COMMISSIONING OF THE INDUS-1 STORAGE RING

G.K. Sahoo, D. Angal-Kalinin, D.D. Bhawalkar, A.A. Fakhri, A.D. Ghodke, Pradeep Kant, Pradeep Kumar,P.K. Nema, A.S. Raja Rao, B. Singh & G. Singh[1]
Accelerator Programme, Centre for Advanced Technology, Indore - 452 013, India

Abstract

Indus-1 is a 450 MeV electron storage ring for the production of the synchrotron radiation. This storage ring was successfully commissioned in 1999. A maximum beam current of 161 mA was accumulated in the ring. The beam lifetime at a design current of 100 mA is nearly one hour at present, which is limited mainly by the vacuum. The beam dynamics measurements carried out during commissioning have been briefly discussed in this paper.

1 INTRODUCTION

The Indus-1 synchrotron radiation (SR) facility consists of a 450 MeV storage ring named as Indus-1 for the production of VUV radiation [1] and its injector system, which has a 20 MeV microtron and a synchrotron. The synchrotron, transfer lines and the microtron have already been commissioned [2,3]. The Indus-1 storage ring was commissioned in 1999. Two bunches out of the three extracted bunches from the synchrotron are injected into the storage ring using a single kicker. The parameters of the injection septum, kicker, dipole, quadrupoles are optimised and a stored current of 161 mA was achieved in July 1999. The beam lifetime at the design current of 100 mA is presently limited due to the vacuum. Results of the initial commissioning experiments are discussed.

2 DESCRIPTION OF THE FACILITY

The layout of the Indus-1 SR facility is shown in Fig.1(a). The photograph of the Indus-1 storage ring is shown in Fig.1(b). The preinjector is a classical microtron, which provides an electron beam with a current of 20 mA in a 1μs long pulse duration at a repetition rate of 1 Hz. This beam is transported to the synchrotron through Transfer Line-1 (TL-1). The injection into the synchrotron is carried out by multiturn injection process in which a compensated bump is created using three kicker magnets. The bump is reduced in nearly 10 turns. The energy of these electrons is increased to 450 MeV in 200 ms. The synchrotron has a circumference of 28.44 m and an RF system operating at 31.619 MHz provides three bunches with an interbunch spacing of 32 ns. The beam extraction at the flat top of a linear ramp is carried out using a fast extraction kicker magnet located into the section S2. The extraction kicker has a rise time of 45ns and thus two bunches out of three can be extracted on the flat top of the kicker pulse. These bunches are transported through a Transfer Line-2(TL-2) to the storage ring Indus-1.

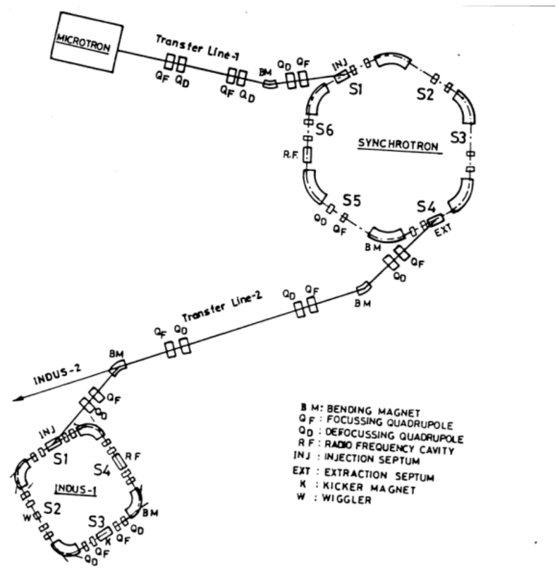

Figure.1(a): Layout of the Indus-1 SR facility

Indus-1 is a 450 MeV electron storage ring designed to satisfy the user requirements in the range 10-100 Å. It is a small ring having a circumference of 18.96m. The magnetic lattice of the ring has four superperiods, each consisting of a dipole magnet with a field index of 0.5 and two pairs of the quadrupoles. Each superperiod has a 1.3 m long straight section. The injection septum, the injection kicker and the RF cavity are installed in S1, S3 and S4 respectively. There is a provision to install a wiggler in S2. To correct the natural chromaticity, a pair of sextupoles is used in each superperiod. The ring has a wide tuning range and the dynamic aperture is larger than the physical aperture.

The beam injection scheme in which the kicker and the septum magnets are located at symmetric points, diametrically opposite to each other has been optimised by tracking motions of the injected and the stored beams. In this scheme, when the kicker is energised, a bump is produced in the injection section. The kicker gives a

[1]Ccorresponding author, E-mail : gurnam@cat.ernet.in

maximum kick angle of 18 mrad for a kicker current of 2500A. The magnetic field in the kicker rises to a required value in 1μs following a sinusoidal shape and it decays exponentially with fall time of 150 ns. The kicker current is optimised in order to inject the beam at different tune points so that the betatron oscillation amplitudes remain within the horizontal aperture.

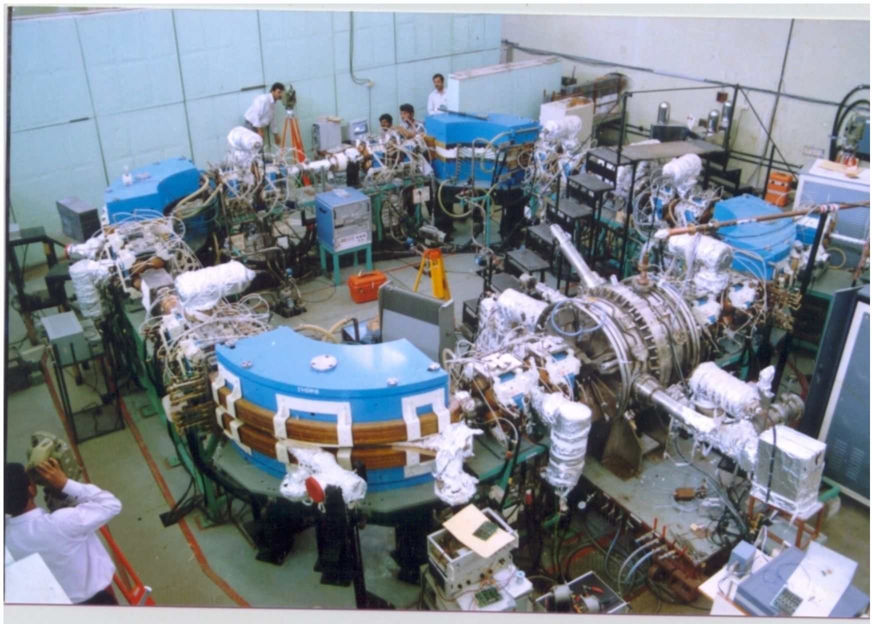

Figure 1(b): Storage ring Indus-1

3 COMMISSIONING

The injector system commissioned earlier has been delivering a 450 MeV beam to Indus-1 regularly. The beam was injected into Indus-1 without the injection kicker and 6 turns were observed as predicted by the theory. The real task of beam injection trials to Indus-1 began in April '99 immediately after the installation of the injection kicker magnet into the ring. Initially, when the kicker was operated at 1700 A current, beam circulation upto 1200 turns was observed without RF. On optimisation of the kicker field and strengths of the quadrupoles during subsequent operations, the current accumulation increased. Two out of three bunches successfully extracted from the synchrotron at 450 MeV are injected into Indus-1 using the above kicker at a repetition rate of 1 Hz. Fig.2 shows the Extraction kicker pulse (Trace-1), two bunches in the 2π-monitor in the end of TL-2 (Trace-2), the injection kicker pulse (Trace-3). The accumulation of the current is shown in the wall current pickup placed in the ring (Trace-4). The filling of the ring has been improved by optimising the parameters of the injection septum, kicker, quadrupoles, correction magnets and TL-2. The fastest accumulation time to get a stored current of 100 mA was ~3 minutes at the operating point (1.69,1.31). The maximum current accumulation in the ring was 161mA in July 1999. Whereas the operational design current is 100mA.

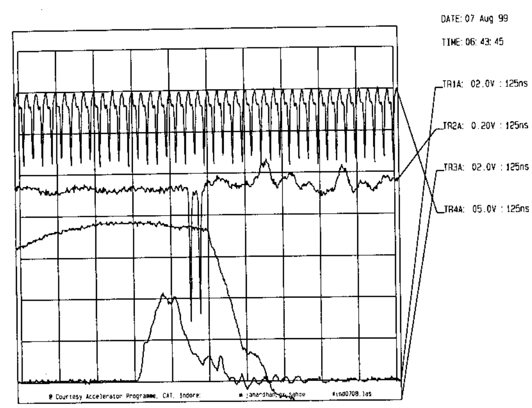

Figure 2: Current signals in TL-2 and Indus-1

The ring was operated at different operating points to study the beam lifetime and rate of filling. The beam lifetime (1/e) was initially poor due to the degradation of vacuum caused by the cleaning of the vacuum chamber by synchrotron radiation. As the vacuum improved, the beam lifetime improved to nearly one hour (calculated for a current decay from 100 mA to 90 mA) at an average pressure of 10 nT. The beam lifetime in this case appeared to be governed by the vacuum. The beam lifetime will further improve, as the required vacuum pressure of one nTorr will be achieved at the beam current of 100 mA.

The betatron tunes were measured by exciting the beam using an Radio Frequency Knock Out method. The tune point at which the maximum current has been achieved is measured as $\nu_x = 1.69$, $\nu_z = 1.31$. The parameters of Indus-

1 at this tune point are given in Table-1. The lattice functions are shown in Fig.3.

Table-1: Parameters of Indus-1

Energy	450 MeV
Current	100 mA (achieved 161 mA)
Bending Field	1.5 T
Circumference	18.96 m
Operating point	1.69, 1.31
Beam emittance (ε_x)	1.5 x 10^{-7} m.rad
Energy spread	3.85 x 10^{-4}
Momentum compaction	0.235
Damping times ($\tau_{x,z,\varepsilon}$)	15.7,15.7,7.8 ms
Natural chromaticities($\xi_{x,z}$)	-1.9,-0.3 (measured -2.6,+3.1)
Revolution frequency	15.82 MHz
Harmonic number	2
Power loss	0.36 kW[a]; 0.05kW[b]

[a] bending magnet ; [b] high field wiggler (3T)

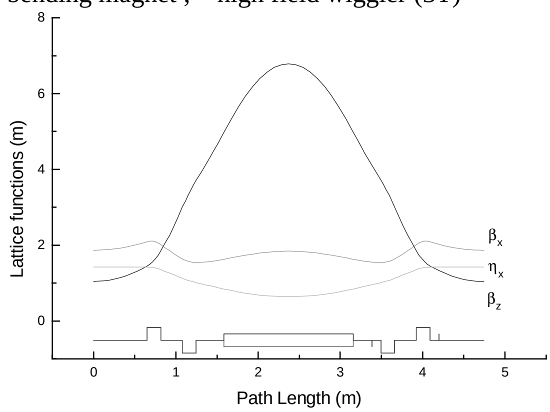

Figure 3: Lattice functions of Indus-1 at (1.69,1.31)

The beta functions at the quadrupole locations were measured by measuring the shift in the tune values by energising the secondary coils of the focussing(Q_F)/ defocussing(Q_D) quadrupoles. The average beta function at Q_F/Q_D in x-plane is 1.8m/1.3m and in z-plane is 1.4m/3.1m. The dispersion functions in the horizontal plane at the Beam Position Indicator (BPI) locations were measured by changing the RF generator frequency and by measuring the change in the orbit. The dispersion function is ~ 0.9m at these locations. The measured values of the average beta functions and the dispersion function are within 10% of the theoretical values. The natural chromaticities were measured by changing the RF frequency and measuring the change in the betatron tune. The chromaticities in x,z plane are -2.6,+3.1. The discrepancy with the theoretical chromaticities may be attributed to the sextupole components in the dipoles. The ring is presently being operated without energising the chromaticity correcting sextupoles. The closed orbit distortion is monitored at the BPI's locations. The orbit correction and operation of the sextupoles are planned during future runs of the ring. The attempts are being made to operate the ring at other tune points including (1.55,1.56) and (1.88,.1.22) selected previously during the design of the ring.

4 CONCLUSIONS

The Indus-1 synchrotron radiation source has been commissioned with maximum accumulated current of 161 mA. The beam dynamics measurements carried out show that the measured parameters closely match the design parameters. Correction of the closed orbit distortion and operation of the sextupoles is planned. As the machine is operated for a longer duration, the vacuum will improve further.

ACKNOWLEDGMENTS

The design and the commissioning of Indus-1 facility is a teamwork of many engineers, scientists and technical personnels of Accelerator Programme, CAT. We would like to thank all group leaders namely; P R Hannurkar, A Jain, M G Karmarkar, S Kotaiah, S K Shukla, H C Soni, B J Vaidya and their colleagues for their contribution.

REFERENCES

[1] G Singh et al, Proceedings of Conference on synchrotron radiation applications, Hefei, China, 1989, pp 122-127.

[2] D Angal et al, Proceedings of 4th International Conference on SRS's and 2nd Asian Forum on SR, Korea, 1995, pp 91-98.

[3] G K Sahoo et al, Proceedings of first Asian Particle Accelerator Conference, KEK, Tsukuba, Japan, 1998, pp 274-276.