INVESTIGATION OF THE INJECTION INTO THE ANKA STORAGE RING BY A TURN BY TURN BPM SYSTEM

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Abstract

Modern BPM Electronics allow turn by turn acquisition of the position for both the injected and stored beam. This offers additional opportunities for diagnostics. In addition to the slow BPM acquisition system installed at ANKA, two LIBERA ELECTRON units (www.i-tech.si) have been installed. The system is used to investigate and optimize the Booster and the injection process into the Storage Ring. Tune and orbit in the Booster could be determined, as well as for the first turns in the Storage Ring. The stray field of the storage ring septum turned out to cause a bump of the stored beam. The settings of the kickers could be optimized for minimized orbit distortion. The phase space of the injected beam could be determined.

INTRODUCTION

ANKA is a Synchrotron Radiation Source with a storage ring generally operated at 2.5 GeV. About 200mA of beam current is accumulated at 0.5 GeV and then ramped to the final energy. The BPM system at ANKA is identical to the system from ELSA/Bonn [1]. It is working reliable for the slow orbit correction, but has no option for single turn measurements. The good experiences with the newly developed LIBERA ELECTRON [2] encouraged us to install 2 of these units in order to use their single turn capability.

MEASURING SETUP

The BPMs in the ANKA storage ring are a four button system with the buttons separated by 20 mm horizontal and 32 mm vertical. The vacuum chamber has a vertical height of 32 mm and a width of 70 mm. Two BPM blocks are installed in each straight section (overall 32) plus two in each section with an insertion device (plus 6). For most of the measurements described in the following, one of the LIBERA has been connected to a BPM opposite to the sector with the last injection kicker, outside the nominal region of the kicker bump. The second LIBERA has been installed in the Booster at a BPM opposite to the extraction kicker. The 8 BPM in the Booster are welded into a round vacuum chamber under 45° angle 33 mm from the centre. In both cases the LIBERA electronics has been also been moved to other BPMs. One aspect to be considered is the filtering of the signals, which increases the orbit resolution at the cost of time resolution. Thus, the 70 ns long signal from a transfer line BPM is distributed over 2 SR turns (736 ns), as shown in Fig.1.

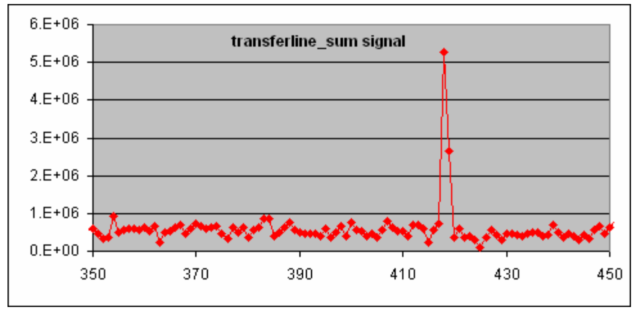

Figure 1: Sum signal from a BPM in the Booster to Storage ring transfer line. The bunch train is 70 ns long. The turn by turn spreads it over 2 turns (736 ns).

BOOSTER BEAM ORBIT

The revolution time in the ANKA Booster is only 88 ns, which could be challenging for the electronics. A further drawback is the multi turn injection process, by which several turns are spilled off and prevent a unique orbit. Nevertheless both the horizontal and vertical tune could be determined by a FFT of the orbit, as shown in Fig. 2 and 3. After merging off the turns, a turn by turn signal could better be detected and the horizontal tune could be determined by excitation with the extraction kicker, which is shown in Fig. 4, but no longer was a vertical tune detectable.

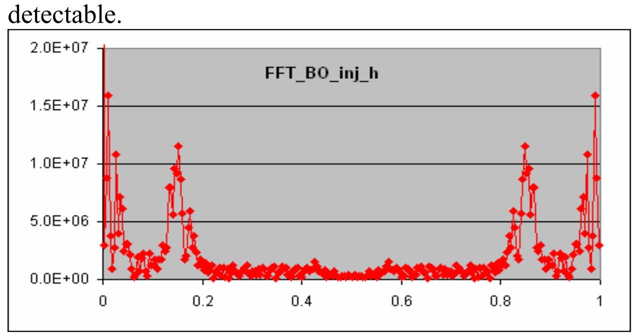

Figure 2: FFT of the horizontal Booster orbit at Injection.

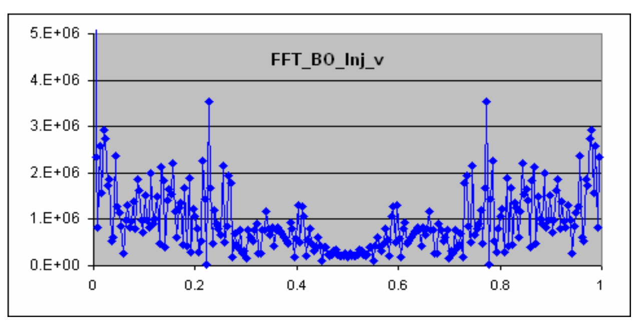

Figure 3: FFT of the vertical Booster orbit at Injection.

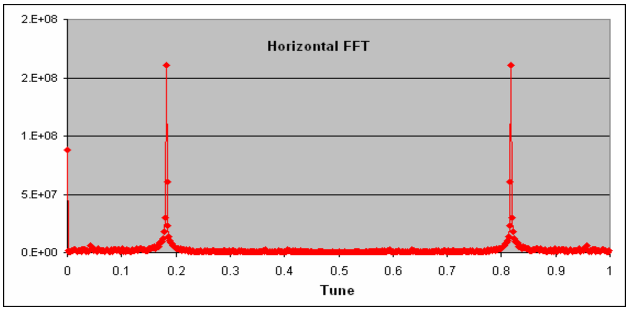

Figure 4: FFT of the horizontal orbit after excitation by the extraction kicker.

Fig.5 shows the orbit at one BPM for a complete acceleration cycle. Since the BPMs in the Booster are very coarse welded into the vacuum tubes (no machined blocks), and also a calibration by 'beam based alignment' is not performed, the large offsets of 4 mm is understandable.

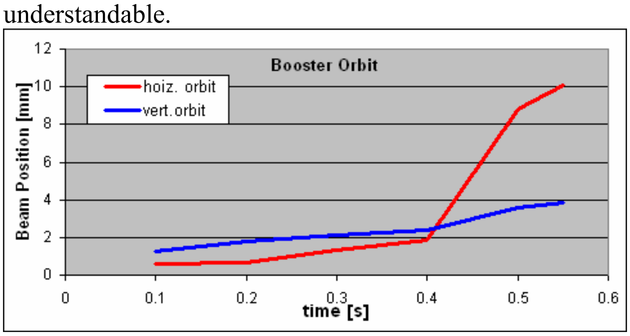

Figure 5: Horizontal and vertical orbit in the booster. The large jump after 0.4 s is due to the excitation of the bumper magnets for the extraction.

STORAGE RING ORBIT AT INJECTION

Measurements of the orbit at injection without RF are shown in Fig. 6 for the sum signal and Fig.7 for the horizontal Position.

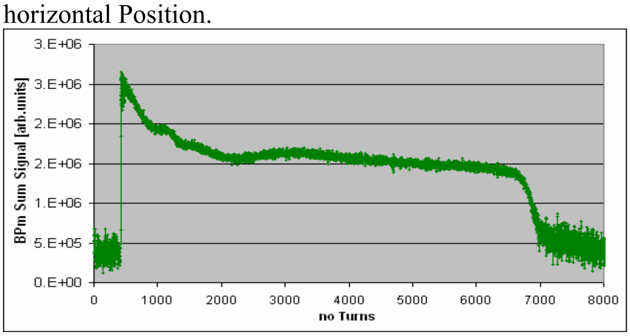

Figure 6: Sum Signal from the injected beam without RF.

The sum signal shows a beam lost after about 7000 turns. With an energy loss of 1 kV per turn this corresponds to an energy acceptance of 1%.

The horizontal orbit is rapidly damped down within 400 turns (150 µs), considerable faster than the 300 ms calculated for SR damping.

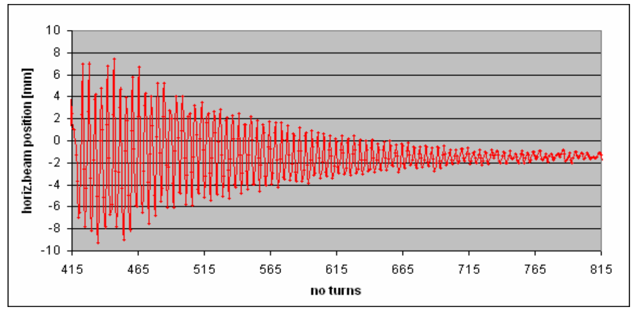

Figure 7: First 400 turns of injected beam.

Both the horizontal and vertical tune at for the injected beam without RF can be determined by an FFT of the first turns data. The FFT spectra are shown in Fig 8 and 9. The FFT signal for the vertical tune is smaller by a magnitude.

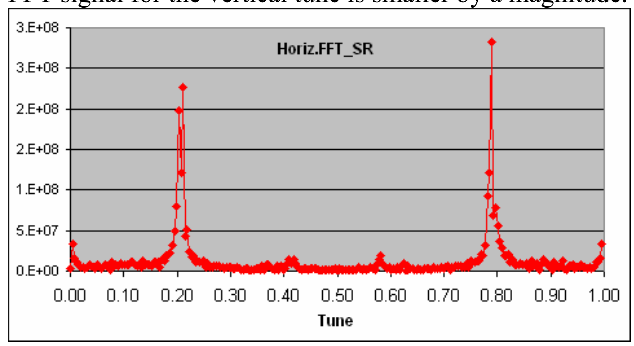

Figure 8: FFT of the horizontal beam position.

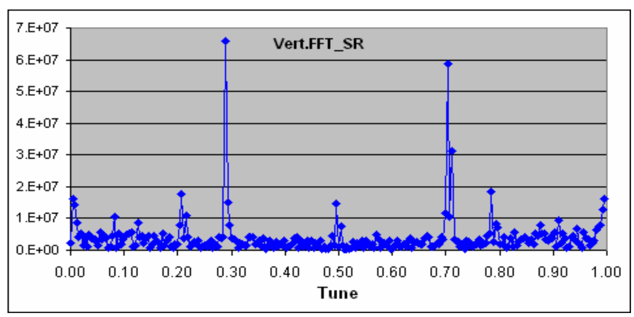

Figure 9: FFT Spectra of the vertical beam position.

The horizontal orbit for a BPM with dispersion is shown in Fig.10. After the oscillations due to the injection process are damped down, a pronounced orbit drift occurs as a function of the time, which is due to the energy loss by the synchrotron radiation (1 keV/turn). The slope is in well agreement with the calculations.

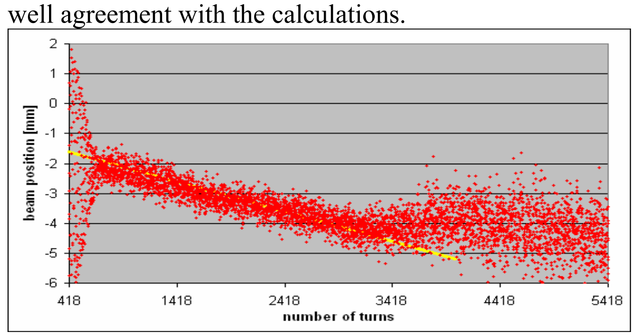

Figure 10: Horizontal Orbit for a BPM with dispersion. The yellow line shows the expected orbit drift due to the energy loss given by the Synchrotron Radiation.

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With the data from two BPMs and the known phase advances and beta functions the phase space can be reconstructed. The calculated phase space for one BPM at injection is given in Fig.11.

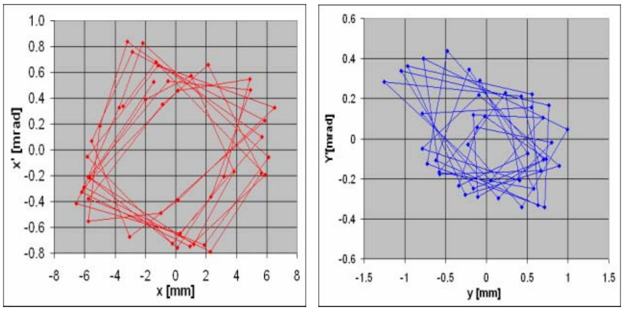

Figure 11: Horizontal and vertical Phase space for the injected beam calculated from two BPMs.

With RF on and accumulated beam the system can also be used for measuring the tunes, due to excitation by septum and kicker. Since the vertical orbit is only weakly distorted, the FFT of the vertical orbit, as shown in Fig. 12 is not as pronounced compared to the FFT from the horizontal orbit (not shown), but shows the horizontal tune, too.

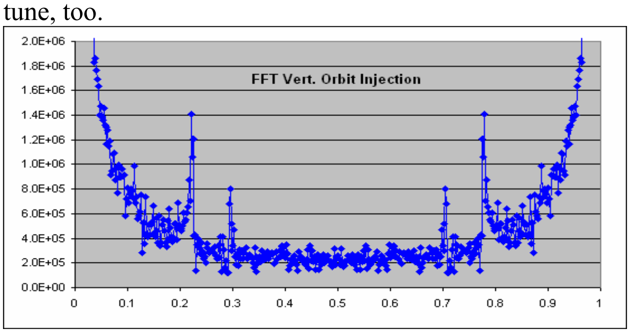

Figure 12: FFT of the vertical SR orbit at injection with 100 mA accumulated, excited by the injection.

SEPTUM AND KICKER BUMP

Ideally an injection Septum deflects the incoming beam without influencing the stored beam. In reality the septum has a stray field which affects the stored beam. To reduce this effect present septum magnets are designed with iron nickel shielding and use full sine excitation. Since the ANKA Septum does not have such a shielding, the stored beam is distorted by the septum. In Fig. 2 the horizontal orbit in the injection section is shown. The orbit bump caused by the septum is about 1 mm. Further visible is the bump caused by the Kickers of 10 mm. The real bump is considerable larger. This is due to the filtering effect of the LIBERA and due to the fact that the BPM signal for locations beyond the offset of the button (10 mm) is nearly constant.

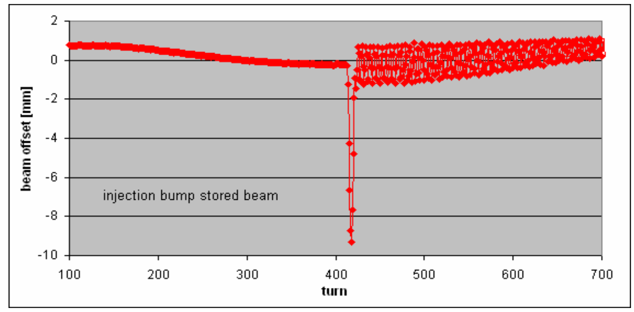

Figure 13: Orbit bump induced by the Septum and the Kickers in the injection section.

The kicker magnets in the storage ring bring the stored beam close to the septum to enable the injection. Ideally a closed bump is performed and there should be no orbit oscillations outside the bump region. This might not be the case. Furthermore the kickers are set for best injection meaning to serve both the stored beam (influenced by 3 kickers) and the injected beam (influenced by 2 kickers). In Figure 14 the measured orbit for the original and corrected kicker settings are shown for the first 300 turns. The amplitude of the orbit oscillation is 5 mm at the beginning. The settings of kicker 2 and 3 were then optimized and the orbit oscillations could be reduced to 1.5 mm.

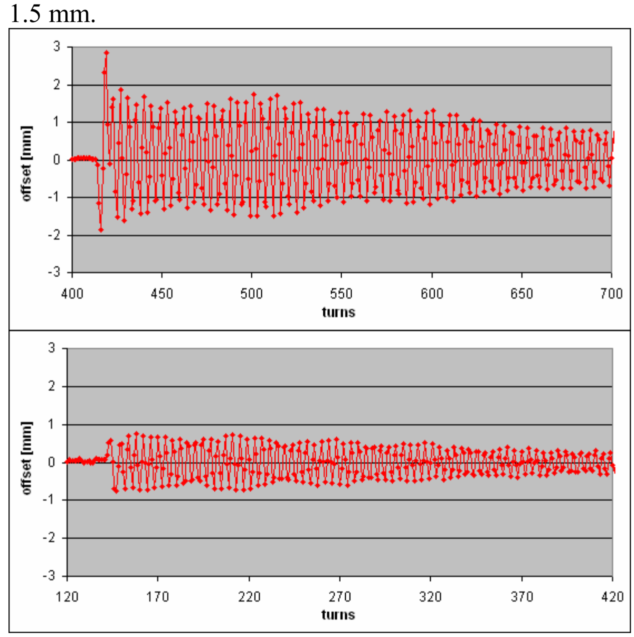

Figure 14: Orbit oscillation due to the kickers before and after optimization.

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