BEAM TRANSFER LINE FOR SYNCHROTRON RADIATION SOURCE INDUS-2

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Abstract

The synchrotron radiation source Indus-2 has a 700 MeV synchrotron as an injector. A beam transfer line for transferring the beam from the synchrotron to Indus-2 is nearly 90 meters long due to the locations of the rings. The optics of this line has been chosen in order to keep the number of magnets and their power supplies to a minimum. A FODO cell repeated several times and powered by a single power supply covers a majority length of this line. Part of this line is the transfer line used from the synchrotron to a 450 MeV synchrotron radiation source Indus-1 which is already commissioned.

1 INTRODUCTION

Beam Transfer Line-3 (TL-3) will transfer a 700 MeV electron beam from the synchrotron to 2.5 GeV storage ring Indus-2. Part of the Transfer Line-2 (TL-2) which transfers the 450 MeV beam from the synchrotron to Indus-1 (a storage ring operating at 450 MeV) and is being routinely operated for injecting into Indus-1 is included in this line. The physical distance between the synchrotron and Indus-2 is chosen on the basis of the building layout which provides an adequate space for beam lines and other facilities. Total length of this line is nearly 90 m. The transfer line design is optimized to transfer the beam optimally and to meet the beam optics requirements at the injection point. The optics is optimally chosen in order to keep the beam sizes to low values throughout the transfer line. The number of magnetic components is kept to minimum while achieving this. The design of part of the line chooses a symmetric structure, repeated number of times so that a single power supply can power a number of magnets. This paper describes the design strategies of this line. Design and operational experience of Transfer Line-1(TL-1: transfers 20 MeV electron beam from preinjector microtron to the synchrotron) and TL-2 has been used in deciding the magnet specifications and the beam diagnostics devices.

2 DESIGN STRATEGY

A layout of the TL-3 in the Indus complex is shown in Figure 1. As a part of TL-3 includes part of TL-2, six quadrupoles (Q1-Q6) and one bending magnet (B1), steering magnets and beam diagnostics devices of this part of TL-2 are available in TL-3.

The first quadrupole doublet(Q1,Q2) and the bending magnet(B1) after the extraction septum (ES) of the synchrotron makes the horizontal dispersion and its derivative zero, so that their contribution in the rest of the line remains zero.

To cover majority of the line with a symmetric structure, various studies were carried out using different quadrupole doublets, FODO cells and symmetric quadrupole triplets. Finally the FODO cell has been chosen as it satisfies all the necessary requirements. The main constraint on the drift space of this FODO comes from the fact that the thick wall between Indus-1 and Indus-2 buildings does not allow placement of any quadrupole for nearly 5.5 m. Thus the drift between the quadrupoles is chosen as 5.5 m and the drift before and after the quadrupoles is chosen as 2 m. This gives moderate beta functions and also a total length of 10.1 m (including lengths of the quadrupoles) can be covered using a single FODO cell. The quadrupole strength of 1 m^{-2} gives the phase advance of nearly 90° and thus minimum of betamax as shown in Figure 2.

The four independently powered quadrupoles of TL-2 (Q3,Q4,Q5,Q6) after B1 are varied to match the necessary beam parameters at the input of this FODO cell. The polarities of these quadrupoles are kept same as used in TL-2, as this part of the line will be switched over as required for the injection into Indus-1 or Indus-2. FODO is repeated 1.5 times before the achromat.

As it is necessary to change the direction of the beam after crossing the hole between these two buildings and at the same time, to keep the remaining line achromatic, an achromat was introduced. To repeat the same FODO cell after this achromat, it is necessary not to disturb the input at the FODO entrance. Achromat is chosen in such a way that the achromaticity is maintained while keeping the required beam parameters at the exit. The achromat includes two 8.5° bending magnets (B2) and a symmetric quadrupole triplet (FDF). As, after the achromat, FODO cells have to be repeated, the necessary condition is to match the lattice functions at the input of the FODO while keeping the achromatic conditions. To achieve this, a symmetric quadrupole triplet FDF has been chosen. The strengths of the quadrupoles have been chosen such that the dispersion function and its derivative become zero after second bending magnet and the alphas in both the planes are zero in the centre of the D quadrupole which is at the center of the achromat. Thus, the structure becomes mirror symmetric and thus can be matched to the FODO input. The lengths of the drift spaces have been optimized to achieve this. The bending magnets in the achromat are rectangular magnets and will be powered using a single power supply. Two F-quadrupoles will be powered using a single power supply and D-quadrupole will be powered independently.

After an achromat, FODO cell is repeated 3 times to cover majority of the line. The operating range for the FODO quadrupoles is kept as 1.2-4 T/m and all nine quadrupoles will be powered using a single power supply.

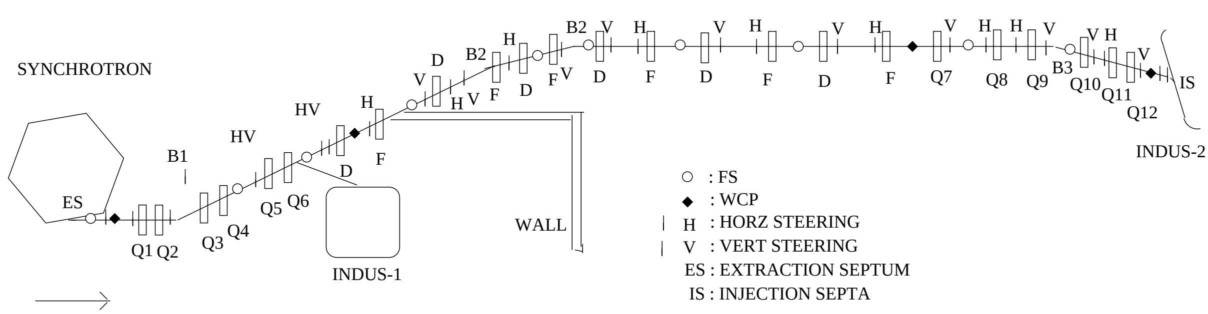

Figure 1: Layout of Transfer Line-3

The last section of the line includes six quadrupoles (Q7,Q8,Q9,Q10,Q11,Q12), one bending magnet (B3) and a thin and a thick septum magnets (indicated as IS in Figure 1). To take care of the dispersion effects of the thin and thick septa, a bending magnet B3 which bends the beam by 14.5° is used. The six quadrupoles match twiss parameters in both the planes and make dispersion function and its derivative zero as required at the injection point. These six quadrupoles are all independently powered and can be varied in a wide range to change the beam parameters at the injection point if required. The beta functions can be varied between 1-20 m while keeping alpha equal to zero. A large operating range of 4-11 T/m have been provided in these quadrupoles for this. The combination of three quadrupoles before the bending magnet and three after, keep the maximum beta function within acceptable limits. The drift spaces between these quadrupoles, bending magnet and septa have been chosen keeping in view the locations of beam diagnostics devices, steering magnets and the transverse space available near Indus-2 components. The lattice functions for TL-3 are shown in Figure 3. The computer program TRANSPORT [3] has been used for designing this line.

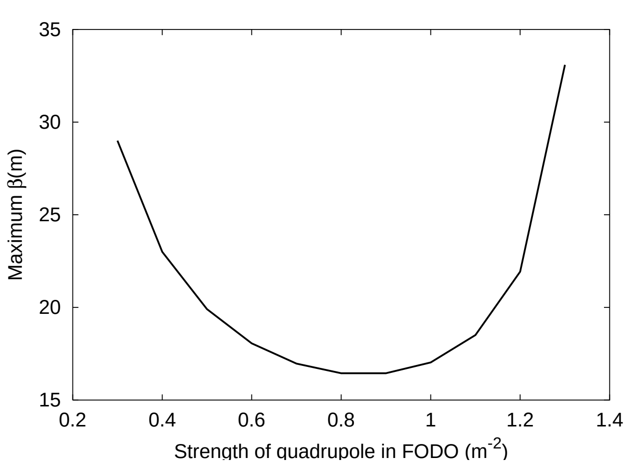

Figure 2: β_{max} as a function of FODO quadrupole strength

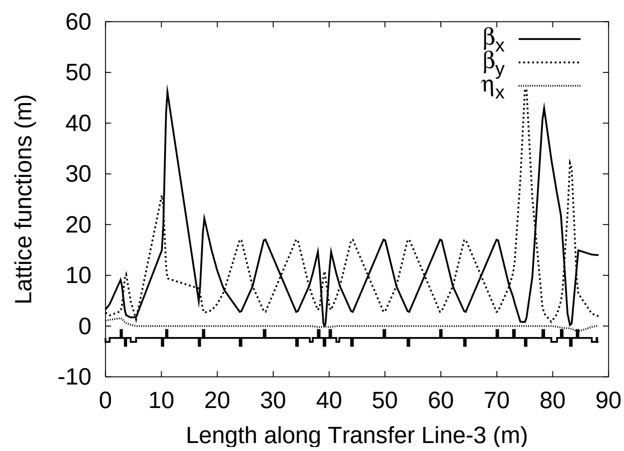

Figure 3: Lattice functions in TL-3

3 BEAM STEERING AND BEAM DIAGNOSTICS ELEMENTS

Due to magnet placement errors, beam may not travel on the design path. It will be possible to steer the beam properly throughout the transfer line using 11 horizontal and 12 vertical independently powered steering magnets (in addition to steering magnets of TL-2). As two bending magnets (B2) are powered by a single power supply, they have additional coil on each of them. With the maximum allowable magnet misalignments of transverse magnet displacement of 0.2 mm and rotations along the axes equal to 1 mrad, the centroid shift has been estimated for various random numbers. In the worse case, the uncorrected centroid can be as high as 17 mm, using the available steering magnets, it can be brought down to 4 mm. The steering magnets can provide a maximum deflection of $\pm$ 5mrad.

To observe the beam spot in the transfer line, remotely operated fluorescence screen (FS) viewed with CCD will be used. The numbers and the locations of FSs have been decided on the basis of the commissioning and operating experience with TL-1 and TL-2. In the FODO cells, the FSs are located at the symmetry locations which will enable to adjust matching of beam parameters at the FODO entrance. Total 8 screens are provided in TL-3. Four wall current pickup (WCP) monitors are proposed at the critical locations to measure the beam current and adjust the beam transfer properly. These diagnostics devices are excluding that in present in existing TL-2. It is also proposed to paint the entering faces of the thin and thick speta by the fluorescence material and view through CCD to enable to pass the beam through septum aperture correctly. Such painting is used for extraction septum of the synchrotron and the injection septum of Indus-1 and has been found to be extremely useful during commissioning and routine operations [4]. There is a provision in the line to install a Secondary Emission Wire Monitor for profile measurement.

Considering the parameters of the extracted beam from the synchrotron, the maximum beta functions in the line and the centroid shift, vacuum chamber inner diameter equal to 45 mm has been chosen for the entire line excepting at the bending magnet locations. At bending magnet locations, the beam sizes are smaller and an aperture of x= $\pm$20 mm and z= $\pm$15 mm has been chosen. Due to uniform circular pipe throughout the line, it will be easier to shift the steering magnets if required. The last two vertical steering magnets and one horizontal steering magnet before the injection septa will be varied alongwith the septum current while observing the FS located inside Indus-2 ring after the injection and WCP installed in the ring.

Pressure in the line will be maintained better than 100 nTorr using sputter ion pumps. The vacuum status will be available in the control room. Gate valves are provided at few locations in the line so as to expose only part of the line if required.

4 MISMATCHINGS AND FAILURES

As majority of the line is covered by the FODO cells powered by a single power supply, the following simulations have been made to detect the problem during commissioning of TL-3.

- The FODO cell quadrupoles differ in integrated strength :with the random variations in quadrupole strengths of FODO quadrupoles upto $\pm 5\%$ from one another, the maximum beta function can be 100 m instead of 50 m, thus the quadrupole to quadrupole variation must be kept below this value.
- Mismatching of twiss paramaters at the FODO entrance :mismatching the required strengths of quadrupoles Q3-Q6 by $\pm 5\%$ than as required to match twiss parameters at the FODO entrance, the maximum beta function in the FODO cells goes upto 90 m, thus the strengths of the matching quadrupoles should be adjusted within this value.
- Failure of one of the FODO quadrupoles :the beta functions become very high at one of the quadrupoles following the failed quadrupole and this can be easily detected at the respective BPM.
- Wrong polarity of one of the FODO quadrupoles :assumming that the polarities of other FODO quadrupoles are correct, if polarity of one of the quadrupoles is not correct, the beta functions become very large in the following FODO cell and thus this can be easily detected.
- If the twiss parameters are matched at the FODO input using Q3-Q6 but all the FODO cells are connected as DOFO, then the beta functions become very high after the achromat.

All the above situations assume that the beam passes through the centres of the quadrupoles, but, in reality this may not be the case and thus to detect such failures will need a careful survey of the line. In each case, it will be necessary to check the beam positions at the previous screens and then scan the steering magnets in the section between the last FS where the beam was observed and the next FS.

To detect the failures of other quadrupoles and bending or steering magnets, FS and/or WCP followed by the failed element will be used. In TL-2, the radiation monitors kept along the line also give a clue as per where the beam is lost and similar devices can be used in TL-3 during commissioning if required. However, the experience with TL-1,2 has very rarely shown such problem during regular operation as in most of the cases the power supply control indication available in the control room is enough to detect the problem.

5 CONCLUSIONS

A transfer line is designed to transport 700 MeV beam from the synchrotron to 2.5 GeV synchrotron radiation source Indus-2. The design of the line has been chosen in order to have minimum number magnets and their power supplies. The FODO cell is repeated number of times to cover the majority length of the line while the achromaticity is maintained. The locations of the steering magnets and the beam diagnostics elements have been chosen based on the commissioning and operational experience of other two transfer lines used in this facility.

6 REFERENCES

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