Experimental optimisation of the RF capture frequency at injection in SIS

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We report here on the evaluation of a method for finding the optimum RF frequency of the SIS acceleration cavities. The method involves the heights of the synchrotron side bands obtained from a Fourier Transform of the longitudinal bunch-current profiles recorded with a Beam Position Monitor. The resulting frequency spectrum of the beam permits a quantitative measure of the strength of the dipolar motion of the bunches in their RF buckets.

When the frequency of the RF cavity is an exact harmonic of the mean revolution frequency of the coasting ions at injection, there should be no residual dipolar motion in the beam during RF capture. Consequently the synchrotron sidebands should vanish. Furthermore, emittance growths will be minimised during the bunching process, which is the principal motivation of this work. The dependency of the synchrotron sidebands on the RF capture frequency has been measured and is shown in figure 1 for three different settings of the cavity frequency.

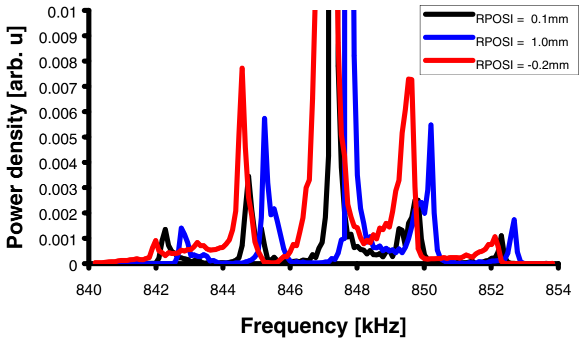

Figure 1. Frequency domain of longitudinal bunch signal for three different cavity frequencies. Resolution band width was 95.4Hz. RPOSI is the radial position at injection. A change in RPOSI of 1mm corresponded to an RF frequency change of 527.6 Hz. Ions: $^{238}U^{73+}$ at ca. 11 MeV/u.

For the linearized synchrotron frequency we have $\omega_s \sim \sqrt{\eta V \cos(\phi_s) / \beta^2 E}$. Thus to avoid distortion of the frequency spectrum, that is to have clearly visible synchrotron sidebands, the gap voltage amplitude V, the synchronous phase ϕ_s, and the total energy E should be fixed. Furthermore under conditions of low beam intensity the Landau damping is strong and any initial dipolar motion in the bunches are effectively gone after just a few core synchrotron periods. Assuming conditions of beam stability under high intensity, the Landau damping is almost entirely supressed and long lived dipolar oscillations persist, which can be as much as over a few 100ms. Such conditions provide sharper synchrotron sidebands in the frequency domain as have been observed in SIS where the bunches were electron cooled to the intrabeam scattering limit [1]. The above mentioned requirements meant that the RF amplitude ramp had to undergo an initial jump from zero to $V=V_{final}$ over a time $<<1/\omega_s$ followed by the constant flattop value V_{final} lasting for several synchrotron periods, ending in a sudden fall of the RF voltage back to zero. The anticipated increase in the peak heights of the synchrotron sidebands due to an increase in V_{final} was checked beforehand by longitudinal tracking simulations using the ESME code [2] under varied conditions of the initial form of the phase space and in particular the relative momentum spread. An attempted search for the correct injection frequency using the aforementioned method is shown in figure 2. The magnetic fields were fixed at injection, thus any changes to the RF frequency resulted in a slight shift in the effective mean orbital radius of the beam.

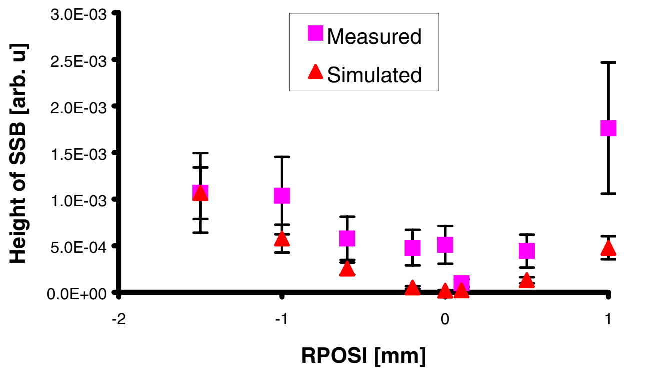

Figure 2. Tuning the RF frequency to match that of the h=4th harmonic of the beam revolution frequency. The y axis is the the height of the left synchrotron sideband (SSB) located approximately at $h\omega_0 - \omega_s$. Ions: $^{238}U^{73+}$ at ca. 11 MeV/u.

From figure 2 we see that the optimum RF frequency lies somewhere close to 847.25kHz or RPOSI=0.1mm. The apparently large fluctuations of the heights of the sidebands, in the vicinity of this value, were believed to be caused by unwanted phase errors caused by the RF system. This was also confirmed by performing an independent set of measurements on an adiabatically bunched then adiabatically debunched beam, where the dp/p of the debunched beam was used as the variable to be minimised. The error bars indicated are largely due to the resolution bandwidth being comparable to the widths of the sidebands. Nevertheless, it would seem possible to use the synchrotron sidebands as a means of RF frequency opimisation. Finally, we point out that efforts towards a data acquisition system for BPMs, which may be used for high resolution Schottky measurements to determine the revolution frequency of the DC coasting beam, are currently underway.

References

[1] M. Kirk, H. G. König, GSI internal report SIS31203.SD, 3 Dec. 2003

[2] J. MacLachan, FermiLab internal report FN-481, April 1988