IEEE Transactions on Nuclear Science, Vol. NS-28, No. 3, June 1981

REDUCTION OF THE HORIZONTAL ANTIDAMPING IN THE DESY ELECTRON SYNCHROTRON

G. Hemmie and M. Leneke
Deutsches Elektronen-Synchrotron DESY
Notkestraße 85
D 2000 Hamburg 52

Summary

In the DESY electron synchrotron the horizontal betatron oscillations are antidamped because of the isomagnetic combined-function lattice. Since the main task of the synchrotron is to supply electrons and positrons at the highest possible injection energy for the storage ring PETRA, a reduction of the horizontal antidamping would be very advantageous for the following reasons:

- smaller horizontal beam emittance improves injection efficiency in PETRA
- injection energy for PETRA could be 8 GeV instead of 7 GeV
- the repetition rate of presently 50 Hz could be reduced to 12.5 Hz without affecting the accumulation rate in PETRA. This would have further advantages for the operation of the synchrotron.

Using the existing backleg windings of the magnets, the antidamping can be reduced as measurements show. Adding quadrupoles to the synchrotron magnet lattice would allow to introduce horizontal damping. The variation of the horizontal beam size during acceleration is shown.

Introduction

Since 1978 the DESY synchrotron was mainly used for the injection of electrons and positrons into the storage rings DORIS and PETRA. While DORIS covers the energy range from 1.5 to 5.1 GeV, the working region of PETRA is mainly above 10 GeV. Since beam instabilities are more severe at low energies, the injection energy of PETRA should be as high as possible. The capability of the magnet power supply as well as of the rf-acceleration system of the synchrotron allow acceleration up to more than 8 GeV in principle. However, the increase of the horizontal emittance due to the antidamping of the isomagnetic combined-function lattice limits acceleration at about 7.2 GeV. Presently the magnets are excited to a top energy of 7.8 GeV, while the ejection is done at 7 GeV to give a sufficiently small horizontal beam width for the injection and accumulation in PETRA (figure 1). In DESY the electrons are injected at 55 MeV, while the positrons are injected at 450 MeV with an emittance ten times bigger than the emittance of the electrons. Hence the horizontal beam size of the positrons limits the maximum injection energy for PETRA. The magnet power supply of DESY can excite the magnet to an equivalent of 8.16 GeV at maximum. The magnetization (.86 Tesla on the reference orbit) is still well below saturation. The rf transmitter can produce about 19 MV circumferential voltage. At 8.16 GeV 12.4 MV are needed for compensating the radiation losses, thus leaving enough additional voltage for phase focusing. At 8.16 GeV the horizontal damping time constant in the storage ring PETRA is 66 ms compared to 105 ms at 7 GeV. The corresponding bunch transfer repetition rates are 80 ms and 120 ms respectively. If horizontal damping in DESY were introduced, the cycle frequency of the synchrotron could be reduced from 50 Hz to 12.5 Hz. This would have the advantage that the ac voltage in the magnet coils would be reduced to one quarter, thus decreasing insulation problems caused by radiation damage. The capacitive leakage current to ground, which seriously affects the closed orbit at 55 MeV electron injection, would be reduced by a factor of 16. The resonant frequency of the ac magnet circuit can easily be changed from 50 Hz to 12.5 Hz without changing the number of capacitors (figure 2).

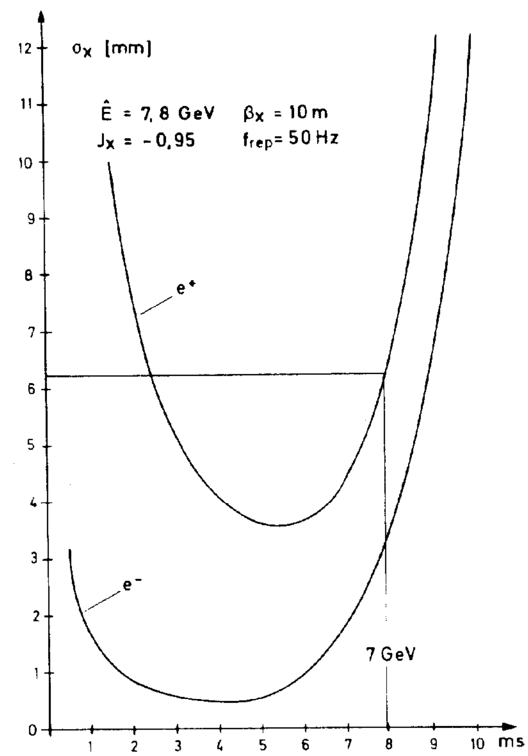

Fig. 1 Horizontal beam size vs. time during normal operation

Beam Emittance and Damping Partition

The dynamic behaviour of the horizontal emittance in DESY can be described by the following differential equation[1,2]

$$\frac{1}{\varepsilon x}\cdot\frac{d\varepsilon x}{dt} = -\left(\frac{\dot{E}}{E} + 2\alpha x\right) + \frac{1}{2\varepsilon x} * \frac{\langle H * N \langle u^2\rangle\rangle}{E^2}$$

The three terms on the right hand side represent the adiabatic damping, the radiation damping and the quantum excitation respectively. The sign of the radiation damping constant αx is determined by the partition number Jx, which in general is given by

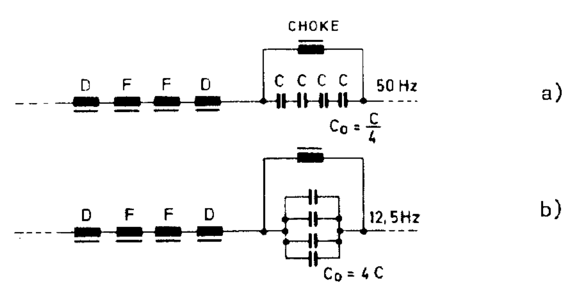

Fig. 2 Magnet circuit a) at present b) proposed

0018-9499/81/0600-2546$00.75©1981 IEEE

$$J_x = 1 - \vartheta$$

with

$$\vartheta = \frac{\oint \frac{D}{\rho^3}(1 - 2\,n)ds}{\oint \frac{1}{\rho^2}ds}$$

D = dispersion
ρ = bending radius
n = field index

For the isomagnetic combined function lattice of DESY one gets

$$J_x = -1 + \frac{\alpha R}{\rho}$$

Since $\frac{\alpha R}{\rho}$ is .0 5, J_x becomes negative and leads to antidamping. The influence of the partition number on the beam width is shown in figure 3 and 4 for repetition rates of 50 Hz and 12.5 Hz. Please note that the beam width in figure 4 at ejection is independant of injection parameters.

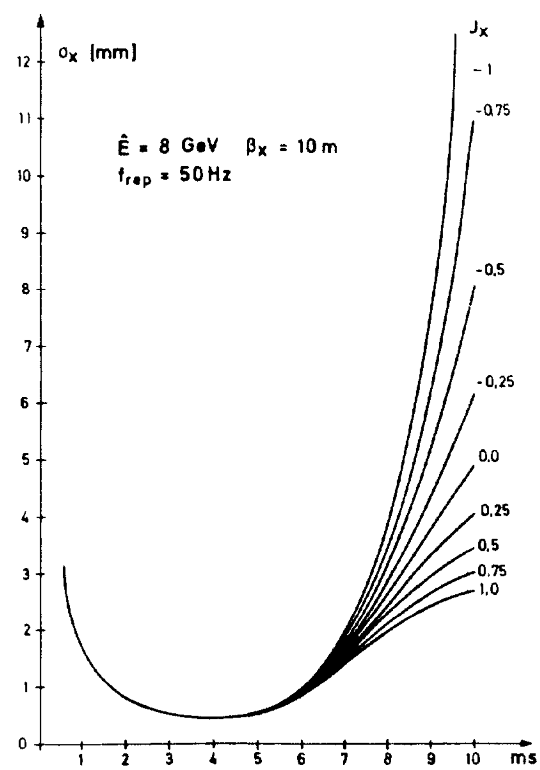

Fig. 3 Horizontal beam size vs. time for 50 Hz cycle frequency

Reduction of Antidamping

If one takes the horizontal beam size of the positrons at 7 GeV in figure 1 as a limit below which the beam size at 8 GeV should stay, than J_x has to be about 0.25 as figure 4 shows. For the reduction of the antidamping in a combined function lattice several ways have been proposed[3,4]. By using the backleg windings of the magnets the magnetization of the F- and D-sectors can be changed by about $\delta = \pm 5$ % at 7 GeV. This would result in $J_x = -0.32$. Further reduction of antidamping can be achieved by adding quadrupoles to the DESY lattice. Figure 5a as an example shows the introduction

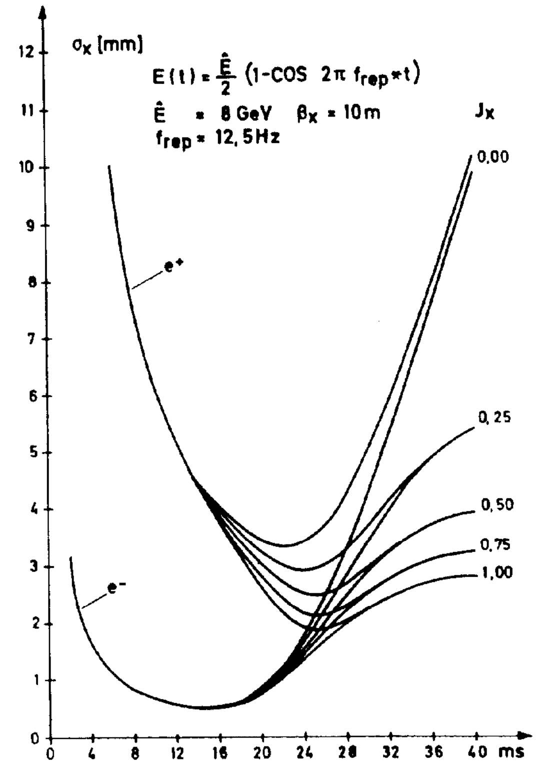

Fig. 4 Horizontal beam size vs. time for 12.5 Hz operation

of 16 quadrupoles to the optics. The result is that J_x becomes zero. A better optical solution will be achieved by optimizing the length of the straight sections (figure 5b). The partition number in this case becomes $J_x = 0.4$. With a wiggler type magnet using synchrotron magnet blocks one gets the best result (figure 5c).

Measurements

First measurements of the behaviour of the synchrotron have been made using the backleg windings of the magnets (figure 6). The working point strongly depends on the backleg winding current. Stable acceleration of electrons from 55 MeV to 7.0 GeV has been achieved at the working points B and C (figure 7). The behaviour of the beam size has been measured for the working points A and C (figure 8). There is a significant reduction of the beam width as expected.

Conclusion

With the backleg windings alone a sufficient reduction of the horizontal antidamping in DESY is not possible. Hence new lattice configurations with additional quadrupoles or wiggler- type magnets have to be considered.

References

1) M. Sands, SLAC-121 (1970)

2) H. Bruck, Accélérateur Circulaire de Particules (Press Universitaires de France, Paris 1966)

3) K. Robinson, Phys. Rev. 11, 373 (1958)

4) A. Hoffmann, B. Zotter, IEEE NS-24, 1875 (1977)

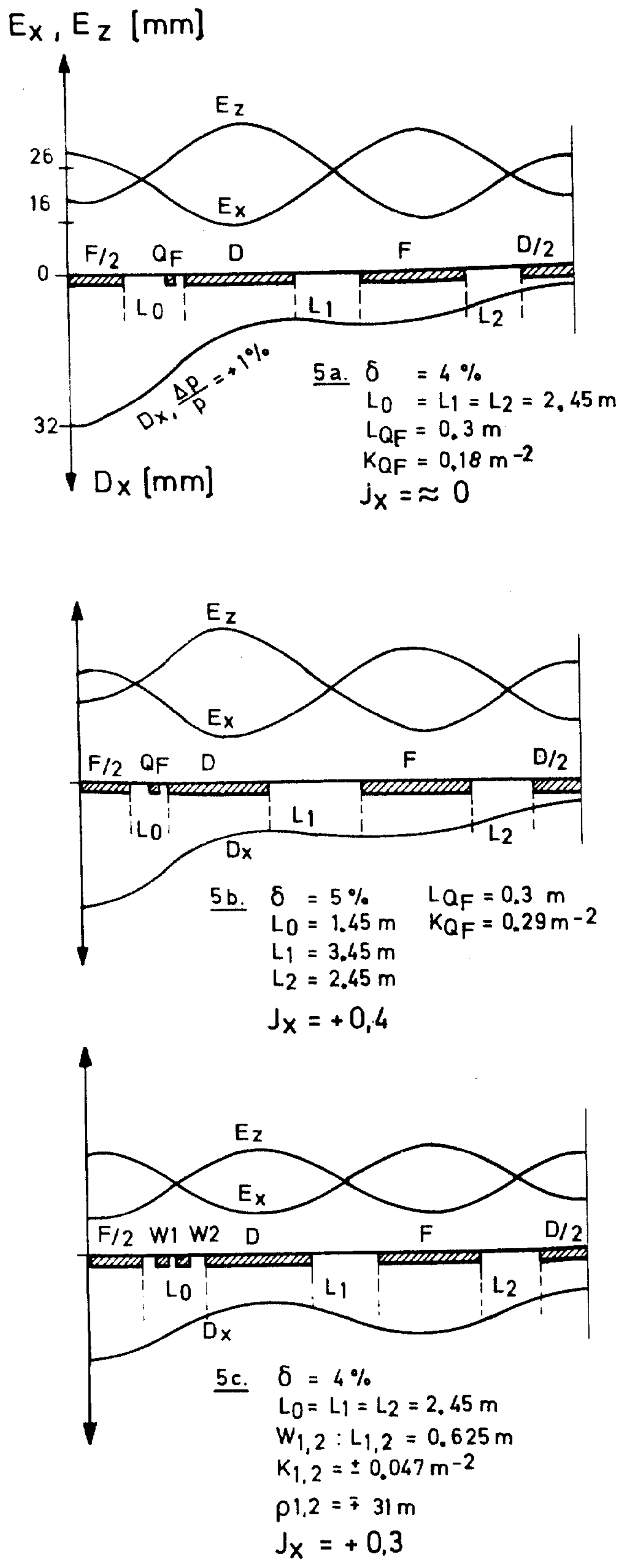

Fig. 5 Various lattice configurations, half cell
$\Delta p/p = 1$ %; $\varepsilon_x = \varepsilon_z = 40\ \pi$ mrad mm;
$l_F = l_D = 4.15$ m
$B_F/B_D = 1 - \delta$; $B_d/B_0 = 1 + \delta$

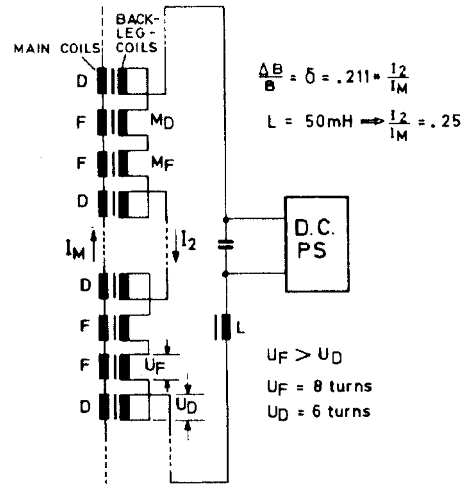

Fig. 6 Backleg circuit

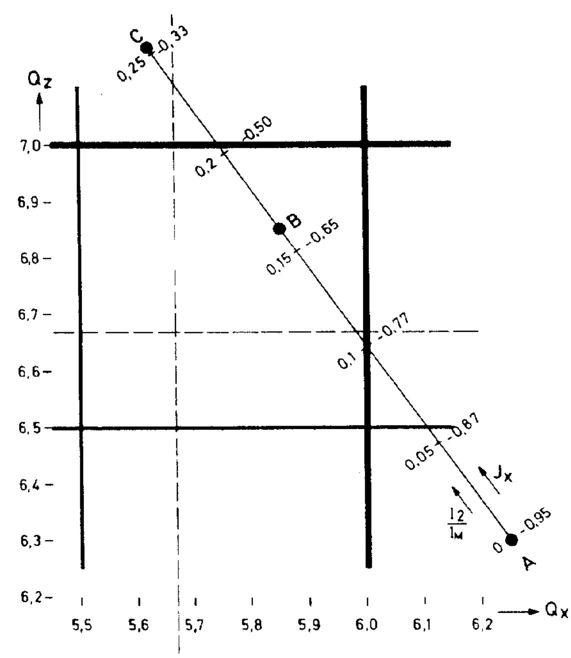

Fig. 7 Working diagram

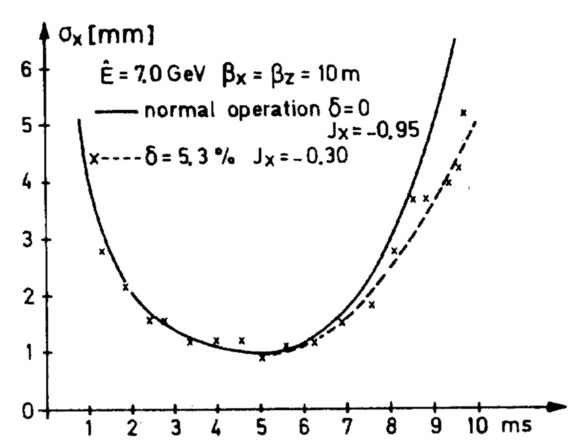

Fig. 8 Beam size vs. time, experimental data