ANALYSIS OF MULTI-TURN BEAM POSITION MEASUREMENTS IN THE ANKA STORAGE RING

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Abstract

The observation of betatron oscillations following a deflection by a kicker pulse offers the possibility to study various machine parameters. The damping of the centre-of-charge signal's amplitude for one bunch, for example, depends on chromaticity, energy loss, momentum compaction factor and impedance. A new multi-turn acquisition system based on LIBERA ELECTRON units (http://www.i-tech.si) has been installed in the ANKA storage ring. First analyses of the thus acquired data for different machine conditions reveal systematic limitations in the current ANKA multi-turn setup. Measurements preformed under varying conditions are presented and discussed with respect to the influence on future analysis.

INTRODUCTION

The storage ring of the ANKA synchrotron radiation source is located at Forschungszentrum Karlsruhe in Germany. It is routinely operated at a beam energy of 2.5 GeV. The beam current is accumulated at 0.5 GeV and then ramped to the end energy. This offers the opportunity to run the storage ring at any energy in the range between 0.5 and 2.5 GeV. The regular BPM system at ANKA consists of 36 beam position monitors used for the slow orbit feedback [1]. Recently two LIBERA ELECTRON units [2] have been installed to set up a system capable of fast multi-turn acquisitions.

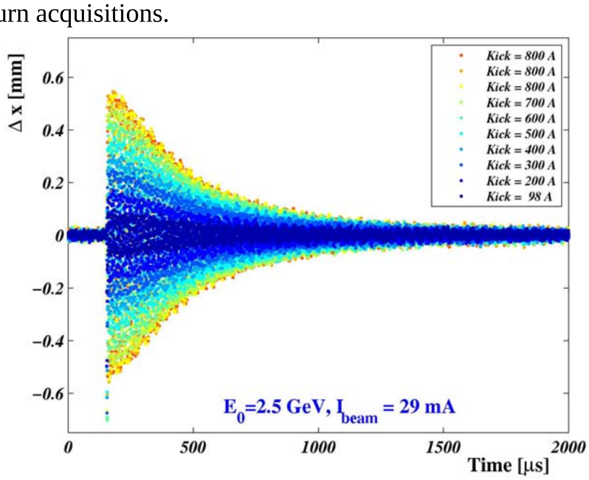

Figure 1: Time evolution of the horizontal centre-of-charge position averaged over all 32 bunches of a train after an excitation with a kicker magnet. The different datasets represents measurements with different kicker strengths. The measurements were performed at a beam energy of 2.5 GeV with a total beam current of 29 mA.

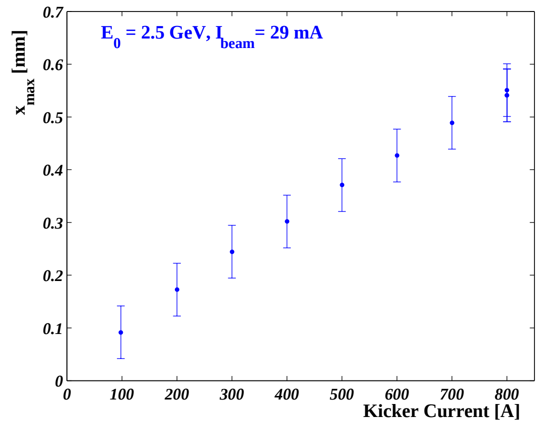

Figure 2: Start amplitude, measured after the decay of the exciting kicker pulse, as a function of the kicker current for the datasets displayed in Fig. 1.

BEAM EXCITATION

In the current multi-turn setup, the beam is excited with a horizontal kicker used for the injection. Figure 1 shows the time evolution of the horizontal centre-of-charge position averaged over all 32 bunches of a train after such an excitation. A verification of the linearity of the excitation is shown in Fig. 2 which displays the start amplitude, measured after the decay of the exciting kicker pulse, as a function of the kicker current for the datasets of Fig. 1. The linear dependence of the amplitude on the kicker excitation is clearly visible. The kicker type used for the multi-turn experiments is slow which causes the beam to be deflected during the pulse length of about 3 μs. This can be seen in Fig. 3 where the first turns after the excitation are shown. Such a multi-turn excitation leads to a complex effective offset in the transverse phase space instead of the clean angular kick given by a fast kicker. For future experiments, an alternative excitation scheme will have to be considered.

DEPENDENCE ON SEXTUPOLES AND BEAM CURRENT

In order to investigate the influence of nonlinearities on the damping behaviour, multi-turn measurements were performed for different sextupole currents. The currents in horizontal and vertical sextupoles were approximately symmetric. A sextupole current of 199 A corresponds to a chromaticity of $Q'_{x/v} = 0.2/5$. It is clearly visible that the damping time decreases with decreasing sextupole current. A straightforward test for the presence of nonlinear

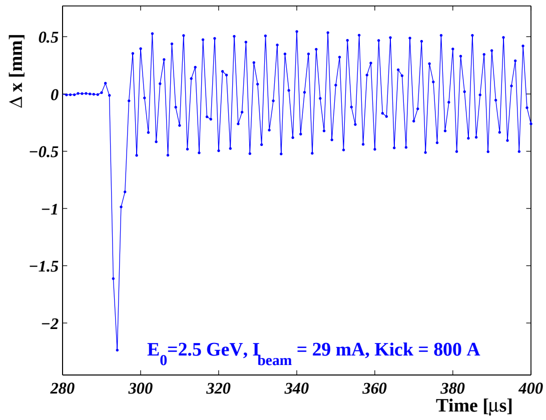

Figure 3: Centre-of-charge position for the first turns after the excitation. The kicker's pulse length of about 3 μs is clearly visible in the data.

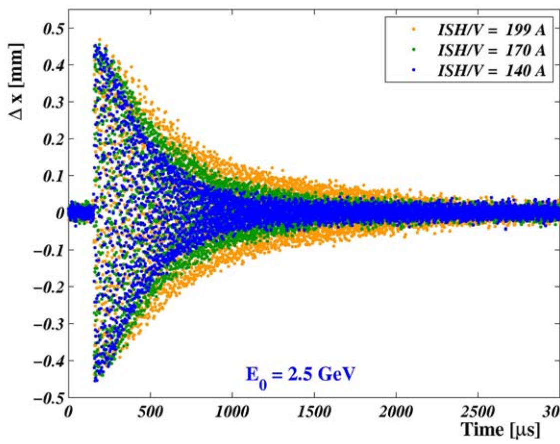

Figure 4: Centre-of-charge position after a kick measured at a beam energy of 2.5 GeV for different currents of the horizontal and vertical sextupoles. For each dataset, the sextupoles currents are approximately equal.

filamentation is to fit an exponential function to the multi-turn dataset. Figure 5 shows such a dataset with the envelope of the oscillation overlayed. It is obvious that the exponential does not represent the data. A closer look to the shape of the envelope (see Fig. 6) reveals two parts which can be described by individual exponentials. The longer of those damping times is about 1.2 ms which corresponds to the longitudinal damping time. The dependence of the observed effective damping time on the beam current is shown in Fig. 7. Again there are two regions of damping. Fitting an exponential to the slower decay yields the damping time as function of total beam current in Fig. 8. The slope in Fig. 8 is determined as (5.8 ± 0.4) ms/A. An interpretation of the observed phenomena is difficult because it is not possible to distinguish between single bunch effects (e.g. head-tail, Landau) and multi-bunch effects. Multi-bunch effects tend to introduce increasing excitation with beam current, whereas single bunch effects tend to increase the damping for higher currents. Comparative measurements with only a few bunches or a single one have to be performed in order to disentangle the contributing effects.

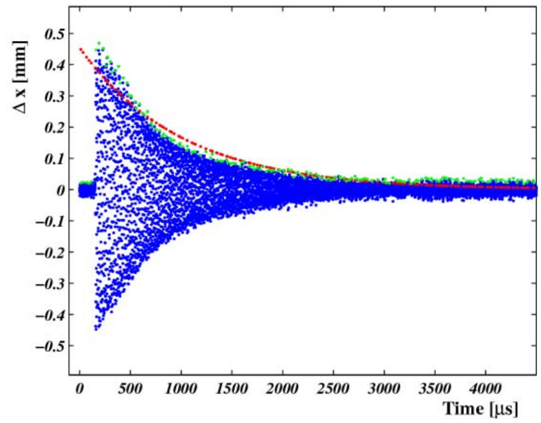

Figure 5: Multi-turn dataset (blue) with the corresponding envelope (green). The red curve is an exponential fit to the measurements. Obviously a simple exponential is not sufficient to describe the dataset.

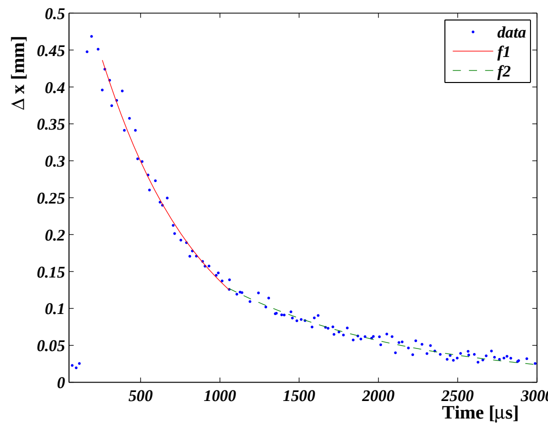

Figure 6: Envelope of the measurement shown in Fig. 6. The red and green curves are to exponential fits to separate regions of the data. The exponential describing the second part of the dataset exhibits a damping time of about 1.2 ms and twice as long as the damping time of the first part exponential (640 μs).

LONGITUDINAL STABILITY

In the ANKA storage ring, transverse stabilisation is achieved by exciting a longitudinal mode in one of the four cavities [3]. If a cavity mode is excited, transverse oscillations are damped quickly whereas they persist a long time in the longitudinally stable case. This is illustrated in Fig. 9: Three multi-turn datasets measured with different cavity temperatures are shown, the lowest temperature corresponding to an excitation of the L5 mode. The exact shape of the amplitude's decay depends on total RF voltage and on the beam current (see Fig. 10). These studies show clearly that an investigation of transverse damping needs to take care of longitudinal stabilisation before drawing any conclusions.

SUMMARY

The new multi-turn setup consisting of two LIBERA ELECTRON devices and the corresponding acquisition framework has been used to conduct various studies of the

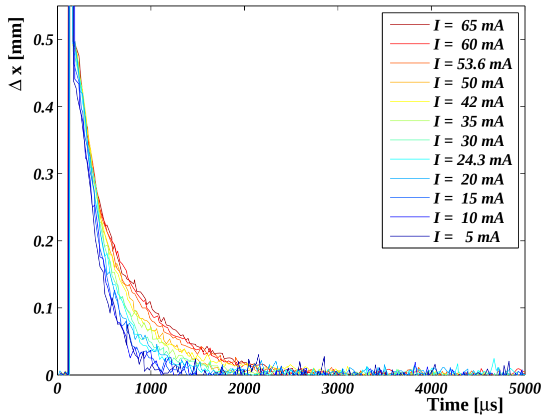

Figure 7: Envelopes of the multi-turn datasets taken at 2.5 GeV for different total beam current in the 32 bunches of one train. After an initial time where all datasets show a comparable behaviour, the damping time decreases with the beam current.

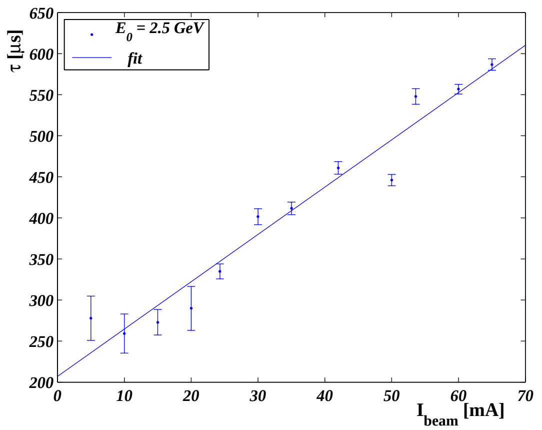

Figure 8: Damping times of the second part extracted from the measurements with different beam currents in Fig. 7 as a function of the beam current.

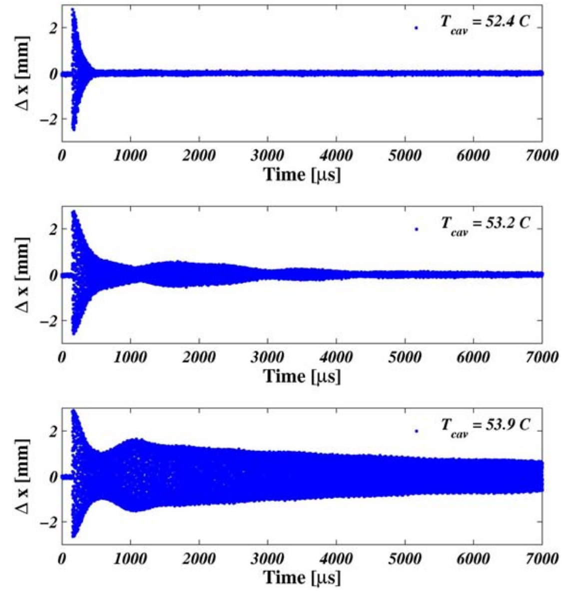

Figure 9: Time evolution of the centre-of-charge measured at a beam energy of 1.3 GeV with a beam current of 10 mA. The three plots show datasets for different cavity temperatures, that is different states of longitudinal excitation. The dataset for the highest temperature, 53.9^oC, was longitudinally completely stable whereas a longitudinal instability was excited for a temperature of 52.4^oC.

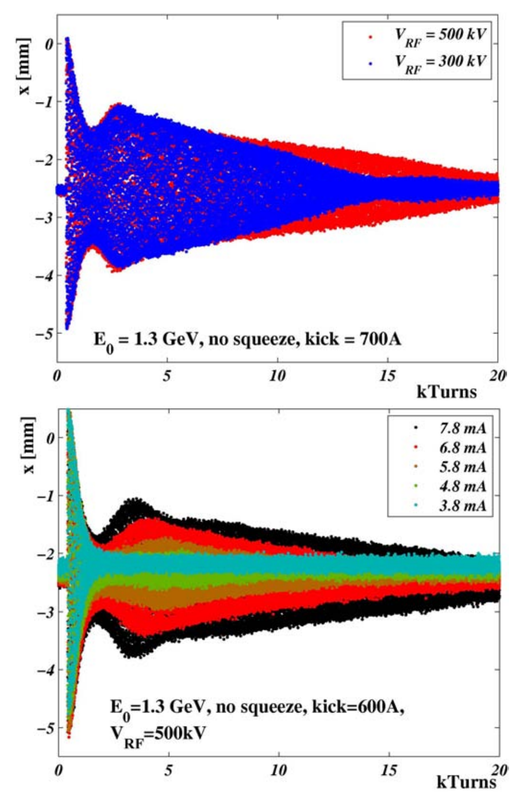

Figure 10: Centre-of-charge evolution at a beam energy of 1.3 GeV in a longitudinally stable state for two different RF voltages. (top) and for different total beam current (bottom). The rise time of the instability is clearly a function of current as is the effective damping time. A higher voltage leads to a longer effective damping than a lower voltage.

center-of-charge amplitude's behaviour after an excitation. The first experiments show systematic limitations of the current setup: the entanglement of single and multi-bunch effects makes an interpretation in terms of beam dynamics difficult. Additionally, a beam excitation spread out over several turns provides a non-trivial starting place in phase space that needs to be taken into account.

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