CHARACTERIZATION AND STABILIZATION OF MULTI-BUNCH INSTABILITIES AT THE ANKA STORAGE RING

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Abstract

ANKA is a 2.5 GeV storage-ring for synchrotron radiation. Up to 200 mA are accumulated at 0.5 GeV and then ramped to 2.5 GeV. In the past, storage-ring operation suffered from vertical multi-bunch instabilities. These could partially be cured by increased chromaticity, a large gap in the filling structure and keeping the beam longitudinal instable. In the mean time a Libera digital **b**unch **by b**unch system (BbB) from ITECH [1] has been installed and commissioned. The system now allows an operation of the storage-ring without exciting longitudinal modes. In addition, the system allows analysing multi-bunch instabilities both transverse and longitudinal, and their dependence from cavity temperature, filling structure and chromaticity.

BUILD UP

Fig. 1 shows a schematic view of the bunch by bunch system. The signals from a BPM are fed into a mono-pulse-comparator which delivers a vertical, horizontal and sum signal at 1500 MHz; this frequency gives the highest sensitivity of the BPM signal. The vertical signal is fed into the LIBERA RF Frontend. Within this unit the 500 MHz RF clock signal is tripled and mixed with the vertical signal to obtain the oscillation at baseband. The phase for the mixing determines if the base band signal is amplitude (needed for transverse feedback) or frequency modulated (needed for longitudinal feedback).

The vertical base band signal is split; one part is fed into an oscilloscope in order to moderate the phase for the modulation, while the other is fed into the BbB unit. In order to reduce sampling demands the BbB splits the input signal into four channels, each with a 125 MHz sampling ADC that is delayed respectively by 2 ns. The signals are then filtered before being recombined and fed to the output DAC. The DAC signal can be time delayed in steps of 2 ns and phase shifted (with respect to the tune frequency) and amplified.

The DAC signal is fed into a fine delay unit and further into a broad band amplifier. The amplifier-output-signal is fed into the downstream port of a vertical strip-line kicker [2]. The upstream port is attenuated and fed into an oscilloscope.

Up to now a 10 W amplifier (Kalmus 0.5-525 10W) is used but has shown limitations due to its available power output. In the near future this will be replaced with a 150W amplifier

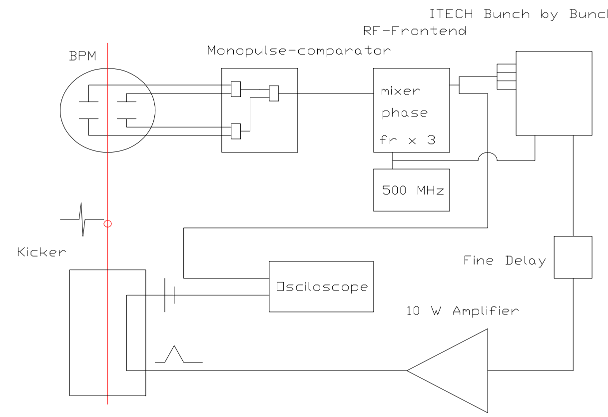

Figure 1: Schematic view of the bunch by bunch feedback set up.

ADJUSTMENT

The feedback needs several adjustments concerning phase, time and amplitude. This is done with ANKA operating in both single and multi bunch modes.

RF-Frontend-Phase

The setting of the phase of the mixer is done by looking at the scope signal of the baseband signal and optimising for an average zero signal for frequency modulation, Fig. 2 (upper part), and a clear amplitude signal when in amplitude modulation, Fig. 2 (lower part); switching between the two modes is done simply by changing the phase of the mixer by 90 degrees.

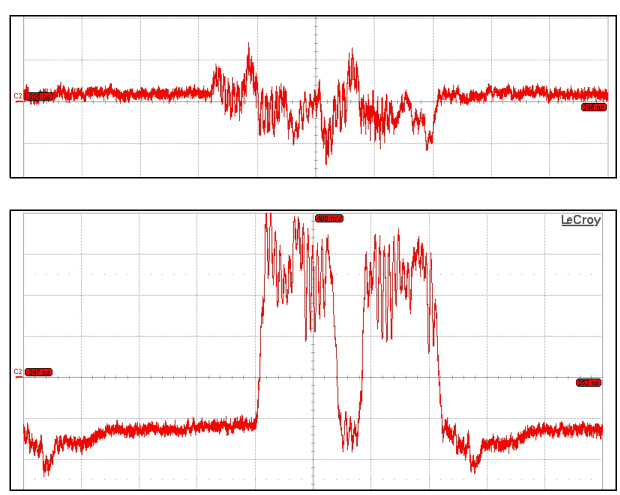

Figure 2: Scope signal for two trains from the RF front end while in frequency (upper graph) and amplitude modulation (lower graph) mode.

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BbB ADCs'-Clock

The timing of the BbB ADCs' sampling clock and the signal from the bunch has to be synchronized. This is done with ANKA in single bunch mode. If the timing is not correct the signal of one bunch is distributed over two ADC channels, as can be seen in Fig. 3 upper part. As the BbB has no means to fine delay the input signal or sampling clock, the timing was changed by adding a 15cm cable. Fig. 3 lower part shows the sampled bunch after the time adjustment.

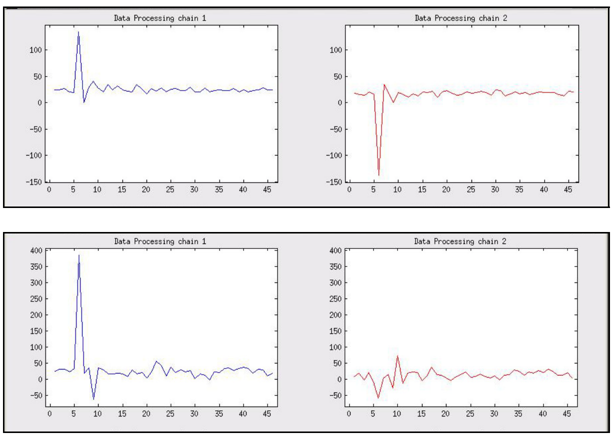

Figure 3: ADC signal of one bunch for incorrect clock timing (upper graph, the signal is distributed over two channels) and correct timing (lower graph).

Feedback Timing

The feedback timing delay must be adjusted so that the processed signal is delivered to the kicker strip-line at the exact time the bunch that has been processed passes by. This alignment is also done in single bunch mode. The scope signal from the kicker strip-line sees both the passing beam and the signal from the BbB amplifier concurrently. In Fig.4 the broad peak on the left is the signal coming from the amplifier while the small needle-like signal is the one from the bunch. The signals are separated by 10 ns. Changing the timing by 10 ns results in both peaks coinciding.

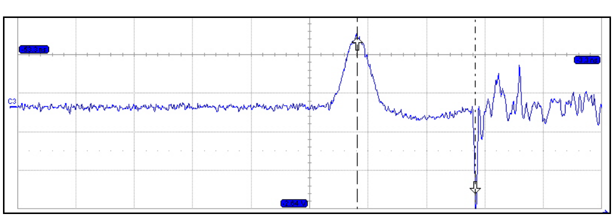

Figure 4: Signal from Kicker upstream port. Left peak from amplifier, right (needle) from bunch.

Further optimization of the timing has been done in multi-bunch mode with the Numerical Controlled Oscillator (NCO) set to excite only one bunch. If the timing is not correct, neighbouring bunches will oscillate, too.

Phase

In order to achieve correct feedback the right bunch has to be hit with the right phase. This is possible by using the BbB output phase adjuster and scanning the phase over the whole range from 0 to 6 radians, while the beam was slightly unstable. The amplitudes of the vertical-tune sidebands as a function of the phase is shown in Fig. 5. In this case a phase of 5rads is used for operation.

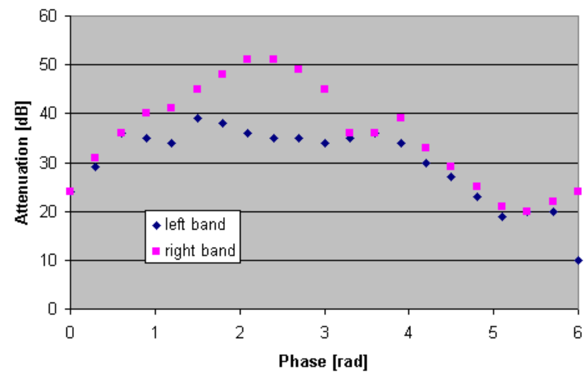

Figure 5: Amplitude of the vertical-tune sidebands when scanning the phase.

Filters

Different symmetric Finite Impulse Response (FIR) filters with up to 2x8 taps can be programmed in the BbB. Presently a 10 tap band pass filter is used centred around the transverse tune frequency of 800 kHz and a -3dB width of 300 kHz and a suppression of the DC component by 35 dBm. Further filters had been tested without any significant change in the performance.

BEVAVIOUR DURING RAMP

Up to now the feed-back is only used at 2.5 GeV and not during the 0.5-2.5GeV ramp. This limitation is due to the fact that the synchronous phase is changing during the ramping process by about 30°. Due to the frequency tripling of the RF frontend this causes a phase shift of 90°. Fig. 6 shows the measured and calculated change of phase during the ramp. Since the ramping is done in 4 minutes a proper adjusted control system should cope with this problem. This task is in progress.

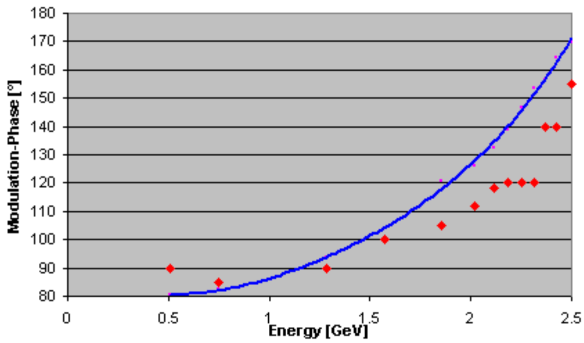

Figure 6: Behaviour of phase during ramping of energy.

INSTABILITIES AND CHROMATICITY

The vertical instabilities do not necessarily cause a beam loss. They rather cause a periodic blow up where they grow to a certain amplitude at which time they are damped due to a dependence on the chromaticity. Fig.7 shows such a grow damp behaviour. For this measurement the BbB feedback signal was turned off after 10,000 turns and turned on again after 60000 turns.

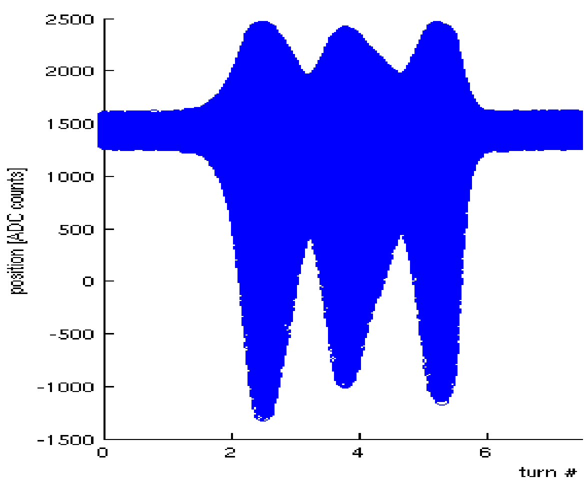

Figure 7: Vertical instabilities at a chromaticity of +3. Scale x10000 turns.

BUNCH CLEANING

Cleaning of bunches is mostly used to achieve high bunch purities in single bunch operation by suppressing residual components in neighbouring bunches [3]. For this the bunches to be cleaned are excited by the vertical tune frequency with a NCO at base band (800MHz) with a sweep of 10 kHz.

At 500 MeV injection energy, cleaning could be done without any problem with the Kalmus 10 W amplifier. However, at 2.5 GeV full energy, 10 W of power was not enough and a scraper had to be used to reduce the vertical aperture to knock out the bunch. For injection energy the bunch could be suppressed to 10^{-2} compared to its neighbouring bunches Fig. 8

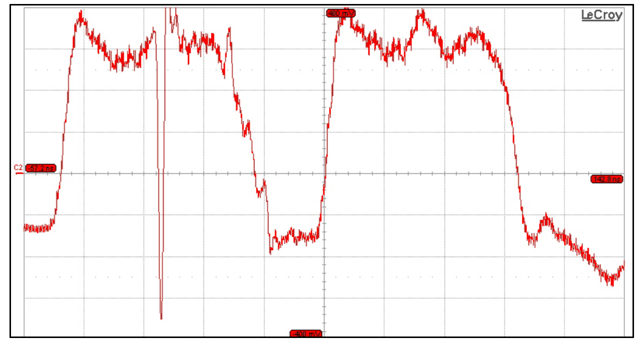

Figure 8: Cleaning of one bunch.

ANALYZING TOOLS

Since the BbB unit stores the data for each bunch for more than 695000 turns it makes for a good offline analysis tool. For example, FFT can be made as a function of the turns to get the tunes and the amplitude of the tunes. Further FFT as a function of the bunch number can give the mode of the oscillation.

ACKNOWLEDGMENT

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REFERENCES

[1] hppt:/itech.si
[2] M.Dehler, V.Schlott, D.Bulfone, M.Lonza, R.Ursic, EPAC00, Vienna, (2000) p.1894
[3] J.M.Vogt, J.C.Bergstrom, S.Hu, V.Poucki, P.Lemut, PAC09, Vancouver, (2009) p.4111
[4] hppt:/www.dimtel.com

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