INDUS-1-THE SYNCHROTRON RADIATION SOURCE AT CAT.

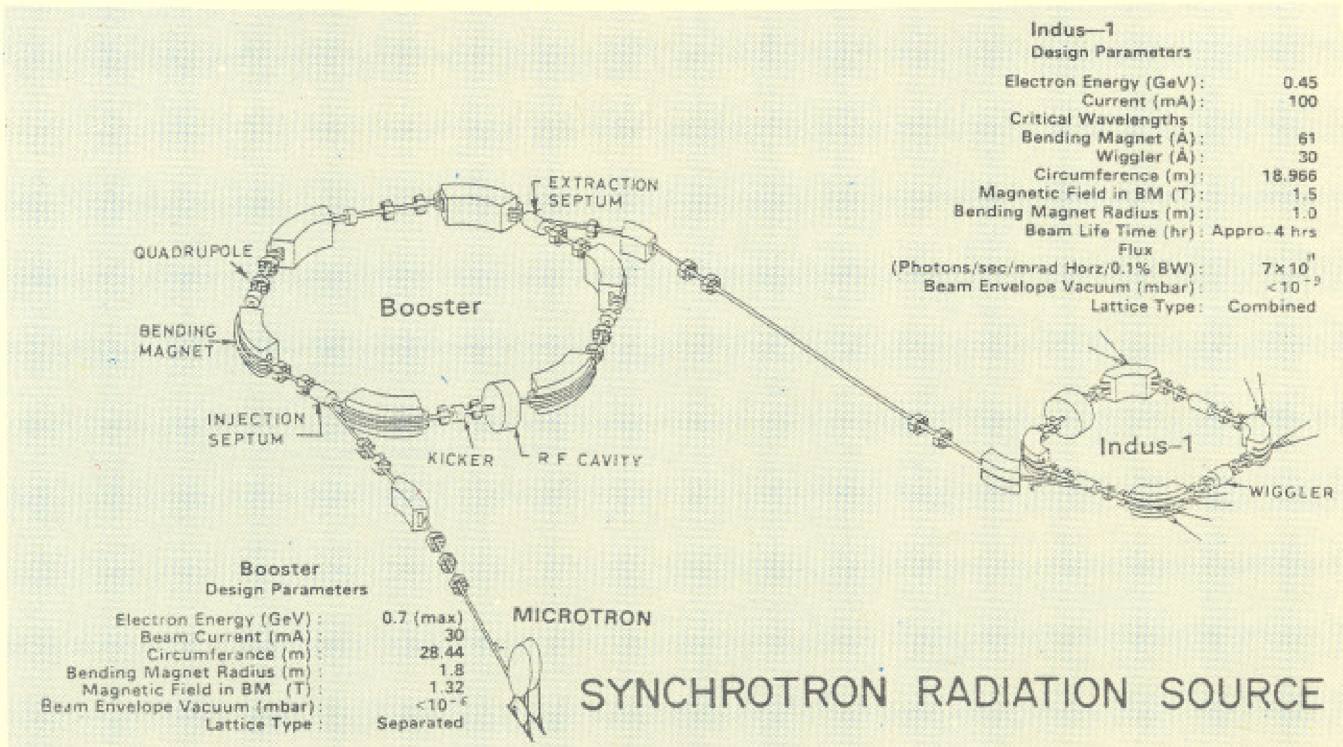
The phenomenon that an electron in a circular trajectory would radiate was predicted more than hundred years ago. It took almost half a century to verify it experimentally. Efforts to design high energy electron accelerators were restricted because of losses due to emission of electromagnetic radiation, later named as synchrotron radiation. These radiations, which were parasitic for high energy accelerators appeared to be a useful byproduct having many unique properties. After recognizing its potential as a powerful radiation source, construction of dedicated Synchtron Radiation Sources (SRSs) was started all over the world. SRS provides a highly intense, bright and collimated beam having a continuum from Infra Red to X-ray region. These radiations are also characterised by their polarised nature and pulsed time structure.

INDUS-I, the SRS being developed at CAT, is a 450 Million Electron Volts (MeV) electron beam storage ring. It has an injector system consisting of a microtron and a booster synchrotron. Pulses of electrons of 20 MeV energy will be injected from a Microtron into booster synchrotron where their energy wil be raised upto 450 MeV. At this energy the electron bunches will be extracted from the booster synchrotron and transferred to the storage ring INDUS-I. This process will be repeated till the desired current of 100 mA is achieved in the storage ring. At this current the beam will circulate in the storage ring for about 2-4 hrs, emitting synchrotron radiation.

The injector microtron being deveoped at CAT is a conventional microtron of 20 MeV energy and 20 mA current. The microtron uses an RF cavity of 2856 MHz for acceleration of electrons. Lanthanum Hexaboride electron emitter mounted in the cavity wall emits electrons which orbit in a vertical plane between dipole magnetic field of 1-2 KG. Electron energy is increased to 20 MeV in 22 orbits. These electrons of 20 MeV energy and pulse duration of 1-2 microsec. will be injected into the booster at 1-2 Hz repetition rate.

The Booster synchrotron has six dipole magnets to bend the beam in a near circular path and six pairs of quadrupole magnets to focus the beam in both horizontal and vertical plane. Special types of magnets, namely septum and kicker magnets will be used for injecting and extracting the beam. All these electromagnets require high precision configuration of magnetic field. The dipole magnet is a C-shaped 60 sector magnet with bending radius of 1.8m and pole gap of 0.05m. While increasing the energy, the magnetic field is ramped from 340 Gauss to 13 KGauss to keep the bending radius unchanged. Since the field is ramped, the core of the dipole magnets is made from laminations. Straight sections between two dipoles accomodate quadrupoles, Radio Frequency (RF) cavity, injection and extraction magnets, beam diagnostic devices and vacuum ports.

Storage ring INDUS-I will have four dipole magnets and eight pairs of quadrupole magnets. Kicker and septum magnets will be used for injecting



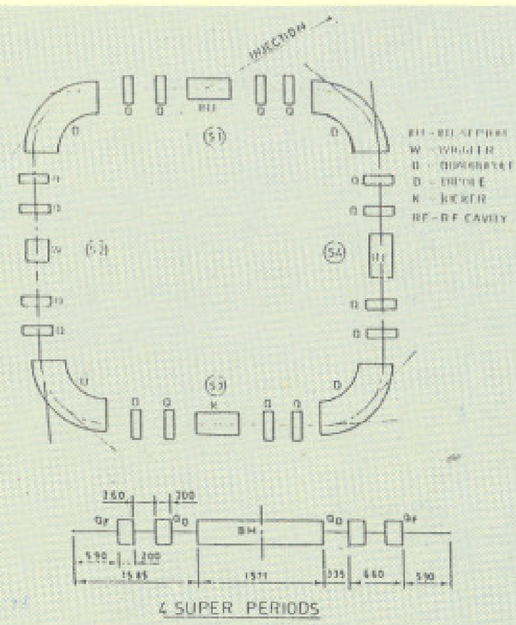
the beam. In addition to these magnets, quadrupole magnets will incorporate sextupole elements to correct the chromaticity arising because of difference in focusing for different energy electrons. Since the energy of electrons remains constant in the storage ring, the field is constant. Therefore the dipole magnet in this case is machined out of low carbon steel forgings. The magnet is a C-shaped 90 sector having field index of 0.5 with a mean radius of 1.0 metre and a pole gap of 0.035 m. Maximum operating field is 1.5 Tesla. The straight sections between two dipoles are used to accomodate quadrupoles, injection and extraction magnets, RF cavity, beam diagnostic devices and vacuum ports.

One of the straight sections in both the rings accommodates Radio Frequency (RF) cavity which will compensate for the loss of energy due to SR. In booster it will also accelerate the beam to the desired energy. Power is transmitted to the electron beam via electric fields set up in the RF cavity. The electrons in the ring travel at nearly the speed of light. These electrons have an orbital revolution frequency which depends on the circumference of the machine. In order to maintain synchronism of acceleration and phase of the electrons in the ring, RF system has to provide accelerating electric field at a frequency which is an integral multiple of the orbital revolution frequency. The RF cavity is a precision machined copper structure with elaborate cooling arrangement. Since any change in dimension affects the resonant frequency of the cavity,feedback control system is used to tune the cavity to desired frequency. The cavity is excited by 10 KW RF ampifier at 31.613 MHz. In this RF amplifier, low level signal from a crystal controlled synthesizer is amplified by a preamplifier and fed to a FET attenuator, whose output is controlled by control signal which can be used for changing the cavity gap voltage. The output from FET is further amplified by a solid state driver amplifier which can deliver about 200 watts of RF power. The required 10 KW is achieved in final power amplifier stage, which is built around a tetrode tube.

Power supplies for variety of magnets are basically current regulated. Storage ring dipole and quadrupoles have a d.c. current power supply. It is required to feed four dipole magnets connected in series. In the case of a booster, a slow ramped power supply is required. During magnet current rise period, the dipole magnet field is raised from 340 Gauss to 13 KG. Provision is made to vary the maximum current from 500 A to 1000 A for different beam energies at extraction. Beam is extracted during current flat top period after which this current has to be brought down to low level for injection in the next cycle. Booster quadrupoles will also have ramped power supplies. Fast pulsed power supplies are required to feed injection and extraction kickers and septums. Stability requirements for these power supplies are very stringent. Current stability of 0.01% is required for DC power supplies in the storage ring and during flat current portions of booster dipoles, while 0.1% stability should be achieved for other magnets.

The presence of electron beam and its parameters in the rings are detected and measured by Beam Diagnostic Devices installed in the rings at various locations. Parameters like beam position, beam intensity, emittance etc. are measured by Beam Position Monitors (BPM), DC Current Transformer (DCCT), Pulsed Current Transformer (PCT), synchrotron light monitors etc. Some of these are interceptive / destructive type and others are nondestructive type. Suitable electronics and computers will be required to analyse the data and thereby keep track of the electron beam.

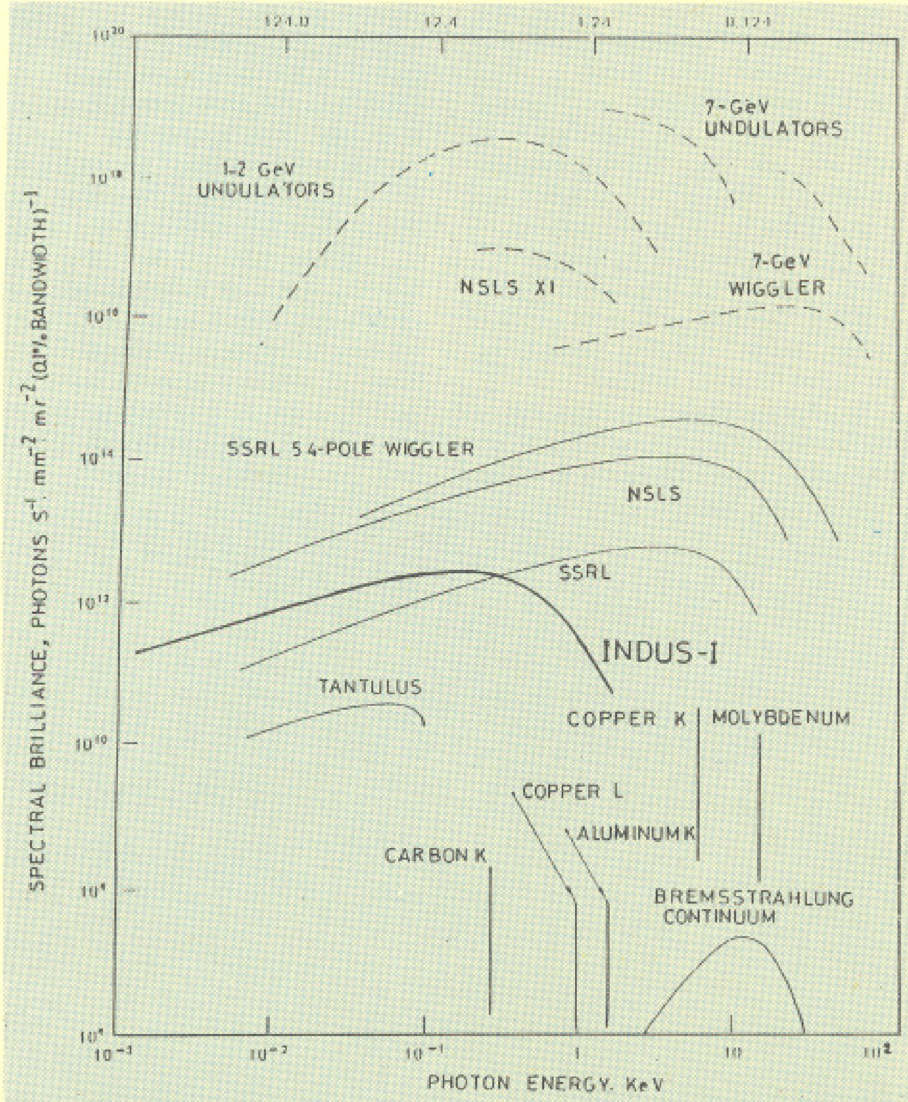
In INDUS-I, as well as in the booster, the electron beam circulates in a stainless steel vacuum chamber. Type of chamber and its cross section are decided by beam optical considerations and its location in the magnet gaps. For adequate beam life time in INDUS-I, the chambers have to be evacuated and maintained at extremely low pressure of the order of 10^{-9} Torr. Vacuum chamber in Booster Dipole is a thin walled bellow or ribbed type curved chamber whereas in Storage Ring Dipole, it is a rectangular, box type, curved chamber with beam ports. In straight sections of rings, standard stainless steel pipes are used as vacuum chambers. Knife edge type of flanges with OFHC copper gaskets are



MAGNETIC LATTICE OF INDUS-I

used for interconnection. The Ultra High Vacuum (UHV) pumping system consists of Turbomolecular pumps, ion pumps and Titanium Sublimation pumps. Pressure measurement is done with Pirani, Penning and BA guages. Residual Gas Analysers (RGA) are also used to monitor gas composition in the chambers. Since the vacuum chambers have large linear size with narrow cross-section, a large number of pumps of smaller capacity (200/270 L /sec) are used. In addition to normal thermal outgassing, the SR hitting on the chamber walls causes heavy gas desorption. This is minimised by using hydrocarbon free, ultra clean and elaborately treated vacuum chambers. The treatments include chemical cleaning, electropolishing, high temperature vacuum degassing and Argon glow discharge cleaning.

Control system for INDUS-I is a centralized one. The status information from all the subsystems, interlocks, radiation monitors etc, is available at a central place. The design is based on the principle of distributed intelligence and parallel processing. The hardware has a modular structure. This imparts the much needed speed, flexibility and expandability to the control system. The control scheme is divided into three levels- -(a) front end instrumentation like sensors and actuators,(b)microprocessor/ microcomputer based data handling systems and (c) supervisory central control at the apex. The measurements and alarm status will be displayed on a number of video monitors. Fast waveforms such as RF, beam profile and position, fast trigger timing sequence etc. will be displayed on fast oscilloscopes. The hardware is based on sixteen bit data bus employing VME bus standards.



SPECRAL BRILLIANCE CURVE OF INDUS-I AS COMPARED TO OTHER SOURCES

The lattice of INDUS-I, described above is optimised to give a small emittance (product of beam size and angular spread) and long lifetime of the beam. Small emittance of the electron beam implies that the photon beam will have high Spectral Brilliance (S.B.). S.B. is the property of radiation that permits experiments requiring many photons to be performed at high spectral resolution on very small samples. S.B. curve of INDUS-I as compared to S.B. of laboratory X-ray tubes, present SR facilities and planned future facilities in the world is shown in the figure. Useful flux of radiation will be upto $6A^{0}$. Five main ports are provided from bending magnet section which in turn can be split in nine ports to provide nine beam lines for tapping the radiation for experiments. An ideal SRS beam line should have maximum transmittancy, maximum resolution and maximum wavelength tunability for the entire VUV region. SRS beamline will consist of fore optics, monochromator, post optics, sample chamber and detector. Proper choice of mirrors ,gratings and monochromator will be done as per the experimental requirement.

Out of nine beam lines being set up, five will be set up by BARC and CAT. These five lines will be used for experiments using Angle Resolved Photo Electron Spectroscopy(ARPES), Photo Electron Spectroscopy (PES) of gases, L-edge spectroscopy etc. ARPES yields detailed electronic Band structure information on bulk as well as surface states. PES of solids and gases conventionally employs photon sources to probe the electronic structure of atoms and molecules. Some sources are extensively used in Ultraviolet Photoelectron Spectroscopy (UPS) to study outer shells. Some other sources are employed in X-ray Photoelectron Spectroscopy (XPS) to study core electrons. There is a large gap between energies of photon sources used for UPS and XPS. For many applications, a tunable source is required. SR, with its continuum, provides such a tool. The technique of Absorption spectroscopy deals with the absorption of x-rays by atoms. This varies smoothly with photon energy except at some discrete energies where abrupt increase called absorption edges occurs. Photophysics beamline will be used for the studies of absorption and fluroscence of molecules, spectroscopy of photofragments,ionic fragmentation using core level ionization etc. One beam line will be used for high resolution VUV spectroscopy. Atomic and molecular spectral studies carried out under high resolution provide a wealth of information about the valence excitations which cannot be achieved easily by conventional sources due to their inherent limitations. One line will be set up for industrial applications in the field of microlithography, for making micro electronic devices and one line will be used for calibration of synchrotron light and its characteristics. Two beam lines will be set up by UGC , which will also set up an inter-University centre for SRS utilisation at CAT.

Computer Facility.

The computer network at CAT named CATNET consists of two super microcomputers (HORIZON-III) hooked to a local area network (LAN) based on standard ETHERNET with a data transfer rate of 10 M Bits/sec For connecting all future mainframe and mini-computers to this LAN , necessary coaxial cables have been laid underground all over CAT , Workstation and personal computers are connectetd to existing super micro-computers using serial line data communication at the speed of 9600 baud . Presently about twenty five personal computers and workstations distributed all over CAT are using CATNET to access online data bases , electronic mail and super microcomputers.

To facilitate easy library information retrieval from multiple points, software has been developed for an on line data base of library information. Using this package , the user can get complete information about any book, its author , publisher and its issue status in the library. Apart from information retrieval , many library management functions , like printing catalogues , lists of new arrivals and various reports are also provided by this package. This package has been developed in the UNIX based minicomputer on UNIBASE (UNIFY like)DBMS. The user interface is highly interactive , menu driven , friendly and self guided with on-line contexual help and other prompts.

A view of the computer facility

Computer aided drafting has been introduced at CAT. Almost half of the CAT drafting work has shifted from conventional drawing board to the desk top computer. PCB layouts are also prepared using CAD. Two high speed eight pen plotters (120 cms/sec) have been installed for the plotting of complex drawings and computer generated scientific figures, graphs etc.

Visits Abroad.

Synchrotron Radiation Sources are built throughout the world by all advanced countries for research and development work , as well as for industrial applications. Many machines which were earlier built as colliders are now converted to work as SRSs. USSR made collider machines at Novosibirsk in Siberia. With their successful experience for last ten years, they have now started fabricating SRS. Two such machines are being installed by them at Moscow. A scientific delegation from CAT formed by Shri S. S. Ramamurthi , Shri V. K. Kulkarni , Shri S. Kotaiah , Shri G. Singh , Shri S.P. Mhaskar visited USSR to gain the information regarding different subsystems of SRS. Full cooperation was offered to the delegation by the USSR scientists.

Another delegation headed by Dr. D.D. Bhawalkar, Director, CAT with Shri Raja Rao and Shri H.C. Soni from CAT and some other members from other organisations also visited USSR in connection with investigations in Laser technology and industrial accelerators. The main fields of interest in their visits to different institutes were the study of engineering aspects of the crystal growing equipments, laser applications in metal fabrication like cutting , welding, engraving, surface heat treatment as well as to see the SRSs which are operational or under construction.

Dr. K.C. Rustagi attended the 4th International conference on superlattices , microstructures and micro devices at Trieste and presented a poster paper. He was also invited to