STATUS OF SRS INDUS-2

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Abstract

Indus-1, the first synchrotron radiation source (SRS) of India was commissioned at Centre for Advanced Technology (CAT) in July, 1999 and is regularly in operation. Indus-2 is the second synchrotron radiation source being constructed at CAT. While the Indus-1 is a 450 MeV storage ring for VUV radiation, Indus-2 will be a 2.5 GeV storage ring for x-rays. A 20 MeV injector microtron and a 700 MeV booster synchrotron will inject the electron beam both to Indus-1 and Indus-2, while doing so at a lower energy of 450 MeV for Indus-1. The paper deals with the salient features of Indus-2 which is now under construction. The machine with a circumference of 172.47M has critical wavelength with bending magnet radiation of 1.986Å and with high field wiggler of 0.596Å. There is provision for 22 beamlines for use of synchrotron radition from bending magnets and 5 beamlines for using the radiation from insertion devices in straight section. While the work on Indus-2 had started in 1996 as a 2 GeV storage ring the proposed energy was increased to 2.5 GeV in 1998 as per the recommendation of International Advisory Committee of the project. The RF frequency was also increased from 189 MHz to 505 MHz as per the recommendations of the RF experts in the committee. Subsequently all the sub system designs had to be accordingly revised to meet the revised specifications and work started afresh. The paper gives the present status of the design and fabrication of various sub-systems of Indus-2 as per the new design.

1 BEAM DYNAMICS

1.1 Lattice Design

An expanded chasman green lattice has been selected and optimised for Indus-2. The beam emittance of the standard chasman green lattice is reduced by modifying the achromat section. Instead of one quadrupole a triplet in FDF configuration with an optimally large gap between F and D quadrupoles is used which will also result in a large dynamic aperture.

The storage ring consists of 8 unit cells each providing a 4.5 M long straight section. The magnetic structure of the storage ring is shown in Fig.1. Its unit cell has two 22.5^0 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. The design parameters of the source is given in the Table below.

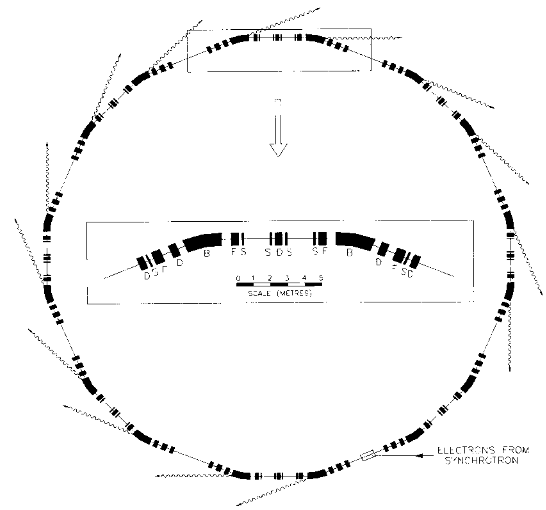

Figure 1 : Layout of Indus-2

Table 1 : Parameters of Indus-2

Maximum Energy		2.5 GeV
Lattice Type		Expanded Chasman Green
Superperiods		8
Circumference		172.4743 m
Maximum Current		300 mA
Beam Emittance	εx	5.81×10^{-8} mrad
	εy	5.81×10^{-9} mrad
Available Straight Section for insertion devices		5
Maximum Straight length available for insertion devices		4.5 m
Beam Size (Cen.of bending magnet)	σx σz	0.234 mm 0.237 mm
Beam envelope vacuum		$< 1 \times 10^{-9}$ mbar
Beam life time		24 Hrs
RF Frequency		505.812 MHz
Critical Wavelength		1.98 Å (Bending Magnet) 0.596 Å (High Field Wiggler)

of the eight 4.5 long straight sections one will be used for injection, two for RF cavities and the remaining for insertion devices.

1.2 Injection into Indus-2

A layout of the injector, booster and storage ring Indus-1 and Indus-2 is shown in Fig.2.

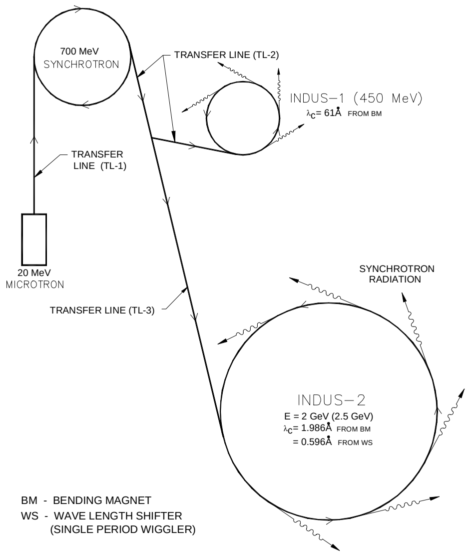

Figure 2 : Schematic Layout of Synchrotron Radiation Sources Indus-1 and Indus-2

A classical type microtron which provides 20 MeV electrons with a pulse current of 30mA, serves as an injector while a booster synchrotron designed to accelerate further the electron beam energy to 700 MeV with a beam current of 30mA. This beam is injected into the storage ring Indus-2 where the beam is further accelerated to 2.5 GeV. The microtron is fully operational while the booster synchrotron at present is working with a beam energy of 450 MeV and beam current of 11mA for injection into 450 MeV storage ring Indus-1. The beam energy will be raised to 700 MeV while injecting it to Indus-2.

The booster synchrotron will provide two bunches each around 1 ns long separated from each other by nearly 30 ns at a repetition rate of 1-2 Hz. After injecting several pulses at 700 MeV to accumulate 300mA, the beam will be accelerated to 2.5 GeV by slowly increasing the magnetic field of the bending magnets. The beam will be injected in the horizontal plane via two septum magnets by a multi-turn injection process in one of the 4.5m long straight sections by employing a compensated bump which will be produced by means of four kickers. The maximum kick angle produced by the kicker is 25 mrad which will produce an orbit bump of $\approx$20mm. The amplitude of the coherent betatron oscillations after the injection will be nearly 13 mm in the injection section. The dynamic aperture available will be more than adequate to accommodate these oscillations. The coherent oscillations of the injected beam will get damped in a fraction of a second and therefore when a subsequent pulse is injected into ring the earlier one will be sufficiently damped and the process is continued till a beam current of 300mA is stored.

1.3 Beam life time

At the peak energy, beam life of several hours is required for carrying out the experiments. The beam life time is mainly decided due to two processes. Columb scattering within the electron bunch (Touschek scattering) and scattering of electrons with the residual gas molecules. With the pressure in the vacuum chamber in which the beam circulates less than 10^{-9} mbar the total beam life time is estimated to be around 24 hours which is adequate for all applications.

2 MAGNET SYSTEM

The main dipole magnet maximum field is designed to be 1.5 Tesla. The 17 dipole magnets (including one reference magnet) are under construction from 50.8mm thick plates of low carbon steel highly homogenous iron supplied by M/s Cockreill Sambre, Belgium. This soft magnetic material was selected for the construction as it is a high purity iron with carbon 0.01%, Mn 0.3%, Si 0.1%, P 0.02% and S 0.02%. High saturation induction of this material will help in the linear response of these magnets. This material has also been used for magnets in LHC Project at CERN, Geneva. Magnetic properties of this material were carefully studied and the design calculations showed that this material is suitable for the application. These magnets will be ramped from 3 KG to 15 KG in a period of 300 seconds and will be constructed vertically arranging 5.8 mm thick plates and welding together. The plates will be insulated from each other which will minimise the field distortions due to eddy currents. The pole gap is 50 mm. The energising coils are oxygen free high conductivity copper (OFHC) square hollow conductors.

A total of 40 nos. of quadrupoles with a field strength of 16 T/m and 32 nos. of sextupoles with field strength of 400 T/m^2 and 16 harmonic sextupoles with a field strength of 200 T/m^2 will be used. The quadrupole magnets have aperture of 85 mm and their length varies from 300 mm to 500 mm comprising of five different lengths of magnets. The magnets are of laminated construction with the laminations stamped from CRNGO silicon steel of 0.50/0.65 mm thick, M-36/M-27 grade. An additional 32 quadrupoles which are located just before and after each dipole magnet are open type. These are constructed of 1.5mm thick soft iron similar in material composition to that of dipole magnets. The energising coils which are isolated and epoxy potted are of OFHC square hollow conductors. The sextupole magnet construction as well as its energising coils are similar to that of quadrupoles. In addition 42 nos. of combined function steering magnets, 8 vertical steering magnets, 16 horizontal steering magnets will be employed apart from steering coils on dipole magnets to correct the beam orbit.

Transfer line (TL-3) approximately of length 90 meters will transport the beam extracted from the 700 MeV booster synchrotron to Indus-2. Part of this transfer line (TL-2) is currently being used to transport the beam from booster synchrotron to Indus-1. The design of the transfer line will take into account the need to keep the beam size as small as possible with suitable optics and use of symmetrical magnetic structures in order to reduce the number of power supplies and provision of beam diagnostic elements and steering magnets. To bend the transfer line in order to reach the Indus-2 location as well as to have achromatic conditions in the line, the beam is bent with two 8.5^0 bending magnets. In all, transfer line from booster synchrotron to Indus-2 storage ring will have five bending magnets and 25 quadrupoles.

As mentioned earlier, injection into Indus-2 will be achieved by two septum magnets (a combination of a thick septum magnet and a thin septum magnet) as well as a set of four fast kicker magnets. While the septum magnets are located within the vacuum chamber of the storage ring, the bump magnets are located outside the ceramic portion of the ring vacuum chamber. The thin septum magnet will have a bending angle of 2^0 with a magnetic field strength of 0.50 T and current of 4500A. The thick septum magnet will have a bending angle of 19^0 with a field strength of 0.9T and current of 8500A. The thin and thick septum is made of copper bus. The coil will be insulated by ceramic coating by plasma spray. The core will be made of nickel iron lamination of 0.1mm thick.

Kickers which are pulsed ferrite magnets have a window frame structure and will be constructed by isoperm type Ni-Zn-Co ferrite blocks which has a pulse permeability of 1500. The maximum magnetic field is 2200 Gauss. Each of the four kicker magnets will produce 25 mrad kick. The design of the septum and kicker magnets have been completed and their fabrication is in progress. Special Ni-Zn-Co ferrites have been specially developed for use.

The core of the main dipole magnets of the storage ring are currently under fabrication at M/s Godrej, Mumbai. The energising coils have been fabricated at CAT. The fabrication for the quadrupole and sextupole magnets are also in progress at M/s Indo German Tool Room, Indore. The coils for these magnets are under fabrication at CAT. Septum and kicker magnets as well as all transfer line magnets are being built in house.

3 POWER SUPPLIES

Both DC and pulsed power supplies are required for the various magnets. The DC power supplies are used to energise dipole, quadrupole and the steering magnets. Pulsed power supplies are required for septum and kicker magnets. All the 16 dipole magnets and a reference dipole magnet will be energised by a single power supply rated for maximum of 900V/840A. A group of quadrupole magnets and sextupole magnets are energised by separate power supplies. 26 power supplies of various capacities (87-783V/180A) are required for quadrupole magnets while 2 power supplies (300V/230A) are required for all sextupole magnets. All the power supplies have to be highly stable in respect of long term stability reproducibility ($\pm$ 5 x 10^{-5}), ripple and noise ($\pm$ 1 x 10^{-4}) and setting resolution ($\pm$ 5 x 10^{-5}). DCCT's will be used as high precision current sensors for the dipole and all quadrupole magnet power supplies. All the steering coil power supplies are bipolar and are based on switched mode power supply design. All the components of dipole power supply have been received and will be assembled and tested at its actual location. The prototype of quadrupole and sextupole power supplies have been built and tested while the fabrication of all the power supplies are in progress.

4 RADIOFREQUENCY SYSTEM

The radio frequency (RF) system is required to replenish the energy lost by the beam in the form of synchrotron radiation. The operating frequency of the RF system is 505.812 MHz. The total energy loss in the form of synchrotron radiation is 672 KeV and the total voltage to be developed across RF cavities is estimated to be 1.5 MV. This demands total 269 KW beam power at 300 mA beam current. Taking into consideration installation of insertion devices, cavity losses, transmission losses, etc. total beam power requirement from RF system will be about 322 KW. Four RF stations will be used to deliver this power to four RF cavities. Orders have been placed with Synchrotron Trieste, Italy for the supply of 4 RF Cavities. The fabrication is in progress and all the four cavities will be available by August, 2002. The cavities will be exited by 60 KW RF power source. The RF source is built around 60 KW multi cavity multi beam klystron tube. The klystrons and circulators are being procured from Russia and are ready undergoing testing. All related power supplies and RF components have been developed. Low level RF control system will be used to regulate amplitude, phase and frequency of cavity gap voltage.

5 UHV SYSTEM

The 16 nos. of dipole vacuum chambers of ante chamber design, being fabricated from aluminium alloy 5083 H321, consisting of upper and lower halves machined separately and welded together after chemical cleaning. Two beam ports at 5^0 and 10^0 are provided in each dipole chamber. In addition, another port at 0^0 is also provided in five dipole chambers downstream of the five straight sections meant for insertion devices. All the dipole chambers have been machined using bridge type milling machine at Hindustan Aeronautics Limited, Nashik. Assembly welding and testing of first chamber is now in progress. Eleven dipoles will be utilised for extracting the synchrotron radiation. Straight section vacuum chambers will be constructed out of extruded aluminium alloy section of specification 6063 T5 which was already been procured. Turbomolecular pumps, triode type sputter ion pumps, nonevaporable getters and titanium sublimation pumps will be employed at suitable locations to obtain the ultra high vacuum of better than 10^{-9} mbar. The ion pumps and titanium sublimation pumps already developed in-house will be used. The pressure monitoring will be done using bakeable Pirani gauges and BA gauges. RF sector valves will be installed to isolate each cell of the ring and also the RF cavities. In addition, quadrupole mass analysers already procured will be mounted all along the ring at an interval of 10 meters to monitor the residual gas composition continuously.

6 CONTROL SYSTEM

The control system architecture is planned to be a 3 layer system. The top layer consists of control room computers serving as user interface, operator consoles, file servers, data base managers and alarm controllers. The middle layer consists of local process computers (LPC) responsible to monitor and control various subsystems like magnet power supplies, RF, vacuum, beam diagnostic devices, etc. These are VME based micro computer system. The third layer which is a root layer is formed by equipment interface units (EIU). It is designed around the VME bus structure. All these computers are interconnected over two layers of the network. It is proposed to use operating systems MS-DOS, Windows-NT and OS-9.

7 BEAM DIAGNOSTICS DEVICES

Several beam diagnostics devices are planned to be distributed around the ring in order to monitor essential beam parameters such as beam position, current, beam profile, betatron tune. Many of these monitors have been developed at CAT and are being fabricated locally while items like streak camera, 2-D photon array detectors and some optical components are being imported. Two bending magnet beam ports will be used for beam diagnostics with synchrotron light.

8 BUILDING & SERVICES

A new building of about 12,000 Sq. Meters area is being constructed to house Indus-2. The ring lattice is housed in a shielded tunnel with a concrete shielding wall of 1.5M thick towards the experimental area, a 0.6M thick wall on inner side and 0.6M thick roof slab. The experimental hall around provides an 18M wide column free space for both experimental beam lines and accelerator systems. The low conductivity water plant with its cooling towers is housed in a separate building close to the main building which is completed. An a/c and ventilation system will take care of the temperature stability required in the building and particularly in the tunnel (± 1^0C). The total electrical power requirement will be about 9.3 MVA. The construction of the tunnel to house the storage ring is already completed. The construction of the experimental hall is now in progress. The LCW plant with a capacity to extract a heat load of 4 MW has been designed and is in the final stages of commissioning. The RF cavities require temperature stability of cooling water within ± 0.1^0C. While one of the chillers to supply the cooling water to one cavity is being procured alongwith the cavities from Elletra the rest of the three chillers are being developed indigenously.

9 ALIGNMENT

As the machine of this type will be very sensitive to positioning errors of various lattice elements and particularly magnets, survey and alignment procedures used play a vital role. Since the machine is housed in a tunnel, measurement for whole of the ring will have to be referenced to a number of internal control points. A suitable control network has been planned. For least square adjustment of network transverse data, it is proposed to use commercially available software package like GEONET or STARNET. The allowable positional tolerances in the radial and vertical directions in respect of the magnet alignment are about 0.2mm for dipole magnets. 0.1mm for quadrupole and sextupole magnets. Further the transverse tilt of the magnets will be within 0.2 mrad.

10 RADIATION SAFETY

Indus-2 is a potential source of high energy bremsstrahlung x-rays and photo-neutrons and adequate radiation protection is therefore planned against these hazards. The radiation shielding has been designed for a permissible dosage of less than 0.1 mrem/hr (<200 mrem/year) for all continuously occupied areas. Radiation monitors will be installed at various locations to monitor the radiation field during operation. Two type of radiation monitors namely 20 nos. of beam loss monitor (range 0.1-1000R/Hr) for high radiation areas and 50 nos. of area monitors (range 0.02-100mr/Hr) for experimental area having user beamlines will be used. Other necessary safety provisions, search & scram system, personal monitoring, a monitoring system for radioactive isotopes in water and airborne radioactive isotopes and ozone monitoring in the tunnel as well as fire protection system have been planned.

11 COMMISSIONING SCHEDULE

As per the present plans, the installation of the machine is expected to be completed by December, 2002 and commissioning may require a further 3 to 4 months.