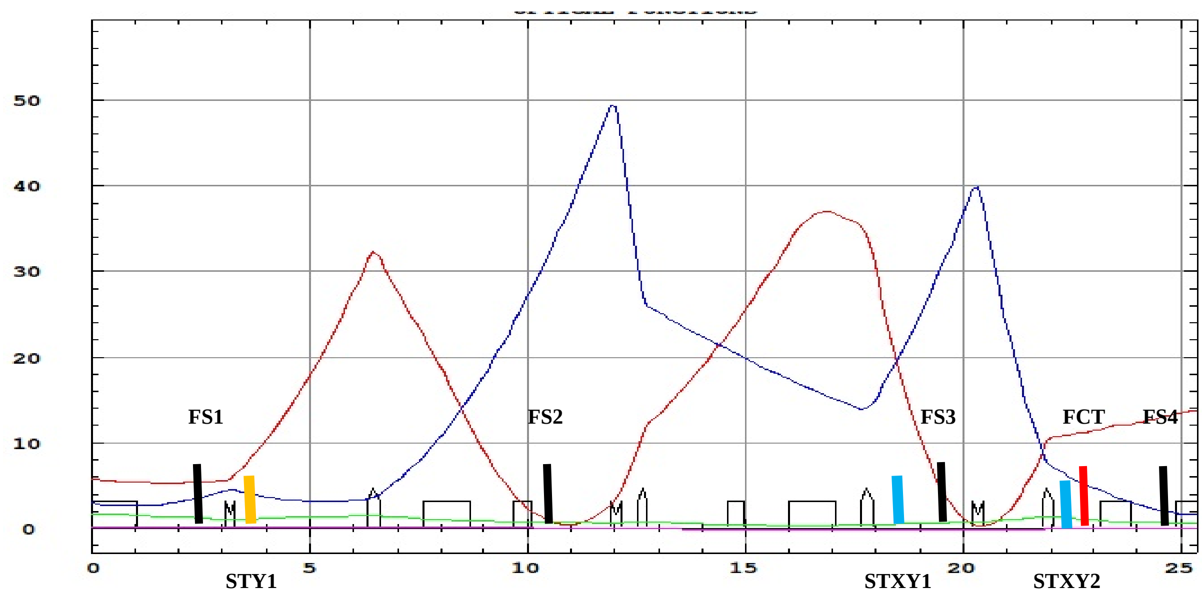

Figure 4: Distribution of diagnostics in transfer line TL2; (black) florescent screens, (red) FCT.

The first 3 screens can be those of old BESSY transfer line (in air screens) while FS4 can be used also for emittance measurement, using the upstream focusing quadrupole, so it needs to be in vacuum screen.

7. The misalignment tolerances of TL2 magnets

The tolerance on magnetic misalignment in TL2 was investigated using beam deviation at entrance of injection septum and the maximum deviation all over the beam line as criteria. Defining the misalignment tolerances was a compromise between what is easy to achieve by alignment and what is as less disturbing as possible to the beam trajectory.

The impact of misalignment on beam trajectory is different from magnet to another depending on strength and location of that magnet relative to TL2 optics. Table 3 lists the maximum allowed rms magnetic transverse displacements dx, dz, longitudinal displacement ds, and rotations around x, z, s-axis. It would be better if these errors are even more minimized during installation.

Magnet	**dx (mm)**	**dz (mm)**	**ds (mm)**	**dϕ_x (mrad)**	**dϕ_z (mrad)**	**dϕ_s (mrad)**
Q1	0.5	0.3	1	0.5	0.5	0.5
Q2	0.3	0.5	1	0.5	0.5	0.5
Q3	0.5	0.2	1	0.5	0.5	0.5
Q4	0.5	0.2	1	0.5	0.5	0.5
Q5	0.3	0.3	1	0.5	0.5	0.5
Q6	0.5	0.2	1	0.5	0.5	0.5
Q7	0.3	0.3	1	0.5	0.5	0.5
BEND1	1	1	1	0.5	0.5	0.5
BEND2	1	1	1	0.5	0.5	0.5
VBEND1	0.5	0.5	1	0.5	0.5	0.5
VBEND2	0.5	0.5	1	0.5	0.5	0.5
Correctors	1	1	1	0.5	0.5	0.5
Thick septum	0.5	0.5	0.5	0.5	0.5	0.5
Inject. septum	0.2	0.2	0.5	0.5	0.5	0.5

Table 3: The tolerances on TL2 magnet misalignments.

References

[1] M. Attal & A. Amro, Technical Note,"*The Trnasfer Line TL2*".

[2] M. Attal, Technical Note, "*Vertical Step in the Transfer Line TL2*".

[3] Internal discussion with E. Huttel.

[4] Internal discussion with E. Huttel and D. Foudeh.