DESIGN OF BEAM TRANSFER LINES FOR THE NSLS II*

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Abstract

The NSLS-II light source [1] which is a proposed facility to be built at Brookhaven National Laboratory utilizes two synchrotron accelerator rings: the booster and the Storage ring (SR). Designing the NSLS-II injector we considered two options for the booster layout, where the rings either a) share the same tunnel, but placed at different horizontal planes or b) booster is located in a separate building.

The booster which accepts beam from the linac, accelerates the electron beam to an energy of 3.0 GeV and the beam is extracted to the Booster to Storage Ring (BtS) transport line which transports the beam and injects it into the SR ring.

The design procedure for each of the two options of the BtS line and other details about the optics and the magnetic elements of the line are presented in this paper.

INTRODUCTION

The Booster to Storage ring (BtS) transport line transports the electron bunches from the Booster synchrotron to the Storage Ring (SR). We considered two options for the NSLS-II injector [2], where either a) booster and storage ring share the same tunnel, but placed at different horizontal planes or b) booster is located in a separate building. Figure 1 is a drawing of the BtS transport line for the two different options (a) (top drawing), and (b) (bottom drawing). The design principles are quite different for the transport lines for these cases. In the paper we discuss first the BtS design for the in-tunnel booster, where space is constrained by the SR tunnel and layout of the SR magnetic elements. Special attention has been paid to cancellation of vertical dispersion at the ring injection point, which is of a high importance for low-loss top-off injection. Secondly we discuss ongoing design of the BtS for the booster located in the separate tunnel.

THE "BOOSTER TO STORAGE RING" TRANPORT LINE (I)

Since the median plane of the SR is located at a lower plane, the BtS line must transport the beam from the median plane of the Booster to the median plane of the SR ring. The starting and end points of the BtS line coincide with the extraction and injection points of the Booster synchrotron and SR ring respectively. Therefore the main optical constraint of the BtS line is that the beginning of the line is matched to the beam parameters of the extraction point of the Booster and the end of the line is matched to those at the injection point of SR Ring. To ease the design of the transport line we partitioned the line in three sections; the first section ("first horizontal achromat") forms an achromatic line and is matched to the beam parameters at the extraction point of the Booster and is also matched to the beam parameters of the starting point of the second section ("Vertical drop achromat"). The "Vertical drop achromat" line-section, transports the beam from the plane of the Booster ring down to the plane of the SR ring. This line-section forms a "dog leg" and is designed to be achromatic in both planes, and defines the Twiss parameters of the BtS line at the beginning and the end points of the "Vertical drop achromat" line-section. The third section of the line ("second horizontal achromat") is matched to the beam parameters at the exit of the "Vertical drop achromat" section, and also to those at the injection point of the SR ring. The procedure for the design of the BtS line and other details about the optics and the magnetic elements of the line will be presented in the paper.

PROCEDURE TO DESIGN THE "BTS" TRANPORT LINE (I)

In this section we describe the design procedure of the BtS line and also present the optical beam parameters (α_{xy}, β_{xy}, η_{xy}) along each of the sections of the BtS transport line.

The "Vertical drop achromat" Section

The main function of this section is to "drop" the beam from the plane of the Booster down to the plane of the SR ring. This vertical drop amounts to a distance of 1.4 m. Although this is the second section of the transport line we present it first, because in this line-section in which we "fix" the beam parameters at the beginning and end of the section with the purpose to satisfy the following constraints: a) the section should be achromatic. b) the maximum value of the function $\beta_{x,y}$ along the section should be less than 30 m, c) the maximum strength of the quadrupoles should be less than 2.2 m^{-2}. This line-section is comprised of two dipoles, one placed at the beginning and the other at the end of the section, and five quadrupoles which help to satisfy the constraints mentioned above. The relative locations of these magnetic elements appear in Figure 1 and Figure 2 as "red" boxes. In Figure 2, plotted are, the beam parameters $\beta_{x,y}$ and $\eta_{x,y}$ of the whole line. The strength of each magnetic element used in this section of the line appears in Table 1.

Table 1: Bend angles of dipoles and $K_1 \cdot L$ values of the quads of the "Vertical drop achromat" line-section.

D1 [mrad]	Q1 [m^{-1}]	Q2 [m^{-1}]	Q3 [m^{-1}]	Q4 [m^{-1}]	Q5 [m^{-1}]	D2 [mrad]
0.108	0.109	-0.66	0.442	-0.66	0.109	0.108

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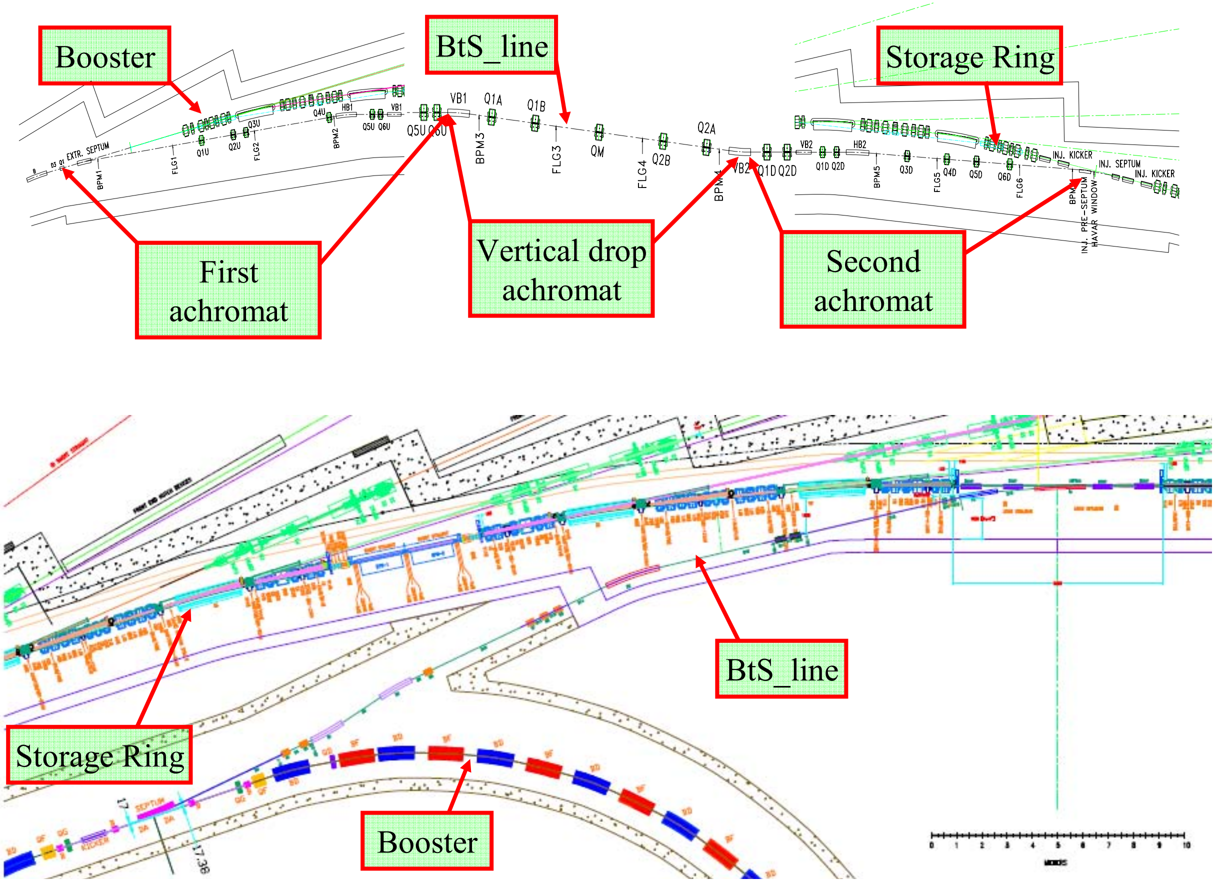

Figure 1: Drawing of the two proposed BtS transfer lines. In the top drawing, Booster and SR share the same tunnel. The three line-sections of the BtS line described in the text are labeled and their extend is indicated by red arrows. In the bottom drawing Booster and SR are in separate buildings.

The "first horizontal achromat" Section

This section of the line, transports the beam from the extraction point of the "Booster" to the starting point of the "Vertical drop achromat" section. This section of the beam transport line satisfies constraints: a) The beam at the exit of the section should be achromatic, b) The beam parameters at the start and end of the section should be matched to the beam parameters at the extraction point of the "Booster" and to the beam parameters of the starting of the "Vertical drop achromat" section respectively. c) the maximum value of the $\beta_{x,y}$ functions should be ~60 m. The magnetic elements required are two dipoles, one of which is the extraction septum, and six quadrupoles and are shown as the first set of blue boxes in Figure 2.

Table 2: Bend angles of dipoles and K_1L values of the quads of the "First Horizontal achromat" line-section.

D1 [mrad]	Q1 Q2 [m^{-1}]	Q3 Q4 [m^{-1}]	D2 [mrad]	Q5 Q6 [m^{-1}]
0.090	0.040 -0.260	0.394 -0.321	0.137	0.646 -0.437

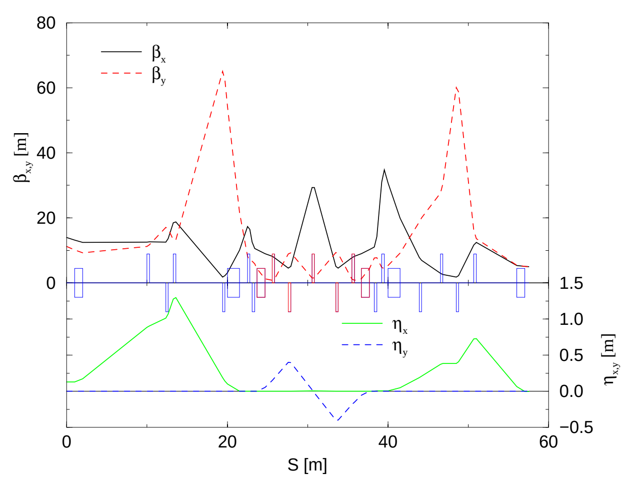

Figure 2: The $\beta_{x,y}$ and $\eta_{x,y}$ functions along the BtS transport line. The "blue" and "red" wide rectangular boxes are the dipoles and thin ones are the quadrupoles used in the transport line respectively. The magnetic elements of "Vertical drop achromat" line-section are the "red" rectangular boxes.

In the same figure, plotted are, the beam parameters $\beta_{x,y}$ and $\eta_{x,y}$ of the whole line. The strength of each magnetic element used in this section of the line appears in Table 2.

The "second horizontal achromat" Section

This section transports the beam from the exit point of the of the "Vertical drop achromat" section to the injection point of the SR ring. This section of the beam-transport line satisfies the following constraints: a) the section should be achromatic, b) the beam parameters at the start and end of this section should be matched to the beam parameters at the exit of the "Vertical drop achromat" line-section and to the beam parameters at the injection point of the SR ring respectively, and c) the maximum value of the $\beta_{x,y}$ functions should be ~60 m. The relative location of these elements are shown in the top drawing of Figure 1 and also, as the second set of "blue" boxes in Figure 2. In the same figure, plotted are, the beam parameters $\beta_{x,y}$ and $\eta_{x,y}$ of the whole line. The strength of each magnetic element used in this line-section appears in Table 3.

Table 3: Bend angles of dipoles and K_1L values of the quads of the "Second Horizontal achromat" line-section.

Q1 Q2 [m^{-1}]	D1 [mrad]	Q3 Q4 [m^{-1}]	D2 [mrad]	Q5 Q6 [m^{-1}]
-0.749 0.614	0.060	-0.555 0.185	0.132	-0.419 0.404

THE "BOOSTER TO STORAGE RING" TRANPORT LINE (II)

The BtS layout for the booster located in a separate building is simplified in comparison with the previous discussion largely due to the fact that the rings are located in the same plane. We are designing the BtS considering: a) reasonable overall length, quantity and strength of the magnetic components and electron beam sizes throughout the BtS, b) minimum separation of the booster and ring elements of about 10 meters for reducing potential magnetic cross-talk, c) having no magnetic elements blocking pathway in the storage ring tunnel (adjacent to the ring injection straight), d) careful matching of the Twiss parameters at the ring injection point, e) independent control of dispersion, horizontal and vertical beta-functions throughout the transport line and f) possibility of having effective diagnostics for the beam characterization during the commissioning stage.

The current BtS layout and lattice are shown in Figure 3, where we start from two booster extraction bumpers with a kicker in between followed by the extraction septum. At this point the beam is out of the booster and enters a horizontal dog-leg comprised out of a doublet and a pair of dipoles for the dispersion cancellation and beta-function matching.

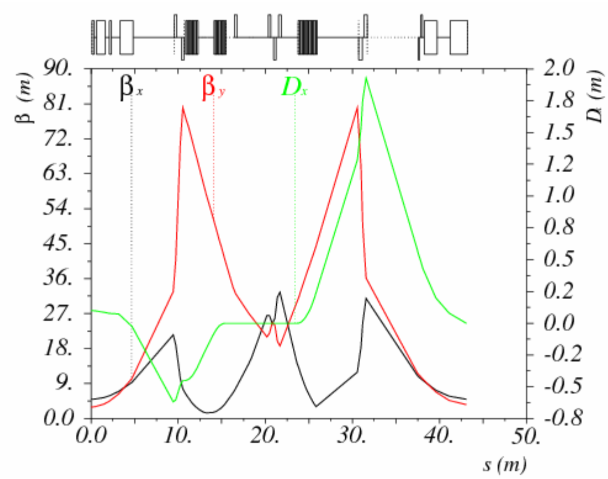

Figure 3: The current BtS layout and lattice.

The following dispersion-free straight section contains a quadrupole and a triplet for the Twiss parameter matching at the injection point. The next part of the BtS is an achromatic bend that ends by the ring injection pre-septum and septum. At the septum's end we cancel the dispersion and obtain the desired Twiss parameters.

So far we needed only 8 quadrupoles for the whole BtS and are planning to place additional weak quadrupoles (as the short doublet just before the injection pre-septum) for increasing the lattice flexibility. We are also including diagnostics, trajectory correction and safety devices as this BtS layout corresponds to the current booster design.

BEAM DIAGNOSTICS "BOOSTER TO STORAGE RING" TRANPORT LINE

The BtS transport line will accommodate ten fluorescent flags accompanied by ten BPM's with log-ratio receivers. Two charge monitors, one placed upstream and the other downstream of the line, will be used for measuring injection efficiency into the storage ring.

REFERENCES

[1] http://www.bnl.gov/nsls2/project/CDR/
[2] T. Shaftan *et al.*, "Conceptual Design of the NSLS-II Injection System," these Proceedings

