COMMISSIONING STATUS OF INDUS-1 SR FACILITY

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Abstract

The Indus-1 synchrotron radiation facility consists of a 450 MeV storage ring for the production of VUV radiation and its injector system which has a 20 MeV microtron and a synchrotron. In this paper, we discuss results of the experiments carried out to commission the synchrotron and Transfer Line-2. Transfer Line-2 transfers 450 MeV electrons from the synchrotron to the storage ring. In the synchrotron, a current of 11 mA has been achieved at 450 MeV and a successful extraction of electrons has also been carried out. We also discuss the results of the initial commissioning experiments carried out with Indus-1.

1 INTRODUCTION

Indus-1 is a 450 MeV storage ring which will mainly provide the radiation in the VUV region of the electromagnetic spectrum [1,2]. The synchrotron is used as an injector which is capable of increasing the energy of 20 MeV electrons as injected from the classical microtron to 450 MeV for injection into Indus-1. The layout of Indus-1 facility is shown in Figure 1. The microtron, transfer lines and synchrotron have already been commissioned. Beam circulation was observed in Indus-1 without injection kicker. In this paper, we describe the status of the Indus-1 facility.

2 DESCRIPTION OF INDUS-1 FACILITY

2.1 Microtron

The 20 MeV microtron is of a classical type. Its major components are an accelerating cavity and a dipole magnet. The directly heated electron emitter LaB_6 has been incorporated inside the accelerating cavity operating at 2.856 GHz. The electrons emitted are accelerated to 20 MeV in 22 orbits. The microtron has been designed to provide an electron beam with a current of 20 mA in a 1-2 μs long pulse duration at a repetition rate of 1-2 Hz. The design horizontal emittance is 1 mm.mrad and energy spread of 0.2%.

2.2 Synchrotron

The synchrotron has a circumference of 28.44 m. It consists of six super periods, each having a bending magnet and a quadrupole doublet. A multiturn injection scheme has been chosen for injecting 20 MeV electrons extracted from the microtron to the synchrotron. The scheme requires three kickers to produce a compensated bump. The synchrotron has a harmonic number of 3 and a repetition rate of 1-2 Hz. The accelerated electrons are extracted using a fast kicker having a rise time of ~ 40 nsec. During the extraction process, one out of the three bunches is lost and only two bunches are extracted.

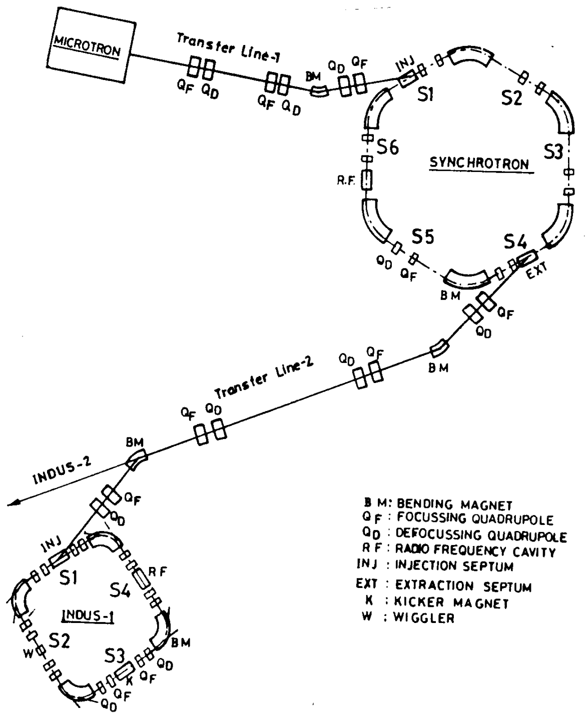

Figure 1 : Schematic layout of Indus-1 SR Facility.

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2.3 Indus-1

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 18.96 m. The magnetic lattice of the ring has four super periods each consisting of a dipole magnet with a field index of 0.5 and two pairs of quadrupole doublets. Each super period has a 1.3 m long straight section. The injection septum and RF cavity are installed in S1 and S4 respectively. The injection kicker and a wiggler will be installed later on in S3 and S2 respectively. A single kicker injection scheme has been chosen. To correct the natural chromaticity, a pair of sextupoles is used in each super period. The ring has a wide tuning range and two tune points have been selected for its operation. The dynamic aperture is larger than the physical aperture. The parameters of Indus-1 are given in Table-2.

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

Energy	450 MeV
Current	100 mA
Bending Field	1.5 T
Critical Wavelength (λ_c)	61.38 Å [a] ; 30.69 Å [b]
Circumference	18.96 m
Typical tune point	1.88, 1.22
Beam emittance $\varepsilon_{x,y}$	7.3×10^{-8}, 7.3×10^{-10} m.rad
Photon flux[c]	7.2×10^{11} [a]; 3.2×10^{12} [b]
Brightness[d]	7.2×10^{11} [a]; 3.0×10^{12} [b]
Bunch length σ_l	11.3 cm
Beam lifetime	1. 8 Hours
Energy spread	3.86×10^{-4}
Revolution frequency	15.82 MHz
Harmonic number	2
Power loss	0.36 kW[a] ; 0.05 kW[b]

[a] bending magnet
[b] high field wiggler (3T)
[c] Flux in photons/s/mrad horz./0.1%BW
[d] Brightness in photons/s/mm^2/ mrad^{2}0.1%BW

2.4 Transfer lines

Transfer Line-1 (TL-1) transports 20 MeV electrons from the microtron to the synchrotron. The beam optics matching requirements of the beam at the injection point of the synchrotron have been taken care of by using three quadrupole doublets and a bending magnet. Transfer Line - 2 (TL-2) transports the beam from the synchrotron to the storage ring. Four quadrupole doublets and two bending magnets are included in this line to take care of the beam matching requirements at the Indus-1 injection point.

3 COMMISSIONING

The microtron was commissioned towards the end of 1994. Since then it is regularly delivering a 20 MeV beam of pulse current 20 mA, pulse length of 1-2 μs at a repetition rate of 1 Hz. TL-1 optics is also optimised for this microtron beam and is being used regularly.

Initially, the synchrotron was operated at the injection energy to carry out some measurements [3]. As the currents in the magnets were increased, the beam was successfully accelerated to 480 MeV with 1.8 mA beam current. At this time, the steering magnets were not energised. In subsequent operations, the current was increased to ~ 11 mA mainly due to the correction of orbit using the horizontal and vertical steering magnets, ramping of the rf voltage from 1.5-6.0 kV and possibly due to improvement in the field pattern of dipole magnets. The RF cavity was detuned by ~ 5 kHz with respect to the generator frequency of 31.616 MHz. Figure 2 shows the DCCT-LP filter signal (1V = 10mA) along with a dipole ramp cycle.

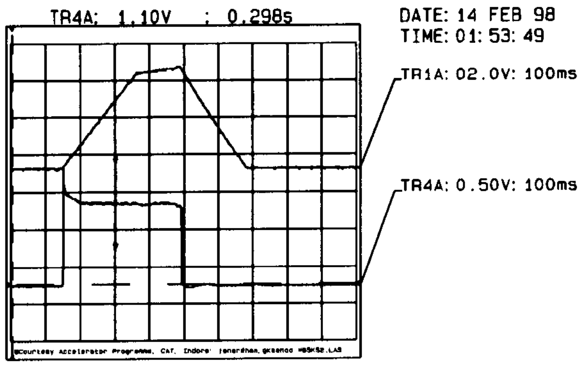

Figure 2: DCCT signal during ramping in synchrotron

To understand the behaviour of the beam during ramping, some experiments were carried out. Betatron tunes were measured using the RFKO method up to ~300 MeV. The horizontal betatron tune was measured at the final energy using coherent excitation of the beam with the help of the extraction kicker. The tune variation was very small during ramping. The horizontal tune at the injection energy was 2.2218 and at the final energy was 2.220, the vertical tune at the injection energy was 1.457 and at the 300 MeV it was 1.456. Synchrotron tune was measured during ramping. The coherent synchrotron oscillations were excited due to the noise present on the signal used for cavity voltage ramping. The synchrotron frequency was 0.002267 at the injection energy and it gradually decreased to 0.0008823 at 450 MeV. The bunch length at the final energy was measured using a wall current monitor. The bunch length was 2σ = 1.4 ns. With this synchrotron frequency and the measured bunch length the momentum compaction of the machine was estimated to be equal to 0.16 which is very close to the design value of 0.151.

Beam Position Indicators (BPI) are installed in S2,S3 and S5 in the synchrotron. To measure the dispersion function at the BPI locations, change in horizontal beam position was monitored with variation in the RF generator frequency. With a measured momentum compaction the dispersion functions at BPI2 and BPI5 locations were found out to be equal to 1.4 m & 1 m respectively. The design values at these locations are 1.35 m and 1.28 m. Beam positions during ramping were monitored. The orbit distortion of few mms is recorded in the BPIs. Orbit correction algorithm will be used for correcting the orbit after installing three more BPIs in the ring in places of BPMs in S1,S4 & S6.

Initially, the extraction kicker magnet was not installed in the ring. It was installed at a later stage when its power supply was ready. The beam extraction trials began after 3-4 mA accelerated current was achieved in the synchrotron. The kicked beam was observed on the mouth of the extraction septum magnet painted with ZnS. As the location of the septum is near the dipole magnet, the intense synchrotron radiation was stopped by a 50μm thin aluminium foil. Using the compensated closed orbit bumps in either plane the beam was pushed into the septum aperture. The two extracted bunches were monitored in TL-2 using a Wall Current Pickup (WCP). This beam was transported up to the injection point of Indus-1. During this passage, the beam was observed at various BPMs in TL-2. The currents in the steering magnets were optimised to centre the beam spot at these screens as well as to maximise the current in the 2π pickup monitor installed at the end of the line. Initially it was noticed that the beam spot used to shift horizontally from time to time. This was mainly due to the dipole current variation (energy variation) at the extraction point in the synchrotron. This problem was rectified by extracting the beam at fixed dipole current. The extraction kicker is synchronised with the dipole extraction current.

Similar to the extraction septum magnet of the synchrotron, the injection septum mouth has also been painted with a fluorescent material and is viewed through a port. Adjusting the steering magnets at the end of TL-2, the beam spot was passed through the centre of the septum magnet. Currents in the septum magnet, dipole and quadrupoles of Indus-1 were optimised to circulate the beam without the injection kicker and with RF cavity off. A beam spot was observed on the BPM placed in S2 and maximum of 6 turns were observed in the WCP placed in S3. The traces of the oscilloscope shown in Figure 3 show the signals of the WCP in the beginning of TL-2, 2π pickup monitor at the end of TL-2 and WCP in Indus-1 along with the extraction kicker signal. Trials to accumulate the electrons will start in April '98 when the kicker magnet is installed in Indus-1.

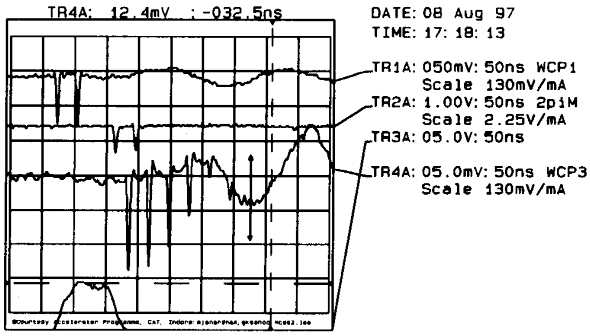

Figure 3 : Current signals in TL-2 and Indus-1

4 CONCLUSIONS

The microtron, synchrotron and transfer lines have been commissioned. Initial trials for circulating beam in Indus-1 in the absence of the injection kicker were successful. It is hoped that after installation of the injection kicker in April'98, it will be possible to store electrons in the ring and the ring will be available to users towards the end of 1998.

5 ACKNOWLEDGMENTS

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