A.1: Indus-2 Operation at 2.5 GeV/100 mA

Indus-2 is regularly operated at 2 GeV beam energy and 100 mA beam current in round the clock mode. The beam energy of Indus-2 is restricted to 2 GeV as the available RF power is not sufficient for beam acceleration to higher beam energy. The limitation on RF power is a consequence of the non-availability of klystrons from its foreign supplier. These klystrons are required for its two RF stations, which have become non-functional due to the failure of their klystrons with ageing. To overcome this problem, an R&D programme has been initiated at RRCAT to develop high power solid state amplifiers as a substitute for the 505.808 MHz klystrons used in Indus-2 RF system. Recently, with augmentation of RF power using the in-house developed solid-state amplifiers, Indus-2 was successfully operated at 2.5 GeV beam energy with 103 mA beam current.

There are four RF cavities in Indus-2 operating at the resonant frequency of 505.808 MHz. These cavities provide the energy required for beam acceleration and for compensation of loss of beam energy, which occurs due to the emission of synchrotron radiation. Till June 2011, only two RF cavities, namely RF cavity #2 and RF cavity #4 were in use. These cavities are energized by the 60 kW klystrons. In August 2011, two solid sate amplifiers of power 10 kW and 15 kW were developed and were deployed to energize RF cavities 1 and 3. By energizing all the four RF cavities, a beam current of 108 mA at beam energy of 2.3 GeV was achieved on August 31, 2011. At beam energy 2.3 GeV, the applied RF peak voltages in RF cavities #1, #2, #3 and #4 were 110 kV, 325 kV, 160 kV and 375 kV respectively.

Next step in the development of solid state amplifiers was the enhancement the power of solid state amplifiers energizing the RF cavities #1 and #3 to 20 kW and 30 kW respectively to facilitate Indus-2 operation at 2.5 GeV beam energy and 100 mA beam current. Trials were made to optimize the parameters of Indus-2 to achieve successful operation at 2.5 GeV with 100 mA beam current. In these trials, initially partial beam loss was observed during beam energy ramp. This was arrested by keeping the betatron tunes almost constant during energy ramping and minimizing the interaction between the beam and cavity higher order modes (HOM) by shifting these modes with optimization of cavity temperatures. During the energy ramp, it was also observed that above beam energy 2 GeV, beam loss occurs due to tripping of RF station#1. This tripping was due to increase in pressure at RF cavity location. The problem of increase in pressure was overcome by applying the vertical closed orbit correction, which is applied in normal operation at beam energy 2 GeV. With increased RF power and all these corrective measures, 103 mA beam current was stored at beam energy 2.5 GeV successfully on December 6, 2011. At beam energy 2.5 GeV, the applied RF peak voltages in cavities #1, #2, #3 and #4 were 215 kV, 350 kV, 250 kV and 350 kV respectively.

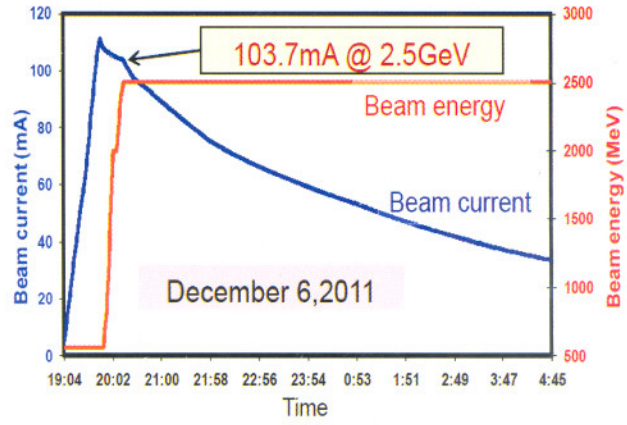

Fig. A.1.1: Indus-2 operation at 2.5 GeV, 103 mA

The beam current variation at injection energy, during energy ramp and storage at 2.5 GeV is shown in the Fig. A.1.1. During beam energy ramp, betatron tunes in horizontal and vertical planes were kept almost constant by optimizing the current of two quadrupoles families located in long straight sections. The variation in fractional horizontal and vertical tune during beam energy ramp is shown in the Fig. A.1.2.

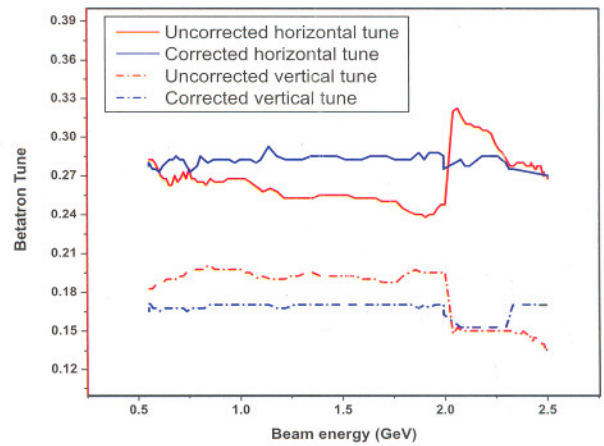

Fig. A.1.2: Horizontal and vertical tune during ramp

Without closed orbit correction and tune optimization, the measured beam lifetime at 100 mA stored current at beam energy 2.5 GeV was ~5 hours.

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