

A VERTICAL MULTI-BUNCH FEEDBACK SYSTEM FOR ANKA

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Abstract

The maximum electron current at ANKA is presently limited by multi-bunch instabilities during injection and ramping. In order to overcome this barrier an analog transverse multi-bunch feedback system was developed and commissioned. During the test phase of the feedback operation a beam stabilization by the feedback system was clearly demonstrated. In the first six months of operation the number of total or partial beam losses related to instabilities was distinctly reduced.

INTRODUCTION

ANKA is a synchrotron light source operating in the energy range of 0.5 to 2.5 GeV with a design current of 400 mA [1]. The maximum electron current is presently limited to 200 mA due to multi-bunch instabilities, mostly in the vertical plane. Those are observed especially at the injection and energy ramp, leading eventually to partial or total beam loss. The implementation of a transversal feedback system (TFS) system is a natural step towards overcoming this constraint and increasing the operation current.

GENERAL SYSTEM LAYOUT

The concept of TFS at ANKA is based on designs for ALS [2], BESSY [3] and ELETTRA [4] (Figure 1). The analog signal processing was chosen as a simple and economic alternative to the digital feedback systems. A standard beam position monitor (BPM) station with 8 mm button electrodes was used for position pickup. The detection was done at 1.5 GHz, where the pickup is most sensitive. The button signals were filtered by four bandpass filters (BSC Filters IB3824). The filtered signals were subtracted and summed up by a monopulse comparator (miteq mpc15006) to get horizontal and vertical beam position. The obtained signal was processed by the Multibunch Transverse Feedback RF Front-End Amplifier (Instrumentation Technologies, RFTF2). In the RF Front end the 1.5 GHz position signal was mixed with the 500 MHz RF signal, amplified in the heterodyne operational mode and low pass filtered at 250 MHz.

The revolution frequency (2.72 MHz) was removed from the vertical position signal by an additional correlation reject filter (*notch* filter). In this narrow band filter the signal was splitted, delayed by the storage ring revolution time

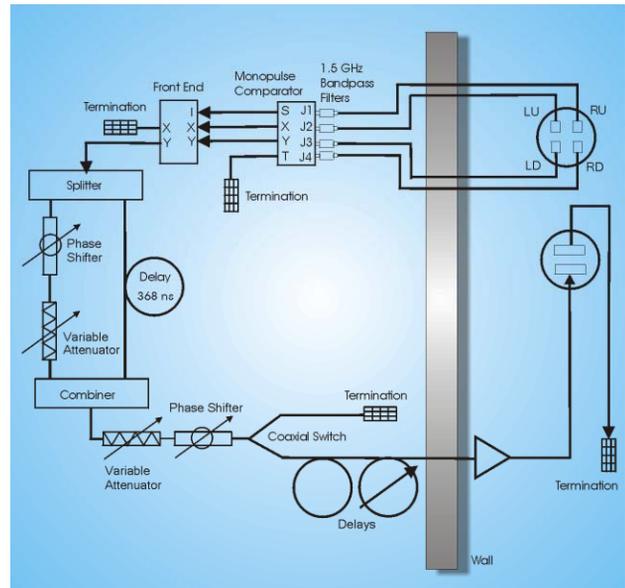


Figure 1: Layout of the analog vertical feedback.

and re-combined with a proper phase and attenuation with the undelayed signal (see Figure 1).

The position signal was delayed to adjust the kick position within the bunch train and amplified by the power amplifier (Kalmus 2752C-CE). Due to the 500 MHz base RF frequency an amplifier with 250 MHz bandwidth was chosen. The amplified signal was fed subsequently to the vertical microwave kicker, which has identical design with SLS and ELETTRA [5]. So far a single kicker electrode is driven by the amplifier, while the other electrode is used for tune measurement and bunch knock out. The external view of the kicker is shown in Figure 2.

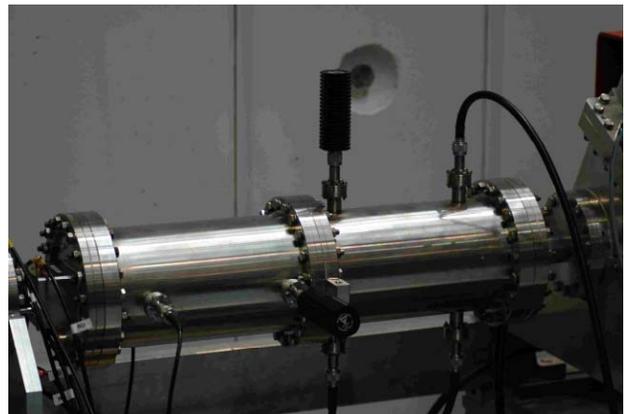


Figure 2: Feedback kicker.

COMMISSIONING AND FIRST RESULTS

For primary TFS tests an experimental station was placed outside of the shielding wall. For reducing RF-signal deterioration between the ring and the test station a geometrical proximity to the signal pickups and kicker, as well as low-noise and -loss 7/8 inch RF-cables were chosen.

Filter Pre-adjustment

The frequency transfer function of the *notch* filter is shown in Figure 3. By adjusting the phase shifter and attenuator of this filter a very narrow reject band (0.2 kHz, 3dB at the first filter harmonic, 2.72 MHz) with extremely high attenuation (-60 dB) can be tuned. For stability reasons the filter has to be readjusted recurrently due to long term drift compensation of attenuator, phase shifter and cables.

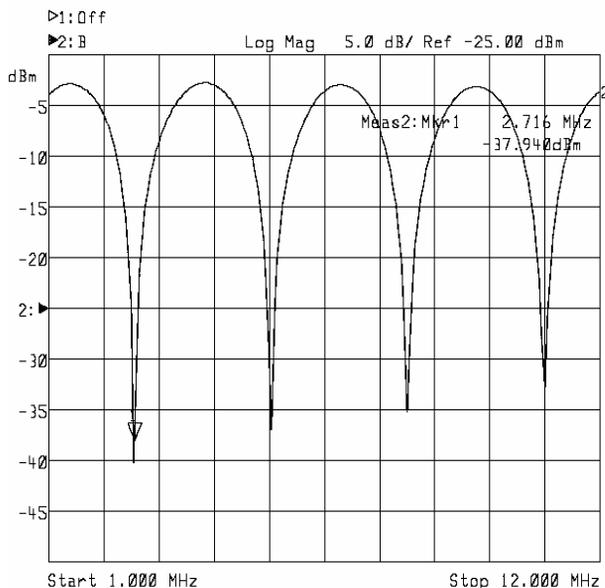


Figure 3: Frequency transfer function of the notch filter. Revolution frequency (2.72 MHz) and three harmonics of the filter are shown.

Feedback Tuning with the Beam

The tuning of TFS parameters is crucial to its proper operation. For better timing and bunch identification the number of bunches in the storage ring was reduced to 3 bunches in one train. For this purpose a resonant knock-out generator was used [6], which allowed the deleting of discrete bundles in the train after the injection is completed. Setting of the timing of feedback systems is usually done in the single bunch mode, which is presently not available at ANKA. The following signals were monitored on a 3 GHz oscilloscope (Figure 4) for TFS adjustment and characterization:

- unamplified feedback signal (position signal),
- kicker electrode signal, which superposes the amplified feedback signal and the signal induced in the kicker electrodes by the beam,
- ring electrode, surrounding the beam and delivering a low-noise signal for detecting the actual filling pattern.

The time base trigger was triggered by the turns. For this purpose a 500 MHz RF reference signal was divided by the harmonic number of the ring (184).

The kicker electrode signal was used for adjustment of feedback timing (see Figure 1). The delay was adjusted in such a way, that induced beam signal and amplified feedback signal, both seen on the same curve, overlap in time (see Figure 4, upper curve). Despite using a fill with several bunches the delay between both signals was clearly interpretable and could be set properly. Figure 4 exemplifies a situation, when the feedback signal is shifted by -40ns with reference to the beam signal.

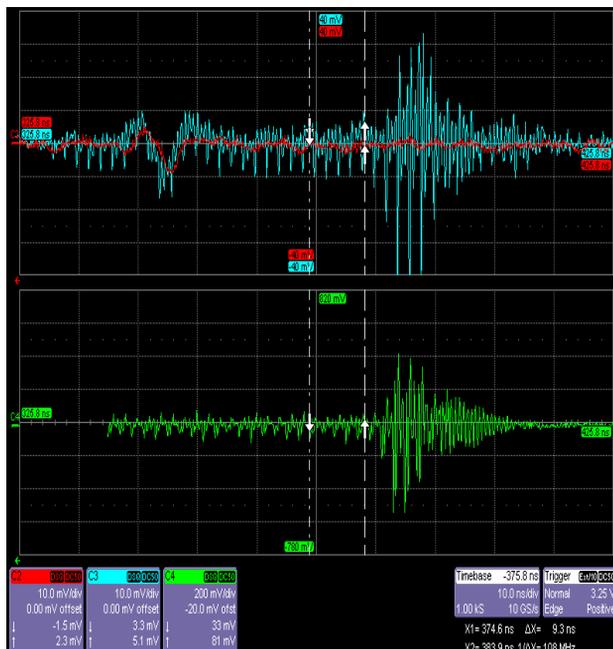


Figure 4: Feedback, kicker (upper part) and filling pattern detected by the ring electrode (lower part) signal as seen on the oscilloscope. For purpose of feedback adjustment the machine was filled with only 3 bunches.

For further adjustments the onset of vertical oscillations was provoked by reducing the vertical chromaticity in the storage ring at 2.5 GeV. Subsequently, to suppress those instabilities the phase of the Feedback RF Front End was optimized by scanning for the best beam stabilization condition.

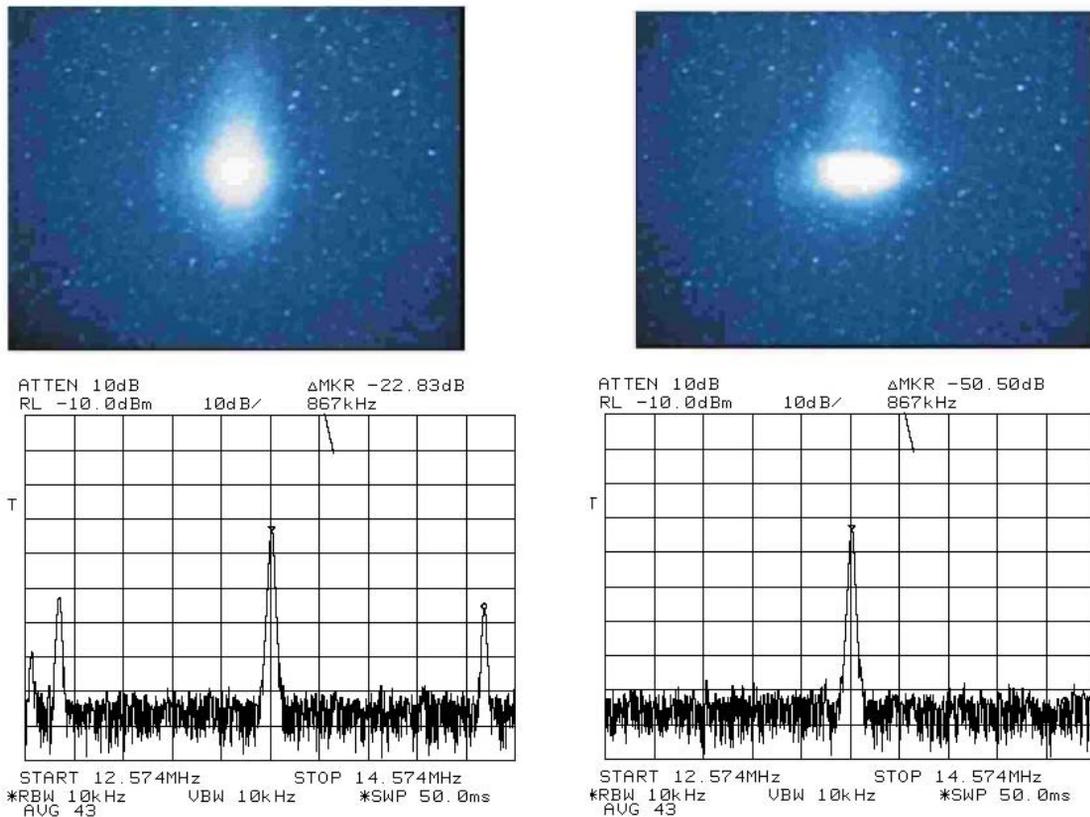


Figure 5: Synchrotron beam profile (upper part images) and frequency spectrum (lower part plots) without (left) and during (right) feedback operation. Note that sidebands vanish completely when TFS is in use.

Suppressing Beam Instabilities

The effect of TFS operation is demonstrated in Figure 5. The left hand side presents a synchrotron light profile from the storage ring at 2.5 GeV after reducing chromaticity in both planes. The corresponding noise spectrum around the fifth harmonic of the revolution frequency is presented in the lower part Figure 5: the sidebands, indicating beam excitation are clearly visible. The right hand side of Figure 5 shows the situation when the beam instabilities are suppressed by TFS. In this case the sidebands vanish and the beam profile becomes narrow in the vertical plane, indicating an excitation-free beam.

CONCLUSIONS AND ACKNOWLEDGEMENTS

The successful operation of TFS in the vertical plane was demonstrated. The TFS has been implemented into the routine machine operation. In the six months of TFS test-service the number of instability-related beam losses at the injection and ramp, as well as observed instability occurrences decreased distinctly. Furthermore, TFS allows a reduction of the chromaticity, thus increasing the energy acceptance of the storage ring. Further studies as well as the integration of TFS into the control system are

necessary. The promising test results of TFS are encouraging to upgrade the system to both transverse planes.

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