STATUS OF INDUS-2 SYNCHROTRON RADIATION SOURCE

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Abstract

Indus-2 is operated regularly operated in round the clock mode at 2GeV since February 2010. The operation of Indus-2 re-started in January 2010 after the installation of injection septa and evacuation of the ring. The beam current at 2GeV was increased to 100mA in March 2010. The main impact of round the clock operation is that the operation time of the storage ring has greatly increased and the beam life time at 2GeV/100mA is now around 10 hours. Indus-2 is presently operated by staff, which has undergone rigorous theoretical and practical training on all aspects of this accelerator system. An automated betatron tune measurement system has been implemented to know the betatron tune during injection, ramping and storage of the beam. In July 2010, trials were made to reduce the emittance of the beam at 2GeV. The optics of the ring was successfully changed in which the horizontal beam emittance was brought down to half of its present value at 2GeV. Experiments are being done to correct the closed orbit distortion employing a global correction scheme and in the initial trials, the rms orbit distortion has been corrected to 1.2mm in horizontal plane and 0.6mm vertical plane. In March 2011, when two additional klystrons are available, Indus-2 will be operated at 2.5GeV and its beam current will be increased to 100mA.

INTRODUCTION

Indus-2 is a 2-2.5 GeV synchrotron radiation source. It is the second synchrotron radiation source built in India at Raja Ramanna Centre for Advanced Technology (RRCAT), Indore. First source, a 450MeV electron storage ring, Indus-1 has been in operation and in use since 1999 [1, 2]. Both these sources share a common injector system consisting of a 20MeV microtron and a 20-550MeV booster synchrotron. The schematic layout of Indus-2 including the injector system is shown in Fig. 1.

Indus-2 is an electron synchrotron cum storage ring in which electrons are injected at 550MeV and accelerated to 2-2.5GeV after a required current achieved with continuous injection from the booster synchrotron. It comprises of 8 unit cells of an expanded Chasman Green lattice. Each unit cell has two dipole magnets, nine quadrupoles and four sextupoles. In this way, the ring consists of 16 dipole magnets, 72 quadrupoles and 32 sextupoles. In addition, there are 48 horizontal and 40 vertical steering magnets for the correction of closed orbit distortion. There are eight 4.6 m long straight sections; two are utilized for RF cavities, one for beam injection and remaining five for insertion devices. The operating parameters of Indus-2 are tabulated in Table 1.

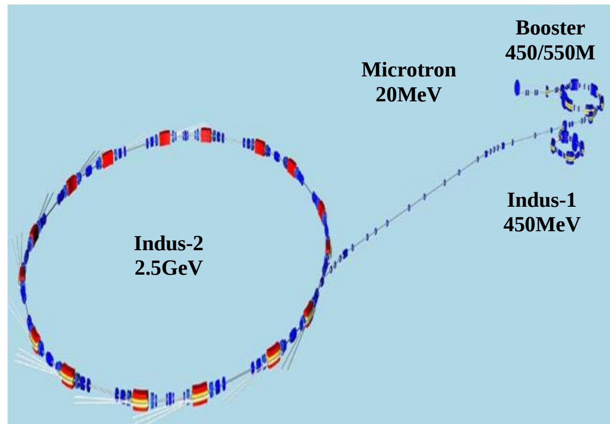

Fig. 1: Schematic layout of Indus-2

Table 1: Operating parameters of Indus-2 ring

Maximum energy	2GeV
Maximum current	100mA
Circumference	172.4743m
Tune point	9.3, 6.14
Beam Emittance ε_x, ε_z	8.5×10^{-8} / 8.5×10^{-9} m.rad
Available straight section for insertion devices	5
Straight length available for insertion devices	4.6m
Beam sizes σ_x ,σ_z (Centre of bending magnet)	0.375, 0.25mm
RF frequency	505.812 MHz
Critical wavelength (From Bending Magnet)	3.88Å
Energy loss per turn (From Bending Magnet)	255keV

Indus-2 was operated at 2-2.5GeV energy upto 50mA beam current until May 2009. A shutdown was taken during June to mid July 2009 to install all first gate valves (GV0) for beamlines. Subsequently, Indus-2 was brought back into operation. However in the last week of July 2009, insulation of the thick and thin septum coils failed. Indus-2 operation was resumed after re-installation of thick and thin septa on 20th January, 2010. In this paper, we discuss about the progress made in the operation of Indus-2 after this date.

REINSTALLATION OF SEPTA

The coil of thick septum failed in July 2009. This coil was redesigned with engineering modifications to provide better

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mechanical stability. Injection septa (thick and thin) are position sensitive elements used for beam injection into Indus-2 ring. Thick septum was reoriented along the beam path, to make use of available good field region, which got disturbed due to the modifications.

OPERATIONAL PERFORMANCE

After reinstallation of the septa and evacuation of the source, the trials to achieve 100mA at 2GeV were started in Jan 20, 2010. The main objective at the beginning of this year was to store 100mA beam current at 2GeV. In order to enhance the availability of the source for beam physics experiments and also for synchrotron radiation users, round the clock mode of operation was adopted since February 8, 2010. In this mode, the source is operated continuously for three weeks followed by a shutdown of one week for carrying out maintenance work. The stored beam current of more than 100mA at 2GeV was achieved on March 6, 2010. This was achieved with optimisation of RF phases, injection parameters, auto-ramping of RF voltages etc. The energy of Indus-2 was restricted to 2GeV as two out of four RF stations are presently not operational. The maximum voltage available from the working RF stations is 750kV. During the year 2010, Indus-2 was operated at 2GeV for 2280 hours and extensively used for experiments. The total beam availability including injection/accumulation time during this period was 3261 hours.

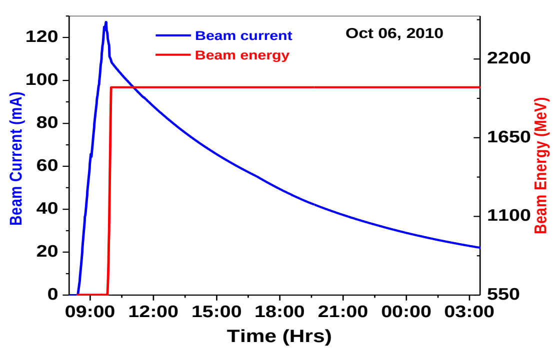


Fig. 2: Beam current in Indus-2

A typical operation of Indus-2 at 2GeV is shown in Fig. 2. A beam current of 127mA was filled at the injection energy. The energy ramping was initiated at the stored current of 122mA and when the energy reached 2GeV, the stored beam current was 109mA. The microtron current during experiment was 17mA and booster current was 3-4mA. The duration in which the beam energy was increased from 550MeV to 2GeV is 10minutes. As evident from Fig. 2, the beam was available uninterrupted for experiments for more than 18 hours. In a trial to store more beam current at the injection energy, a beam current of 175mA was stored. To operate Indus-2 at 2.5GeV with 100mA current, we need RF voltage higher than 1.2MV and RF power of 200kW. This is to be achieved by making all the 4 RF cavities and stations operational for which additional two 60kW klystrons are being procured and they are likely to be received in March 2011. Trials to operate Indus-2 at 2.5GeV, 100mA will thus be carried out in March 2011

For smooth, efficient & reliable operation of Indus facility, a dedicated operation team having an integrated approach and knowledge of all the sub-systems is required. An elaborated training and licensing programme has been initiated at RRCAT which includes lectures, literature studies, on job training, clearing checklists, written and walkthrough examinations followed by an interview by a licensing committee. One batch consisting of 31 persons have already been trained and now also deployed for the round the clock operation presently being practised. The training of the second batch is presently going on and is on the verge of completion.

BETATRON TUNE MEASUREMENT

Knowledge of betatron tunes during beam injection, ramping and storage is essential for optimization of the performance of any synchrotron. Betatron tune of Indus-2 is measured by swept frequency excitation method. In this method, a transverse excitation is applied to the beam, which causes the beam to execute coherent betatron oscillation. A beam position monitor is used to measure the resulting beam response and its frequency analysis gives information about the fractional part of the betatron tune value. The measurement system employs a spectrum analyzer equipped with a tracking generator. A strip line kicker is used to excite the beam. The tune measurement system has been automated by interfacing a spectrum analyzer (SA) with a PC on GPIB bus. Variation in the measured tune with the beam energy is shown in Fig. 3.

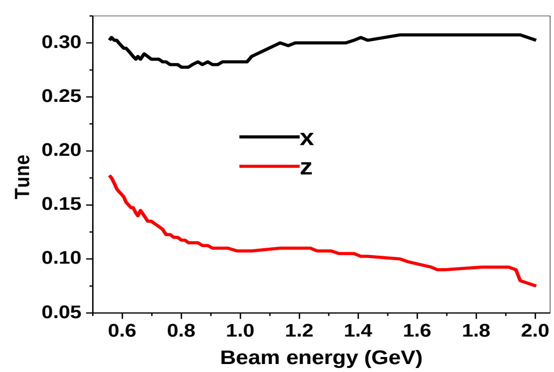


Fig. 3: Measured tune with the beam energy

LOW EMITTANCE OPTICS

Presently, Indus-2 is operated with beam emittance of 85nm.rad (moderate optics) at 2GeV. In order to reduce the beam emittance to half of this value (~40nm.rad) its dispersion function has been modified by properly choosing the quadrupoles strengths of the lattice [3]. In the low beam emittance optics, the dynamic aperture reduces due to higher strengths of the sextupole magnets and may not be sufficient for beam injection. A procedure has been evolved and implemented to shift the beam emittance of stored beam at 2GeV without changing the tune of the machine, so that beam is not lost due to crossing of harmful resonances. The lattice functions of the moderate and low emittance optics are shown in Fig. 4 and Fig. 5 respectively.

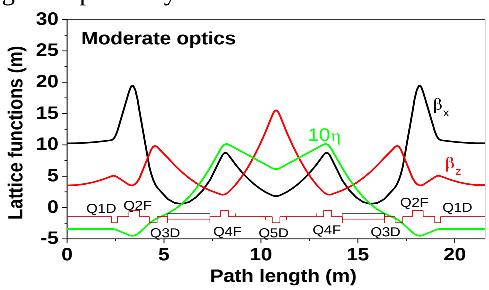


Fig. 4: lattice functions of the moderate optics

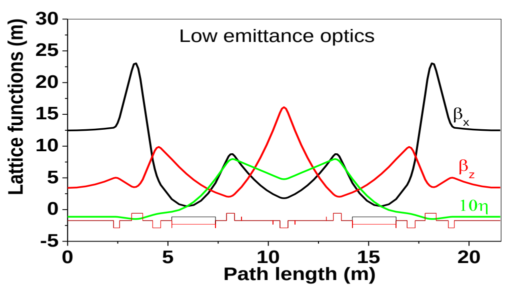


Fig. 5: Lattice functions of the low emittance optics

The scaling factors for the beam emittance variation and variation of the strengths of quadrupoles (QPs) and sextupoles (SPs) are shown in the Fig. 6 during the process of switching over to the low emittance optics.

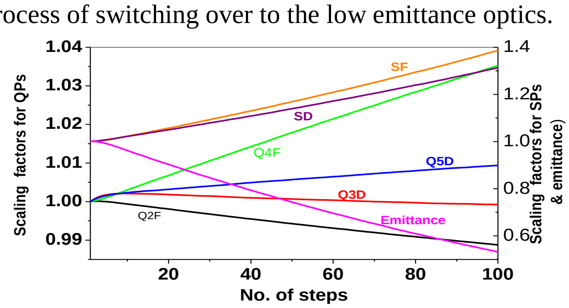


Fig. 6: Scaling factors of emittance variation, quadrupole and sextupole strength variation during switch over to low emittance optics.

CLOSED ORBIT CORRECTION

The COD correction scheme has been developed for Indus-2. An important feature of this scheme is MATLAB based interactive global orbit correction software, which helps to correct the COD from the Indus-2 control room. The COD correction software requires the beam position data and response matrix of the Indus-2 to calculate required steering magnet strengths for correction. Singular Value Decomposition method is used for the orbit correction. The MATLAB based software has also been developed to automatically generate the Indus-2 response matrix in horizontal (x) and vertical (z) planes. The software is integrated with existing Indus-2 control architecture, which displays COD & steering strength data graphically and statistically (rms, minimum & maximum). The initial trials of COD correction using this software have been performed recently [4]. In these trials, using a model response matrix, the rms COD in horizontal plane was brought down from 4.2mm to 1.3mm at injection energy and from 4.5mm to 1.2mm at 2GeV. Similarly in the vertical plane, the rms COD reduced from 1.7mm to 0.6mm at injection energy and from 2.8mm to 0.6mm at 2GeV. In these trials, 48 horizontal steering magnets & 40 vertical steering magnets were used for orbit correction using the beam position data obtained from 51 beam positions indicators. The uncorrected and corrected horizontal COD at the locations BPI for the beam energy of 2GeV is shown in Fig. 7 and for vertical plane it is shown in Fig. 8. For further reduction in COD, the measured response matrices in both the planes are required. The trials are going on to measure these response matrices.

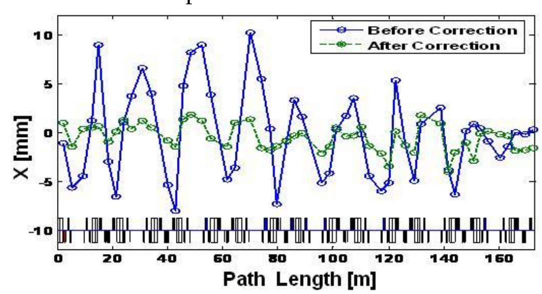


Fig. 7: The uncorrected and corrected horizontal COD

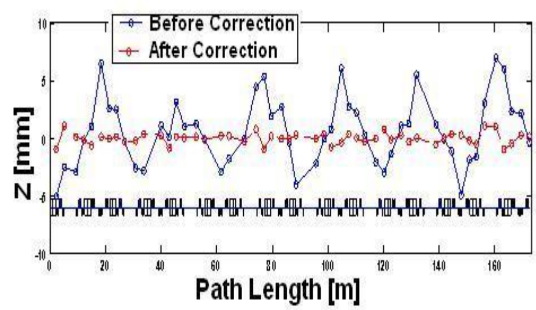


Fig 8: The uncorrected and corrected vertical COD

BEAM LIFETIME

An improvement in the beam lifetime has been observed due to improvement in the average vacuum conditions, which is the consequence of cleaning process of the vacuum chamber due to emitted SR radiation. The beam lifetime at 2GeV/100mA which was less than 2 hours in March 2010 has increased to 10hours. Beam lifetime for different stored beam current at the beam energy of 2GeV is shown in Fig. 9.

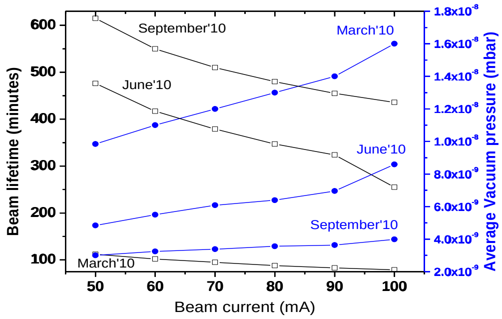


Fig. 9: Beam lifetime and vacuum conditions

During these studies two RF stations were energized at 375kV each. Since RF acceptance is same, the contribution of Touschek lifetime remains unchanged with time. We conclude that the improvement in beam lifetime is due to the improvement in vacuum conditions in the ring [5].

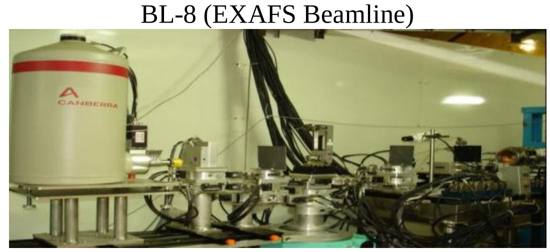
BEAMLINES

At present, 8 front-ends (FEs) have been installed at different bending magnet ports of Indus-2. Three beamlines namely BL-8 (EXAFS Beamline), BL-11 (EDXRD Beamline), BL-12 (XRD Beamline) have been commissioned and are operational. Fig. 10 shows the photographs of these beamlines. Five more Beamlines namely BL-7 (SDXL Beamline), BL-13 (GIXS Beamline), BL-14 (XPES Beamline), BL-16 (XRF Beamline) and BL-21 (Protein Crystallography Beamline) are under installation and expected to be operational in 2011.

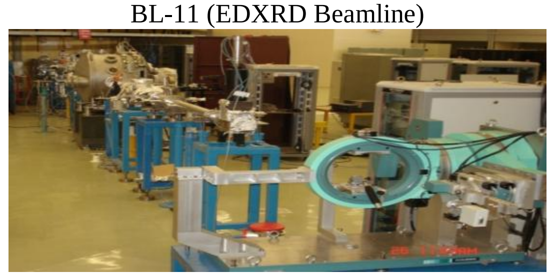
CONCLUSIONS

Indus-2 is regularly operated at 2GeV in the round the clock mode. During the year 2010, beam current at 2GeV was increased to 100mA and synchrotron radiation was regularly provided to the users for experiments. Three beamlines are operational now. The moderate optics was successfully switched to low horizontal beam emittance optics at 2GeV. The values of COD were significantly brought down using SVD method with the software developed at RRACT. The trials for the operation of Indus-2 at 2.5GeV/100mA will begin in March 2011.

BL-8 (EXAFS Beamline)



BL-11 (EDXRD Beamline)



BL-12 (XRD Beamline)

Fig. 10: Operational beamline in Indus-2

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