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THE TRANSVERSE FEEDBACK SYSTEM IN DESY

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Summary

To overcome single bunch instabilities at high intensities, a transverse feedback in DESY was necessary. A position-monitor detecting the coherent betatron oscillations delivers a signal which is amplified, matched in phase and used to power a kicker magnet. The latter consists of a two turn air coil which - with additional capacitors - has been made resonant in the betatron frequency range. Fine tuning of the system is effected by a ferrite loaded inductance in series with the kicker coil and biased by a variable magnetic field. The frequency range can be changed by switching capacitors. Appropriate triggering of the amplifiers and phase shifters allows the use of the same system for both electrons and positrons which are accelerated in different cycles.

Introduction

After the PETRA storage ring came into operation, the DESY synchrotron has normally operated in a single bunch - rather than in the original 528 bunch mode. In this mode the intensity was limited by head-tail instabilities. Furthermore unavoidable energy trigger jitters at injection lead to coherent oscillations. Both problems can be cured with the help of a feedback system. In this mode of operation, either single bunches of electrons or positrons are accelerated within one cycle, so the feedback can be rather slow. An estimate of the necessary kicker strength, utilizing the method of the normalized transverse phase space[1] leads to a relative change of amplitude

$$\left\langle \frac{\Delta a}{A} \right\rangle = \bar{\alpha} = \frac{\varepsilon}{2} \sin \pi q = -\frac{1}{a}\frac{da}{dn}$$

The solution of this equation is

$$\ln A/a = \bar{\alpha}\, n$$

Assuming the damping to a tenth of the inital amplitude will be sufficient, we find $\bar{\alpha}\, n = 2.3$ and from that follows the factor ε to be

$$\varepsilon = \frac{2\,\bar{\alpha}\, n}{\sin \pi q} \cdot \frac{1}{n_c}$$

which determines the kicker strength

$$\alpha K = \varepsilon * \frac{X_M}{\sqrt{\beta_M \beta_K}\, \sin \Delta\varphi}$$

where n_c is the necessary damping time in numbers of revolutions. This is mainly determined by the growth rate of the instability and the coherence time, which depends on the chromaticity of the synchrotron. The possible energy trigger jitter at injection causes coherent oscillations with a maximum amplitude of X_M = 2 mm. High detection sensitivity is essential for keeping the necessary kicker strength small for damping head-tail instabilities. The lowest detectable amplitude is about 1 mm. The coherence time, within which the coherent oscillation becomes incoherent due to Landau damping is much shorter than the growth rate of the head-tail instabilities which is about 1 ms[2]. So the requirements for the strength of the feedback system are determined by the position monitor sensitivity and the Landau damping. The kicker fields necessary to meet these conditions are

$$B_K l_K [\Gamma\, m] = 20 \cdot \frac{X_M[\,mm\,]}{n_c} \cdot p\ [GeV/c]$$

n_c	X_M [mm]	p [GeV/c]	$B_K l_K$ [Γ m]	B_K [Γ] for l_K = 0.6 m
100	2	0.055	0.022	0.036
100	2	0.450	0.18	0.3
100	1	7.0	1.4	2.3

To generate the necessary field on the beam axis, a resonant circuit is used. A ferrite loaded inductance is connected in series with the kicker coil for tuning the circuit to the betatron frequency. To match the circuit to the final amplifier a resonant transformer is used. A block diagram of the system is shown in figure 1.

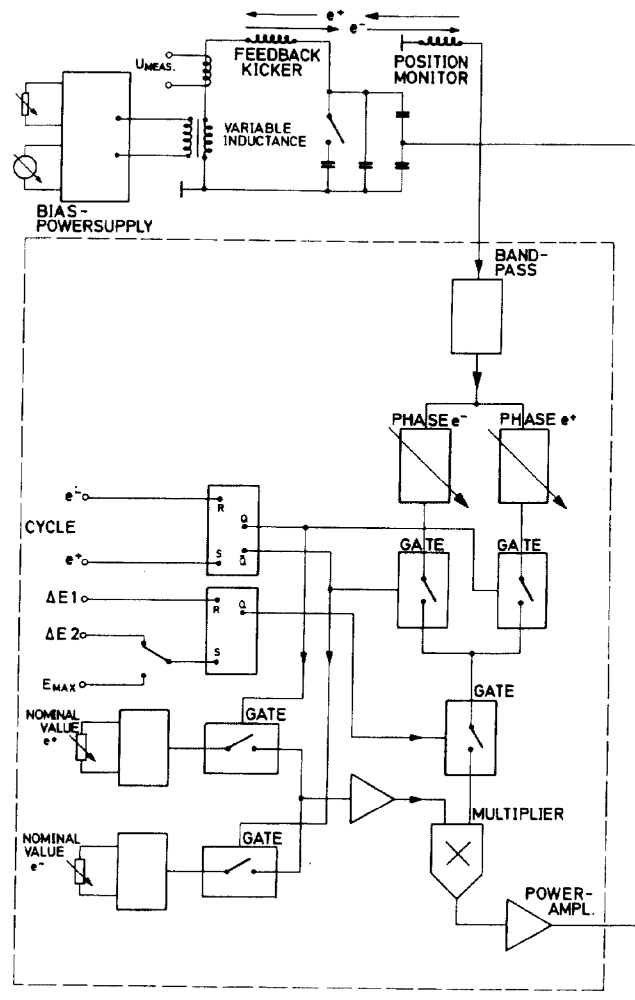

Fig. 1 Block diagram of the feedback system

Triggered phase shifters and amplifiers are used to adjust phase and gain for both beams. The threshold for the head-tail instability in the DESY synchrotron is about $1.5 \cdot 10^9$ particles per bunch. Normally DESY runs with about $4 \cdot 10^9$ electrons and positrons per bunch, so the feedback system is necessary

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for routine operation. At maximum 10^{10} particles per bunch were accelerated under stable conditions with the help of the feedback system. This number is by a factor 3 to 5 larger than that previously achieved with additional sextupoles or octupoles in the synchrotron magnet lattice.

Acknowledgement

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References

1) E. Keil et al., Feedback Damping of Horizontal Beam Transfer Errors CERN 69-27 (1969)

2) W. Ebeling, S. Kheifets, Coherent Betatron Oscillations at Injection DESY S 1-77/03 (in German)