A.1: Indus-2 up-gradation with two insertion devices: A step towards 3rd generation regime

A major boost in the performance of Indus-2 synchrotron radiation source heralding its entry into 3rd generation storage ring regime has been accomplished in RRCAT. Two insertion devices, both planar undulators, have been successfully commissioned in the Indus-2 ring to enhance spectral brightness of the synchrotron radiation by 2 to 3 orders of magnitude compared to the bending magnets. The two planar undulators (U1 and U2) for Atomic Molecular Spectroscopy (AMOS) beamline and Angle Resolved Photoelectron Spectroscopy (ARPES) beamline have been fabricated (Kyma, Italy) as per our design specifications. These undulators have an array of permanent magnets of different pole strength and periodicity. The design parameters of these undulators are given in Table A.1.1.

Table A.1.1: Design parameters of the undulators U1 and U2

Parameters	Specifications of undulators	
Configuration	Pure Permanent Magnet (PPM) (B_r = 1.25 T)	
Length of Magnet Assemblies	2.45 m ± 0.05 m	
Energy of the output radiation	6 eV to 250 eV (U1) 30 eV to 696 eV (300eV 1st Harmonic) (U2)	
Gap range	Pole gap: 23 mm to 250 mm	
Period length (λ_u) Approx. block size	U1: 126.8 mm (105x41.1 x31.6) mm^3	U2: 85.2 mm (96x32 x21.2) mm^3
Peak magnetic field (B_0)	~1.06 T	~0.86 T
RMS phase errors	= 3°	

Frequency of radiation emitted from undulator is tuned by varying the pole gap from 23 mm to 109 mm for U1 and 23 mm to 61 mm for U2. The design spectral brightness of the two undulators and the bending magnets for the Indus-2 storage ring is shown in Fig. A.1.1.

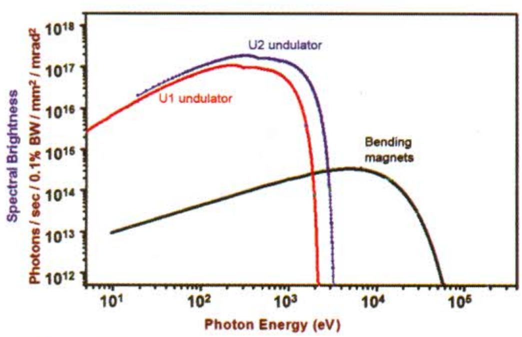

Fig. A.1.1: The design spectral brightness of the two undulators and the bending magnets.

The presence of undulators in storage ring can have undesirable net effects on the closed orbit distortion. In addition, it can cause betatron tune shifts, beating of amplitude functions and reduction in dynamic aperture etc. Orbit distortions are also, in general, a strong function of the magnetic pole gap of the undulator. An undulator needs to have its gap changed whenever different photon energy is needed. These orbit perturbations can be limited by setting maximum values for the first and second field integrals of the magnetic field through the insertion device. The first field integral through the undulator determines the angle between the incoming and outgoing particle trajectory, while the second field integral determines the displacement of the outgoing particle trajectory. To ensure the orbit perturbation limit at all the magnet pole gaps within 10% of the beam sizes and beam divergences, the tolerances of magnetic field integrals were evolved which are listed in Table A.1.2.

Table A.1.2: Field integral tolerances

Field Integrals	Values
1st vertical magnetic field integral	±50 G-cm (on axis = ±30 G-cm)
2nd vertical magnetic field integral	±10000 G-cm^2
1st horizontal magnetic field integral	±20 G-cm
2nd horizontal magnetic field integral	±8000 G-cm^2

After receiving the undulators from the manufacturer, the measurements of the magnetic field integrals as well as higher order magnetic multipoles were carried out and they were found to be within the specified limits. The two undulators, weighting 4.6 ton each, were taken inside the Indus-2 tunnel, after successful offline characterization. Both the undulators have been installed in their designated positions in the storage ring with accuracy better than 100 micron. Fig. A.1.2 and Fig. A.1.3 show the sections of Indus-2 storage ring housing the two undulators.

Fig.A.1.2: Undulator U1 installed in LS-2

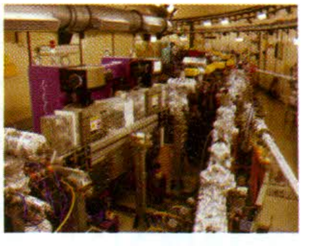

Fig.A.1.3: Undulator U2 installed in LS-3

The new undulator vacuum chambers along with their peripheral components were installed and isolated using RF sector valves. After installation of the new components, baking cycle was carried out. This was followed by activation of NEG coated undulator vacuum chambers at 180 °C for 24 hours. All the TSPs, BAGs and SIPs were also fired during vacuum conditioning of all these chambers. This resulted in achieving an average vacuum of 7×10^{-10} mbar in the ring and hence Indus-2 ring was made ready for beam injection trials with undulators.

These undulators have been provided with PLC based control system. Remote operation of the undulators is facilitated through network communication over ethernet link using client server software components. Two low gap beam position indicators (LGBPI) are installed at entry and exit of each undulator for monitoring the electron beam position and angle. A beam dump signal will be generated to abort the electron beam if position and angle are found to be deviated from pre-decided values. The undulator operation from control room is served through a Graphical User Interface (GUI) based client application.

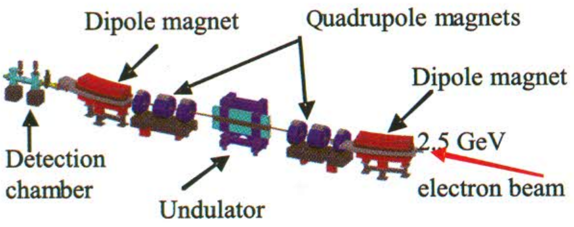

Fig. A.1.4: A schematic of the section of the storage ring housing an undulator, and detection chamber.

The effect of undulator action on the orbit stability at the 2.5 GeV electron beam energy was studied. There was no significant distortion of the orbit. The beam current was increased to 50 mA in small steps over a period of 10 days to allow vacuum conditioning of the chambers. Further, the functional testing of the undulators with 2.5 GeV electron beam circulating in the ring was carried out by measuring the photo-electron beam current profile generated by undulator radiation using scanning wire and recording its image. A schematic of the section of the storage ring housing an undulator and its neighboring dipole and quadrupole magnets is shown in Fig. A.1.4. Two detectors, a scanning wire monitor and a chrome doped alumina ceramic sheet beam viewer, were placed in a vacuum chamber mounted on the zero degree port of the downstream dipole magnet.

The photoelectron current profile measured using scanning wire monitor for the U1 undulator for different pole gaps is shown in Fig. A.1.5. It is seen that the peak current decreases with increasing pole gap. While the peak current for the minimum pole gap is predominately due to undulator radiation that for the maximum pole gap of 250 mm (i.e. undulator poles wide apart) is only due to adjacent bending magnet radiation. Experimentally observed variation of the peak current with pole gap is found to be in good agreement with the design calculations. The undulator radiation intensity is much larger than that from the bending magnets.

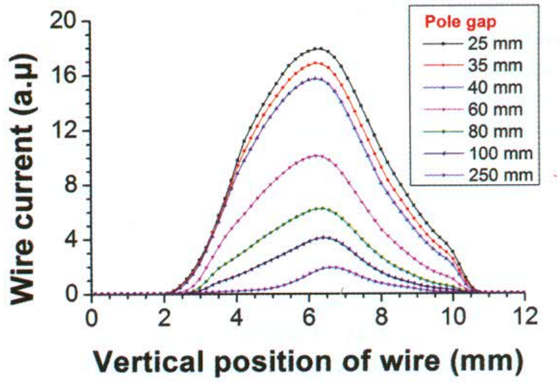

Fig.A.1.5: Photoelectron current measured using scanning wire monitor for the U1 undulator for different pole gaps.

The beam image of the synchrotron radiation coming from the U1 undulator and its neighboring magnets was recorded using chrome doped alumina ceramic sheet beam viewer in the configuration shown in Fig.A.1.6. The measurement was done at a beam current of 80 μA to avoid saturation of the detector. The beam image for the undulator pole gap of 25 mm (Fig.A.1.6a) is primarily due to the undulator radiation. When the pole gap is increased to the maximum value of 250 mm, the beam image is only due to bending magnet radiation (Fig.A.1.6b). It is clear to see that the undulator radiation is much brighter than the bending magnet radiation.

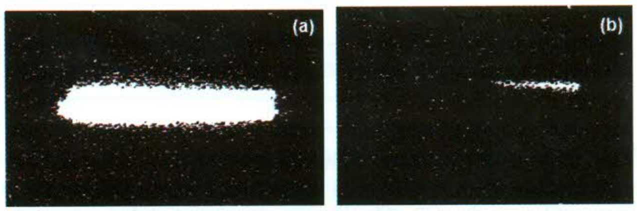

Fig.A.1.6: Beam profile of the synchrotron radiation: (a) U1 undulator radiation with a pole gap of 25 mm, (b) bending magnet radiation when U1 undulator pole gap of 250 mm.

After successful installation and initial characterization of undulator photon beam and aligning the electron beam to the minimum orbit, the normal round the clock operation of Indus-2 synchrotron radiation source is resumed. The successful installation of undulators is outcome of an excellent team effort and dedicated hard work by several divisions and sections of Accelerator Programme.

Reported by:
P R Hannurkar (hannurka@rrcat.gov.in)
On behalf of Indus-2 team