A.1: Indus-2 reached beam current of 200 mA at 2.5 GeV.

Last year in December 2013, Indus-2 was successfully operated with more than 175 mA stored beam current at 2.5 GeV (RRCAT Newsletter, Vol. 27, Issue 1, p3). This year on June 19th, yet another achievement was witnessed in Indus-2 operation, when the stored beam current could be increased to more than 200 mA at 2.5 GeV. For achieving this high current at 2.5 GeV, on 19th June, 2014, 255 mA beam current was accumulated in Indus-2 at the injection energy of 550 MeV and then beam energy ramping was performed. After completion of ramping, the beam current of 203 mA was successfully obtained for the first time in Indus-2 at 2.5 GeV, which is shown in Fig. A.1.1. Further exercise has been carried out to arrest the remaining partial beam losses throughout the ramping. The efforts, made for achieving more than 200 mA beam current at 2.5 GeV along with the lossless beam energy ramping, are discussed in this report.

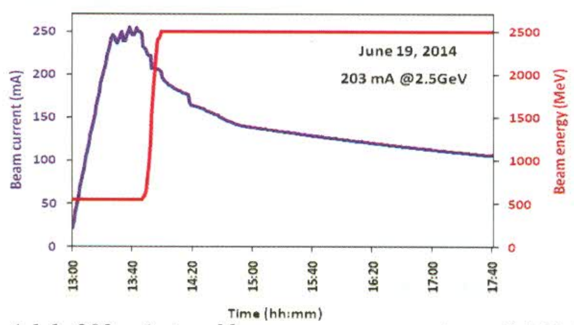

Fig A.1.1: 203 mA stored beam current operation at 2.5 GeV in Indus-2

At 2.5 GeV with 200 mA of beam current, the power radiated from the bending magnets, in the form of synchrotron radiation (SR), is 125 kW. The installed RF power capacity of the indigenously developed Solid State Power Amplifiers (SSPA) was increased to 225 kW providing total RF power of 275 kW from Indus-2 RF system. During these trials, it was found that due to higher beam current, temperature of vacuum chamber was increasing at the locations of septum magnet and at few dipole magnets. This temperature rise was due to the heating from the intense synchrotron radiation originated from such a high stored electron beam current. To overcome this problem, it was decided to carry out the exercise of further optimizing the electron beam orbit throughout the beam energy ramp cycle. After this correction, rootmean square (RMS) orbit distortion in horizontal and vertical plane was brought down to smaller values so that beam path remained away from the boundary of the vacuum chamber during the entire energy range. The coil currents in three steering magnets reached to maximum permissible value and thus restricted further corrections in beam path specifically beyond 1.7 GeV of beam energy. The modified orbit causes the shift in betatron tunes from the previously optimized values due to feed-down effects caused due to off centring of the closed orbit in higher multipole magnets. Therefore, after orbit correction, the betatron tunes were again corrected to keep the final operating tunes away from various harmful resonances. These exercises succeeded in lowering the temperatures of vacuum chamber at the dipole locations, except at the location near the septum magnet. To lower the temperature near the septum magnet location, local orbit bump on the 16th dipole magnet situated just before the septum magnet was applied. With these tunings of orbit and betatron tunes, temperature was controlled at high beam current operation.

Another challenge in higher beam current operation was the accumulation of sufficient beam current at the injection energy. At injection energy of 550 MeV, the radiation damping time of betatron oscillations in Indus-2 is large, i.e. ~470 ms and during this time, injected beam completes nearly ~0.8 million turns. The injected beam exhibits betatron oscillations with larger amplitudes before it gets fully damped and thus, while traversing the beam in the ring, even a small perturbation can degrade the beam injection efficiency and makes higher beam current accumulation difficult. Bunch by bunch instability feedback system was optimally tuned to damp the large beam oscillations to improve the injection efficiency facilitating the smooth higher beam current accumulation. Moreover, the optimized filling pattern (200 bunches out of 291 available RF buckets) further helped in higher beam current accumulation. The temperatures of precision chillers of RF cavities were optimized for tackling the harmful Higher Order Modes (HOMs). With these efforts it was possible to accumulate ~255 mA of beam current.

It was observed that during beam energy ramping, at some energy, there was a partial beam loss. To control these losses at higher beam current, chromaticities in both the planes were measured at various energies, in steps, throughout the ramp. Chromaticities in both the planes were further optimized in energy ramping procedure to overcome the resistive wall instabilities which was diagnosed using spectrum analyser. This succeeded in arresting the partial beam losses which were occurring during energy ramping up to 800 MeV. Further it was observed that amplitudes of HOMs L1 (~950 MHz) and L2 (~1072 MHz) were above normal values causing partial beam loss around 1.3 GeV during energy ramping. By the optimization of Higher Order Mode Frequency shifter (HOMFS) in RF cavities, these harmful modes, L1 and L2, were suppressed keeping all other modes within safe limits. This resulted in arresting partial beam loss occurring around 1.3 GeV. Above 2.4 GeV, phases of RF stations were also re-optimized to obtain a balanced RF power between all four RF stations. With these efforts, partial beam losses during beam energy ramping at higher beam current are completely avoided.

Due to higher beam current and modified electron beam orbit, at some places, especially in the RF cavities, the new areas of vacuum chamber were exposed by the fan of emitted synchrotron radiation, which increased the residual gas pressure and thus degraded the vacuum conditions. Careful monitoring the pressure and allowing the beam to stay in the stored condition at the different energy level for cleaning the photo induced gases. This resulted in the conditioning of vacuum chamber. With these efforts, in Indus-2 operation more than 200 mA beam current was successfully stored at 2.5 GeV.

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