LOW EMITTANCE ELECTRON BEAM OPTICS COMMISSIONING IN INDUS-2

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Abstract

Currently Indus-2 is normally operated with beam emittance of 85 nmrad at 2.0 GeV. In order to reduce the beam emittance to half of this value its dispersion function has been modified by properly choosing the quadrupoles strengths of the lattice. At this low beam emittance optics dynamic aperture reduces and may not be sufficient for beam injection thus a procedure has been evolved and implemented to shift the beam emittance of stored beam at 2.0 GeV.

INTRODUCTION

The magnetic structure of Indus-2 is an expanded Chasman Green (ECG) lattice. The ring is consist of eight superperiods each having two dipoles, five quadrupole magnet families for the optics matching and two sextupole magnet families for the chromaticity correction. Presently, it is being operating in high emittance mode [1, 2] ~85nmrad (moderate optics). Initially optics with an emittance of 40nmrad with tune point (9.3, 5.2) was used in Indus-2. When Indus-2 was tuned at this optics, a partial beam loss was observed during beam injection and also, there was some difficulties in the beam energy ramping. It may be due to injection errors [3] and small dynamic aperture, due to the strong nonlinear sextupole magnetic fields used for correction of large chromaticity. The strong sextupole magnetic fields are required due to the small energy dispersion function. In the moderate optics the value of the dispersion function is kept high to increase the dynamic aperture. The estimated horizontal dynamic aperture is ~9mm for the low emittance optics and 15mm for the moderate optics. To achieve a low beam emittance, a procedure has been evolved and implemented. In this procedure the beam injection and the beam energy ramping were carried out on the moderate optics, so that the effect of the injection errors can be minimized and higher dynamic aperture is available during beam injection as well as during the beam energy ramping. When the beam energy is 2 or 2.5GeV the strengths of magnetic elements are slowly changed to those corresponding to the low emittance optics keeping the tune point fixed. The beam with the low beam emittance produces higher photon beam brightness at final energy. Thus at final energy the moderate beam optics is changed into the low emittance optics.

OPERATION SCHEME

The emittance change over procedure is carried out under the following constraints (1) transverse betatron tunes in both horizontal and vertical planes should remain constant or should be controlled as per requirement, so that betatron tunes kept far away from the dangerous resonances lines (2) Value of the energy dispersion function should be shaped appropriately (3) Sensitivity of the beam optics towards linear and nonlinear imperfections shall be as smooth as possible (4) Chromaticity correcting sextupoles strengths shall be adjusted as per natural chromaticities of the low emittance optics. It is found that, at least three families of quadrupole magnets (QPs) and two families of chromaticity correcting sextupole magnets (SPs) are required to vary synchronously in a well defined procedure. Two families of QPs are used for adjustment of the betatron tunes and the third family in the achromat section is used to control the energy dispersion function. If additional constraints are kept on the beta functions, they can be achieved using remaining two QPs families. In the moderate optics, measured horizontal tune (υ_x=9.3) nearly matches with the theoretical tune and the measured vertical tune (υ_z=6.09) is less in comparison to theoretical tune (6.15). In the switching over processes the υ_x was kept constant and the υ_z was increased by 0.05 so that amplification factor for closed orbit distortions (COD) in the vertical plane can be reduced. Computer program Burhani [2] was used for simulations. Various constraints were kept on the beta functions in the simulations. It was observed that when all QPs families were used, the change of QPs strengths was irregular. The four QPs families, Q2F and Q3D in insertion section and Q4F and Q5D in achromat section as shown in figure 1 were used to obtain solution. The optical functions for moderate optics and the low emittance optics are plotted in figure 1 and 2 and their amplitude dependent tune shifts considering sextupoles fields as small perturbations are tabulated in Table-1.

Table 1: Amplitude dependent tune shifts

Parameters	**Moderate Optics**	**Low emittance Optics**
$d\upsilon_x$	$-63.21x^2–73.72z^2$	$-104.7x^2– 130.6z^2$
$d\upsilon_z$	$-25.34x^2+34.93z^2$	$-35.8x^2+78.15z^2$

In the low emittance optics mode, the sensitivity of linear imperfections in the vertical plane was reduced and is increased in the horizontal plane as shown in the figure 3. The multiplication factors for the beam emittance variation and strength variations for QPs and SPs are shown in the Figure 4 during the tuning.

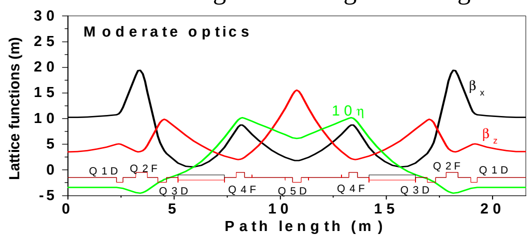

Figure 1: Lattice functions of moderate optics

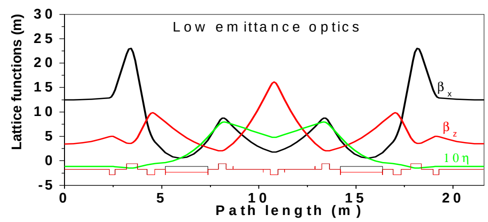

Figure 2: Lattice functions of the low emittance optics

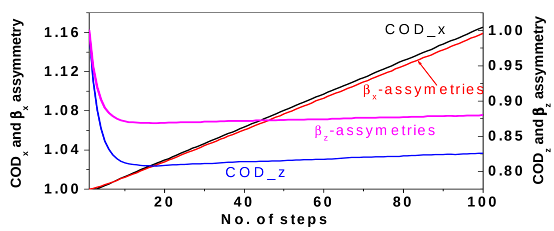

Figure 3: Multiplication factors for amplification factors of COD and β-asymmetries during the tuning

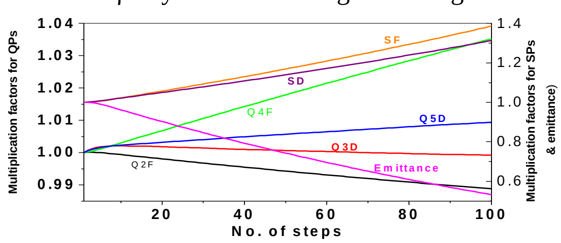

Figure 4: Multiplication factors of QPs and SPs strength & emittance variations during the tuning

RESULTS AND DISCUSSION

In the switching over processes as shown in figure 3, a look up table for the magnet currents was generated and fed to the hardware by using the existing ramp software[4], so that the mode transfer process was executed by synchronously changing the field strengths of QPs and SPs families. This process was carried out in the presence of uncorrected COD. In the first trial, sextupole strengths were excluded; only four QPs families strengths were changed. In the first attempt, fast decay in beam current was observed. It indicates that the SPs strengths set for moderate optics are insufficient to compensate the head tail instability in the low emittance optics. In the next attempt, required variations in SPs strengths are also included and natural beam decay was observed. The measured COD is shown in Table-2. In the low emittance optics, it is observed that vertical COD is reduced, whereas horizontal COD is increased.

Table-2: COD measurements

COD (mm)	**Nominal optics**		**Low emittance Optics**	
	x	**z**	**x**	**Z**
Maximum	10.0	5.6	11.1	-3.8
Minimum	-7.6	-4.9	-8.7	3.6
RMS	4.8	2.9	5.4	2

In the low emittance optics, the measured υ_x is found lowered by 0.02 and the υ_z is increased by 0.03. In the horizontal plane, the mismatch in tune, may be due to the higher values of horizontal COD at sextupole locations. To confirm this υ_x was increased to 0.44 using Q2F and Q3D families and keeping the same emittance and making the measured rms COD same as moderate optics. The measured tune values are almost matching with theoretical prediction.

In the low emittance optics, beam lifetime is 284minutes at 100mA beam current, which is less in comparison to moderate optics (482minutes). The beam lifetime improved to 420minutes when υ_x was increased by 0.1 and υ_z by 0.02 as shown in Figure 5. This also resulted in the reduction of rms COD in x-plane to 4.95mm.

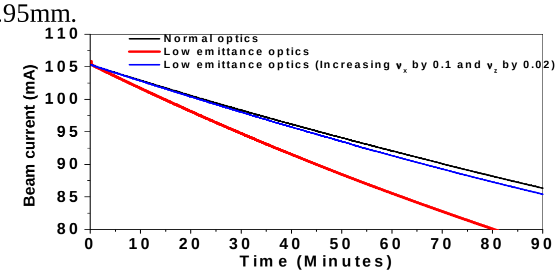

Figure 5: Beam current in different operating condition

CONCLUSION

With this procedure the stored beam is successfully shifted to the low emittance optics. After COD correction, further reduction in the beam emittance may be possible.

REFERENCES

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