COMMISSIONING RESULTS OF THE TRANSVERSE FEEDBACK SYSTEM AT BESSY II*

S. Khan, T. Knuth†, BESSY, Berlin, Germany
W. Barry, J. Byrd, G. Stover, ALS-LBL, USA

Abstract

To cure coupled bunch instabilities at high currents in the BESSY II storage ring, an effective feedback system is required. A transverse bunch-by-bunch feedback system which is similar to the ALS design has been developed. We present an overview of the main components of the system and their functionality. This paper describes the commissioning period and reports some measurement results, which show the effect of the feedback on the beam.

1 INTRODUCTION

As a synchrotron light source of the 3rd generation, one of the most important parameters for the BESSY II storage ring [1] is a very small transverse beam size. A potential source for increasing the effective beam size of the electron beam is the transverse multibunch instability, essentially driven by the interaction of the electron beam with the vacuum chamber (resistive wall effect) and higher order modes (HOM's) in cavity-like structures. In order to damp all possible modes arising from those interactions, a transverse bunch by bunch feedback system (TFB) has been installed and commissioned in December 1999. It has been in operation since and proved to be an excellent tool to keep the beam size on the smallest possible level. Table 1 shows some feedback related parameter of the BESSY II storage ring.

Table 1: Accelerator and feedback design parameter

Beam energy E	1.7 GeV
Rf frequency f_{rf}	499.6 MHz
Harmonic number h	400
Typical current I	200 mA
Vertical tune ν_y	6.73
Horizontal tune ν_x	17.84
Required feedback bandwidth Δf_{fb}	250 MHz

2 SYSTEM LAYOUT AND FUNCTIONALITY

Figure 1 presents an overview over the general system layout. It has been designed in an all analog fashion, very similar to the transverse feedback system operating at the ALS [2].

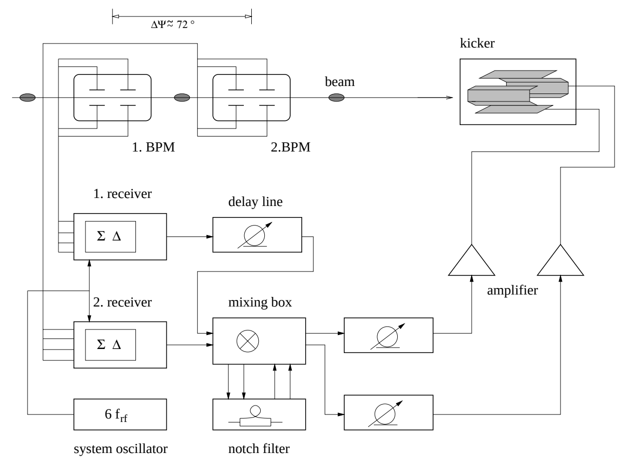

Figure 1: Schematic view of the BESSY II bunch-by-bunch TFB-system

The signal path in both transverse directions consists of identical components. For the detection of the transverse beam position, four common BPM electrodes for each receiver are used. The betatron phase advance between the receivers is about 72 degrees in both directions as a compromise between a good sensitivity and space constraints. Phase matched cables are used to feed the receivers with the BPM signals. The transverse dipole moment (current times position) is detected at $6f_{rf}$ and downconverted to baseband by the receivers operating in heterodyne mode.

The following mixing box produces a correction signal (90 degrees out of phase with the transverse beam position at the kicker) as a weighted sum of the corresponding signals from x- and y-direction. Static signal components are suppressed by a notch filter which consists basically of a temerature stabilised cable with the length of the storage ring circumference.

The correction signals are amplified by a broadband 220 Watt power amplifier in each direction. The kick is applied by a stripline kicker [3] which assembles both pairs of electrodes in only one structure due to tight space requirements. A model of the kicker structure which has been used for adjusting the line impedance to 50 Ω in the end field region of the electrodes is shown in figure 2.

C-shaped electrodes in x-direction and flat electrodes in y-direction reassemble the shape of the vacuum chamber in order to minimize the loss factor. Either a pair of striplines

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† Email: knuth@bii.bessy.de

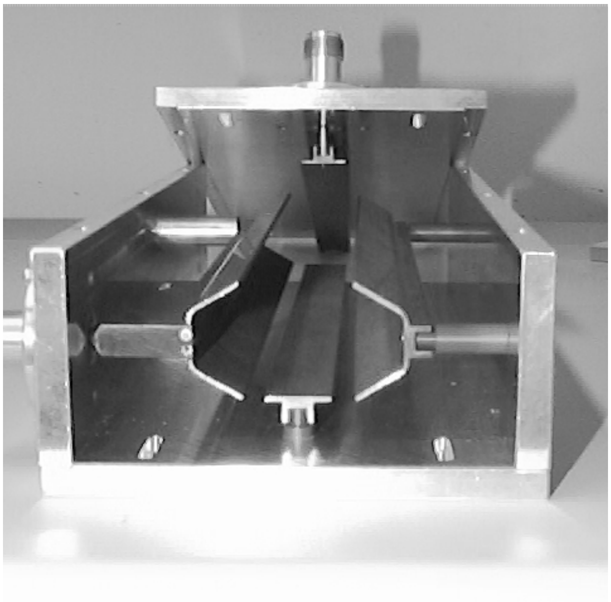

Figure 2: TFB kicker model showing the C-shaped electrodes in horizontal direction and the flat electrodes for the vertical plane

can be driven in differential mode using a 180 ° power divider or only one single stripline can be driven.

3 COMMISSIONING RESULTS

The TFB system was commissioned in December 1999. After a complete hardware check of all components most of the work was done in single bunch operation focussing on timing issues. Many signal measurements have been done using a 50 GHz sampling oscilloscope in order to:

- allign the BPM signals entering the receiver,
- adjust the reference signal for heterodyne detection,
- allign the position error signals on the mixing box input,
- overlap the beam induced signal from the stripline with the correction kick.

Since all cables have been phased beforehand by using a network analyser, the timing procedure turned out to be a straightforward task. The notch filter was tuned by adjusting the relative attenuation of both signal paths in order to obtain the best suppression of the revolution harmonic (about -40 dB) in the low frequency region, where the resistive wall effect has the strongest destabilizing contribution. The minimum attenuation over the entire frequency range of 250 MHz is -25 dB. Figure 3 shows the vertical correction signal after passing the notch filter in a frequency range from 0 Hz to 1.377 MHz. The suppression of the first revolution harmonic at 1.25 MHz relative to the vertical tune lines can be clearly seen.

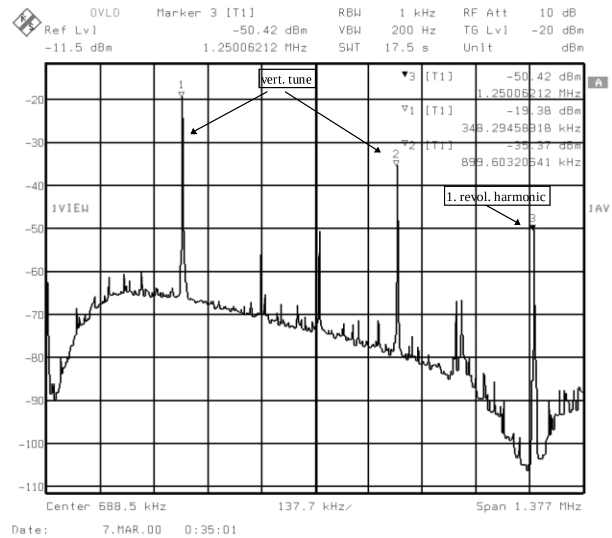

Figure 3: Correction signal in the vertical plane after passing through the notch filter; Frequency range: 0-1.377 MHz

The final commissioning task was the phasing of the system by setting the relative height of the four signal amplitudes of the pickups. By observing the damping effect of multibunch modes on a spectrum analyser as a function of the coefficient setting, a good operating point could be found. Once the coefficients were set and the feedback gain adjusted it has not been changed. Due to the successful damping of all coupled bunch modes tested up to currents of 350 mA the initially intended measurements of beam tranfer functions in order to establish the optimum phase conditions have not been neccessary.

Figure 4 shows the unstable beam spectrum without feedback in a frequency range from 499.5 MHz to 510 MHz which includes 9 revolution harmonics.

The relative amplitude of the tune lines indicate a stronger vertical than horizontal bunch motion as expected from the smaller vacuum chamber aperture in y-direction. The suppression of transverse beam motion of at least -45 dB with a closed feedback loop can be seen in figure 5.

During the commissiong phase the performance of the TFB with two electrodes powered in differential mode as well as only one electrode could be successfully checked. Under the current operating conditions the system runs with only one electrode powered, since the remaining two striplines can be used for diagnostics applications.

A measurement of the source size under the influence of the horizontal and vertical feedback system is shown in figure 6. It demonstrates the need of the feedback system in order to establish optimum conditions for the users. The lower left picture shows the source size of the synchrotron light with no feedback in both directions. A small horizontal reduction in beam size can be observed by switching the horizontal TFB on (right pictures). A drastic reduction in vertical beam size is shown in the two upper pictures with

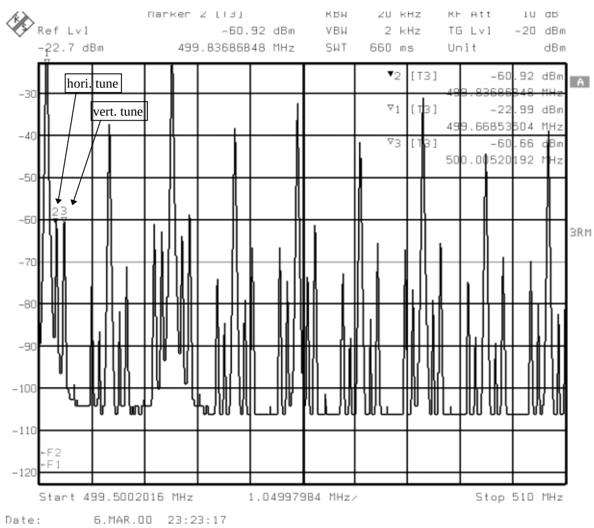

Figure 4: Unstable beam spectrum at 150 mA and chromaticity $\xi_{x,y} = 1$ between 500 MHz and 510 MHz; TFB off

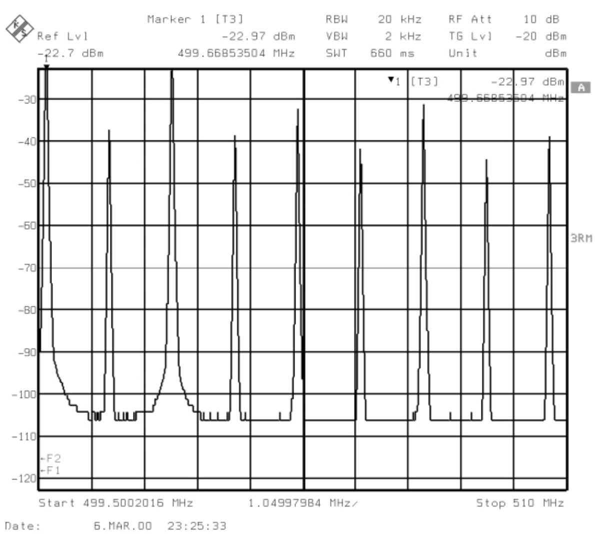

Figure 5: Stable beam spectrum at 150 mA and $\xi_{x,y} = 1$ between 500 MHz and 510 MHz; TFB on

the horizontal plane off (upper left) and both planes on (upper right). The corresponding beam size of $\sigma_x = 65\ \mu m$ and $\sigma_y = 45\ \mu m$ agree well with the expected beam size at the position of the optical system.

In order to damp transverse coupled-bunch dipole modes a chromaticity of $\xi_{x,y} = 4.5$ had been applied before the installation of the TFB system. That led to a reduction of the dynamic aperture and therefore to a reduction in life time. Due to the feedback the chromaticity could be lowered to $\xi_{x,y} = 1$.
An improvement in life time of about 40 % at 200 mA could be observed [4].

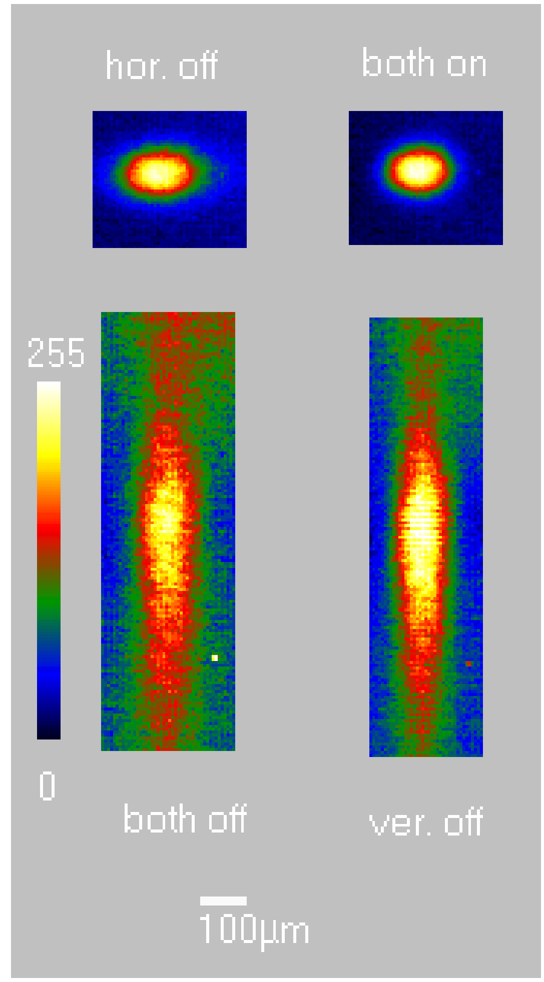

Figure 6: Source size of the electron beam observed with an optical system

4 CONCLUSION

The commissioning of the transverse feedback system turned out to be a straightforward task which was quickly done. After adjusting all relevant timing parameters, those parameters did not need to be changed since. It could be shown that the TFB system works reliably and delivers stable beam conditions for the BESSY II storage ring.

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