Emittance growth in bunches with space charge due to damping of transverse oscillations

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An emittance growth is an important issue in synchrotrons, which can reduce machine performance. One of the main sources of the transverse emittance blow-up is damping of coherent oscillations appearing after the bunch-to-bucket transfer between synchrotrons. The damping can be passive (decoherence due to chromaticity, octupoles and residual nonlinearities [1,2] and active (transverse feedback system). This process is strongly modified by space charge and rf nonlinearities, which is important for the SIS18, SIS100 synchrotrons of the FAIR project. Decoherence in long bunches due to chromaticity with space charge has been studied using measurements at the SIS18 heavy-ion synchrotron and particle tracking simulations in [3].

Recent measurements at the SIS18 were dedicated to study the influence of transverse nonlinearities and moderate space charge on the decoherence process. Bunches of Ni_{58}^{26+} ions were stored at the energy of 100 $\mathrm{MeV/u}$ and kicked transversally with a kick duration of one turn. The resulting transverse oscillations have been recorded with the help of beam position monitors. At the same time, the time evolution of the transverse emittance (using an ionization profile monitor) and the beam current has been stored. In order to model the effect of transverse nonlinearities (because of absence of octupoles magnets at the SIS18) the closed orbit was optimized or distorted for different measurements.

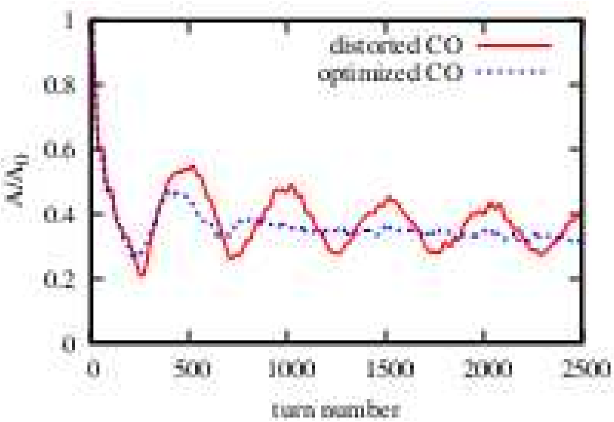

Figure 1: The time evolution of the bunch offset amplitude

As an example figure 1 shows the evolution of the bunch offset amplitude A normalized by the initial value A_0 extracted from the measured signals for two closed orbit settings. Figure 2 produced by plotting the bunch vertical traces and subtracting the total bunch offset, thus reducing the contribution of the head-tail $k = 0$ mode, shows a clear one-knot structure of the mode $k = 1$ which was not damped in the case of induced transverse nonlinearity. For this case the stronger emittance blow-up and beam losses were observed. The goal of theses studies is a detailed understanding of the interplay of the different effects.

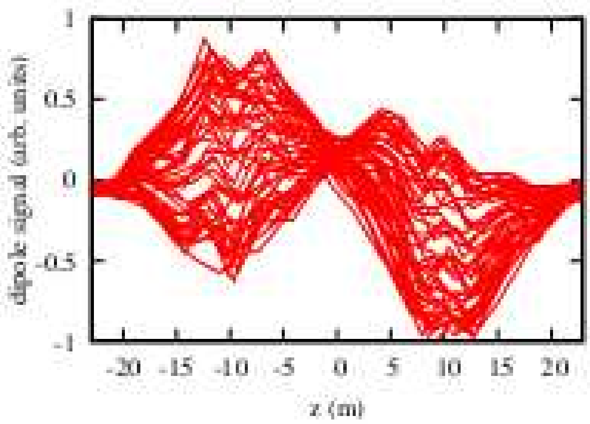

Figure 2: Traces of the transverse bunch signal for 50 consecutive turns. This result proves that the $k = 1$ remains during the process of bunch decoherence in the case of strong transverse nonlinearity.

For the SIS100 synchrotron the resulting bunch decoherence and beam blow-up is due to a combination of the lattice settings (like chromaticity), nonlinearities (residual or imposed by octupole magnets), strong space-charge, and the transverse feedback system. The next step is to study these effects for the SIS100 parameters using particle tracking simulations with the objective of correct combinations for a controlled beam blow-up. The results will be used for determination of requirements for the active and passive damping of coherent bunch oscillations at the SIS100.

References

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