STUDY OF INDUS-2 LATTICE WITH FINITE DISPERSION

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Abstract

An extended Chasman Green lattice has been chosen for Indus-2, a 2 GeV electron storage ring for synchrotron radiation. The ring consists of 8 cells each having two 22.5° bending magnets, a triplet of quadrupoles for the control of dispersion in the achromat section, two quadrupole triplets for the adjustment of beam sizes in the long straight sections and four sextupoles in the achromat section for the correction of chromaticities. This lattice which gives a emittance of 3.7×10^{-8} m.rad is briefly discussed. The lattice has been studied further for finite dispersion in insertion section to obtain lower emittance. From these studies, it is found that it is possible to achieve an emittance of 2.2×10^{-8} m.rad with a dispersion of 0.2m in insertion section and the dynamic aperture remains sufficiently high for beam injection and storage. The lattice parameters and dynamic aperture results are discussed.

1 INTRODUCTION

The Centre for Advanced Technology (CAT) is constructing two synchrotron radiation sources; Indus-1, a 450 MeV electron storage ring for VUV radiation and Indus-2, a 2 GeV storage ring for x-rays. The Indus-2 is designed to provide the synchrotron radiation from bending magnets with field strength of 1.2T at a critical wavelength of 3.88 Å. Initially, two insertion devices are also proposed to be installed in the ring. A 5T wavelength shifter will provide radiation with a critical wavelength of 0.93 Å. The second insertion device will be a 1.8 T multipole wiggler with 6 periods. This device will provide radiation with a critical wavelength of 2.6Å. It is also planned to install undulators in the ring at a later stage to enhance flux and brightness at particular wavelengths. In this paper, we will cover the design details of Indus-2 lattice for zero dispersion in insertion sections. To further lower the beam sizes in insertion centre, the beam emittance is lowered by allowing a finite dispersion in that section keeping the operating tune the same, whereas, β functions are moderately changed. The effect of insertion devices in beam emittance and the dynamic aperture at the finite dispersion point in the presence of chromaticity correcting sextupoles are discussed.

2 THE LATTICE

The minimum beam emittance achievable from both Chasman-Green and Triple Bend Achromat lattices with zero dispersion in insertion section is nearly the same and is given by

$$\varepsilon_x \text{ (m.rad)} = 10^{-7} E^2(\text{GeV})\, \theta^3(\text{rad})$$

whereas, the actual achievable emittance is much higher. In this equation, E and θ are the beam energy and the angle of deflection per bending magnet respectively. If one relaxes the dispersion in that section beam emittance much lower than this can be achieved. One such magnetic structure classified as an expanded Chasman Green (ECG) lattice has been selected and optimized for Indus-2[1].

The storage ring Indus-2 consists of 8 unit cells each providing a 4.58m long straight section. Its unit cell has two 22.5° bending magnets, a triplet of quadrupoles for the control of dispersion in the achromat section, two quadrupole triplets for the adjustment of beam sizes in the long straight sections and four sextupoles in the achromat section for the correction of chromaticities in both transverse planes. An additional advantage of this lattice is that the two 2 m gaps between the focussing and defocussing quadrupoles in the achromat section provide a lot of space for accommodating beam diagnostic and vacuum devices. The design parameters of the source are given in the table. A similar structure with a gradient in bending magnets has been adopted for the synchrotron radiation source ELETTRA at Trieste(Italy). Though the gradient has some beneficial effects on the beam optics, we have chosen normal parallel edged magnets to avoid fabricational problems associated with gradient magnets. The operating point of the ring has been selected by avoiding the major resonance lines viz. $3\nu_x = 4$ & 5, $2\nu_x = 3$, $\nu_x + 2\nu_y = 3$, $\nu_x - 2\nu_y = 1$ etc. The tune per super period is chosen as (1.15, 0.65). From the radiation brightness and beam dynamics considerations of wigglers and undulators the radial and vertical β functions in the insertion straight sections are selected in the vicinity of 14m and 2m respectively. The length of the straight section between the focussing quadrupole and the defocussing quadrupole of the achromat has been adjusted to obtain a good decoupling of β_x and β_z and a small beam emittance. A thorough study of the lattice has been carried out using an indigenously developed

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program[2]. The lattice functions at the tune point (9.2, 5.2) are shown in Figure 1 in which one gets a beam emittance of 3.7×10^{-8}m.rad with a zero dispersion in the insertion section. This beam emittance is 1.54 times higher than the minimum theoretically achievable beam emittance of 2.42×10^{-8}m.rad. The design parameters of Indus-2 are listed in Table 1.

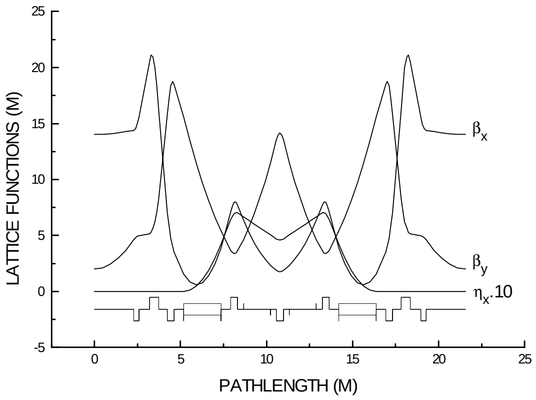

Figure 1: Lattice functions of Indus-2

Recently, the rf cavity frequency has been changed form 189.67MHz to 505.808MHz. Since the circumference of the ring has been changed by 0.2m, there is no appreciable change in the lattice parameters.

Table.1 **Parameters of Indus-2**

Energy	: 2 GeV
Current	: 300 mA
Bending Field	: 1.2 T
Critical Wavelength (λ_c)	: 3.88Å (BM)
	: 0.93Å (WS)
	: 2.59Å (MW)
Circumference	: 172.4743 M
Typical tune point	: 9.2, 5.2
Beam emittance ε_x	: 3.72 x 10^{-8} m.rad
ε_y	: 3.72 x 10^{-9} m.rad
Electron beam size and divergence	
Centre of dipole σ_x, σ_y	: 0.187, 0.190 mm
$\sigma_{x'}$, $\sigma_{y'}$	: 0.287, 0.050 mrad
Centre of insertion σ_x, σ_y	: 0.722, 0.0865 mm
$\sigma_{x'}$, $\sigma_{y'}$	: 0.0515, 0.043 mrad
Bunch length $2\sigma_l$	: 1.9 cm
Beam lifetime	: 20.0 Hours
Energy spread	: 7.2 x 10^{-4}
Revolution frequency	: 1.73817 MHz
RF frequency	: 505.808 MHz
Harmonic number	: 291
Power loss	: 76.3 kW (BM)
	: 4.3 kW (WS)
	: 5.2 kW (MW)

BM : Dipole Magnet; MW : Multipole Wiggler (1.8T); WS :Wavelength shifter (5 T)

3 RESULTS OF FINITE DISPERSION

It is found that if a finite dispersion could be allowed for the straight sections, the overall beam emittance, could be lowered by a factor of 2-3 compared with the zero dispersion case[3-5]. A plot showing the variation of beam emittance and momentum compaction factor as a function of dispersion in an insertion section is shown in figure 2. The machine can be operated with a beam emittance of 2.2×10^{-8}m.rad allowing a dispersion(η) of 0.2m in the insertion section with a moderate change in beta functions. The minimum of beam emittance is achievable by allowing dispersion is 1.4×10^{-8}m.rad for dispersion of 0.55m, but at this point the required sextupole strengths are much higher for compensation of chromaticity.

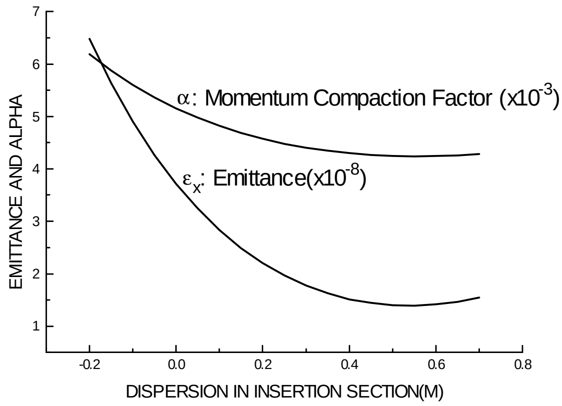

Figure 2 : Variation of beam emittance and momentum compaction factor with dispersion in insertion section of Indus-2 lattice

The comparative study of beam sizes at centre of insertion devices and dipole magnets for both modes of operation with dispersion are,

Insertion section

η m at ID	β_x m	β_y m	σ_x mm	$\sigma_{x'}$ mrad	σ_y mm	$\sigma_{y'}$ mrad	ε_x m.rad $x10^{-8}$
0.0	14	2.0	0.72	0.051	0.086	0.043	3.719
0.2	16	1.88	0.61	0.037	0.064	0.034	2.203

Dipole centre

η m at ID	β_x m	β_y m	σ_x mm	$\sigma_{x'}$ mrad	σ_y mm	$\sigma_{y'}$ mrad	ε_x m.rad $x10^{-8}$
0.0	0.8	9.7	0.19	0.287	0.19	0.049	3.719
0.2	0.7	10	0.14	0.22	0.149	0.039	2.203

The dynamic aperture was calculated in the presence of chromaticity correcting sextupoles using RACETRACK and the results are shown in figure 3.

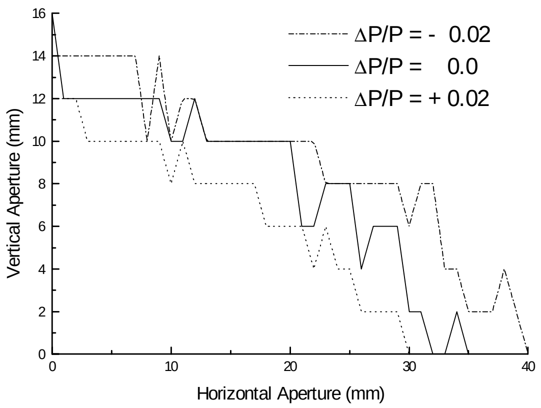

Figure 3 : Dynamic aperture of Indus-2 with finite dispersion for 1000 turns

If the dispersion is 0.2m in the insertion straight sections, the over all emittance of the machine will remain unchanged or will be slightly lower. This is due to the fact that the high field wave length shifter will increase the beam emittance by 2% whereas, the multipole wiggler will reduce it by 5% as shown in figure 4.

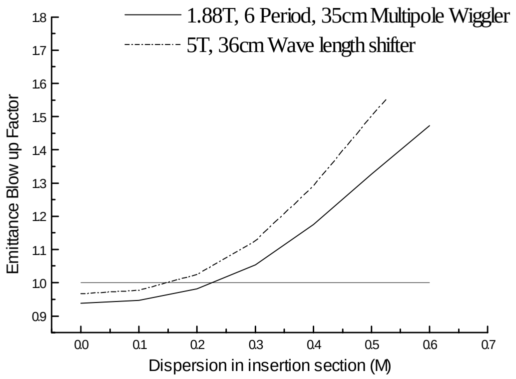

Figure 4 : Horizontal beam emittance blow up factor for wave length shifter and multipole wiggler.

With finite dispersion the brightness of the radiation was calculated and found that there is 50% increase in brightness from that of zero dispersion cases for radiation from dipole magnets as well as from the wave length shifter.

So, it is found that Indus-2 can be operated at finite dispersion point to enhance the brightness of the radiation. The effect of dispersion in rf cavity section which may cause synchro-betatron resonances is under study.

4 REFERENCES

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