IEEE Transactions on Nuclear Science, Vol. NS-30, No. 4, August 1983

PERFORMANCE OF THE 800-MeV INJECTOR FOR THE BESSY STORAGE RING

G.v. Egan-Krieger, D. Einfeld, W.-D. Klotz, H. Lehr,
R. Maier, G. Mülhaupt, R. Richter and E. Weihreter
Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung m.b.H. (BESSY)
1000 Berlin (West) 33, Lentzeallee 100

Abstract

The injector for the BESSY storage ring is an 800 MeV synchrotron with a 20 MeV microtron as preinjector mainly manufactured by Scanditronix AB. The synchrotron was designed as a separated function machine. The bending magnets, the focussing and the defocussing quadrupoles are powered by three independent White-circuits. These circuits are phase-locked to each other via a microprocessor. The repetition rate of the synchrotron is 10 c/sec. The max. extracted current measured at 570 MeV was 12 mA/50 ns. The emittance was $\varepsilon_x = 1.6 \times 10^{-6}$ πm rad, $\varepsilon_y = 0.25 \times 10^{-6}$ π m rad. The energy was changed to 776 MeV in August 1982. The extracted current was 7 mA/50 ns.

I. Introduction

For the BESSY storage ring a strong focussing separated function synchrotron is used as injector with a maximum energy of 800 MeV and a repetition rate of 10 c/sec. The 20 MeV preinjector was completely, the injector synchrotron mainly constructed and manufactured by Scanditronix AB. A scheme of the synchrotron is shown in fig. 1, the parameters are listed up in fig. 2. The typical data of the 22 MeV microtron, used as preinjector of the synchrotron, are shown in fig. 3. The total power consumption of these machines is less than 200 kW.

II. The injector synchrotron

The 20 MeV beam from the microtron is inflected horizontally with an electrostatic inflector and one kicker in the opposite straight section. The trigger for these elements is derived from a peaking strip signal, which corresponds to the main dipol field of 20 MeV at the injection.

The synchrotron has a six fold symmetry with a substructure for each unit cell of F B D B F (see fig. 1). The unit cell and the main optical parameters are shown in fig. 4. The H-type bending magnets have a maximum field of 1 T, whereas the maximum gradient of the quadrupoles is 5,7 T/m. All magnets are laminated and welded. The thickness of the steel plate is 1 mm. To avoid a coupling of mechanical oscillations from the bending devices to the building the H-type magnets are only supported and tightened in the oscillation nodes.

The bending magnets, the focussing and defocussing quadrupoles are powered by three independent White-circuits. They are phase locked to each other via a microprocessor (Z80). The White-circuits and their controll scheme are shown in fig. 5.

To control the beam during acceleration it is important to get the tune shift ΔQ due to tracking errors of the quadrupole field relative to the bending field as small as possible. This means that the quadrupole strength K, given by the gradient $g(t) = \frac{\delta B}{\delta r}$ and the energy E (t) determined by the field B (t) of the bending magnets should be constant as function of time

$$K = ec \frac{g(t)}{E(t)} = \text{const.} \tag{1}$$

In order to get a tune shift of $\frac{\Delta Q}{Q} < .01$ the tracking of g (t) and B (t) for this machine has to be

$$\frac{\Delta K}{K}(t) < .005 \tag{2}$$

The relative deviation $\frac{\Delta K}{K}(t)$ according to field measurements during the acceleration cycle from injection at $t_I = 5$ ms to the extraction at $t_E = 55{,}5$ ms is shown in fig. 6. These deviations are due to unavoidable higher harmonics induced by the AC-excitation of the magnets. Measuring the Q-values at different times in the acceleration regime gives time shifts of $\frac{\Delta Q}{Q} < .01$ as shown in fig. 7.

It was possible to choose a one cell structure for each White-circuit, which is powered by a DC- and an AC-power supply. The DC-power supply is current regulated, its stability is $\frac{\Delta I}{I} < \pm 5 \times 10^{-5}$. The AC-power supply consists of a DC-part, providing a constant voltage and an inverter, triggered by the microprocessor (see fig. 5). The AC-amplitude is controlled by a feed back loop as shown in fig. 5. The relative stability of the AC-amplitude and the frequency is better than $\pm 1 \times 10^{-4}$. The phase lock of the three White-circuits is achieved by controlling the time delays between the triggers for the inverters of the quadrupole circuits (slaves) and the trigger for the circuit of the bending magnets (master), whereas this circuit is locked to a quartz clock. The zero cross of the AC-amplitudes of the quadrupole circuits is detected relative to the zero cross of the AC-amplitude of the bending magnet circuit. From these measurements the corrections for the triggers and for the inverters of the quadrupole circuits are calculated.

For the synchrotron a stainless steel vacuum system has been choosen.In order to avoid eddy currents the wall thickness of the chambers in the magnets is .3 mm. These chambers are like hydroformed bellows. Ion sputter pumps are used. The total intrinsic pumping speed is about 1000 l/sec. The pressure reached is better than 10^{-7} mbar.

The RF-system consists of a 500 M c/sec-clystron power amplifier driving one $\lambda/2$ one cell cavity (DORIS- type). The maximum available RF-power is 2 kW. Typical data of the RF-system are listed up in fig. 2.

The extraction from the synchrotron is done horizontally with a slow beam bump supported by a fast kicker magnet with a rise time of 30 nsec moving the beam towards a pulsed septum magnet.

The upper limit of the vertical emittance as function of energy, was measured by determining the size of the extracted beam with radiation sensitive paper. The measured data are shown in fig. 8. For comparison the dashed curve shows the depending of the vertical emittance as function of energy due to adiabatic damping assuming $\varepsilon_z = 2 \times 10^{-6}$ π m rad at injection. Taking into account radiation damping and radiation excitation in addition one gets the dotted curve. As an upper limit for the emittances of the extracted

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beam the values $\varepsilon_x = 0.71 \times 10^{-6}\ \pi$ m rad and $\varepsilon_z = 0.034 \times 10^{-6}\ \pi$ m rad at E = 754 MeV has been obtained. The injector synchrotron has gone into operation at the beginning of April 1981. The maximum energy of 800 MeV has been reached in June 1981. The maximum extracted current measured at an energy of 570 MeV was 12 mA/50 ns, at 776 MeV a value of 7 mA/50 ns has been reached so far.

The operation mode of the machine is to run for 8 to 10 hours per day providing beam for the storage ring. During the night the power consuming equipments are set to low values. Normally it takes less than 1 hour for starting up (stable beam).

FIG1 Scheme of the BESSY Injector Synchrotron
Scale 1:50

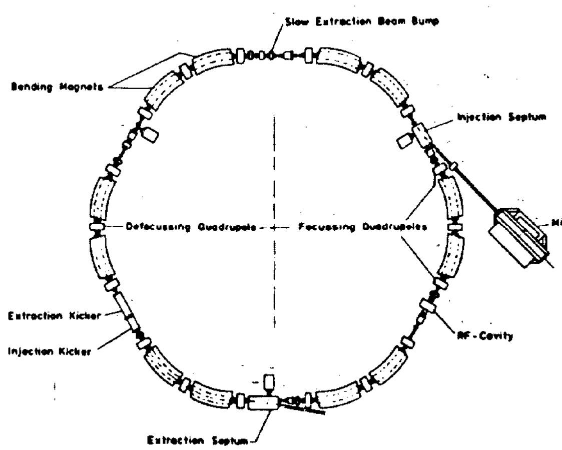

FIG. 2
Characteristics of the BESSY-Synchrotron

Max. energy		800 MeV
Injection energy		20 MeV
Circumference		38.4 m
Superperiodicity		6
Structure		separated function F B D B F
No. of bending magnets (H-type)		12
No. of focussing quadrupoles		12
No. of defocussing quadrupoles		6
Repetition rate		10 c/sec
Q-values	Q_x =	2.22 ± 0.01
	Q_y =	1.31 ± 0.01
Momentum compaction factor α		0.18
Harmonic number		64
RF-frequency		500 M c/sec
RF-output power		2 kW
Cavity shunt impedance		3 MΩ
Current at 776 MeV		7 mA/50 ns
Vertical emittance		≤ 0.034 π mm mrad
Horizontal emittance		≤ 0.71 π mm mrad

FIG. 3
Characteristics of the BESSY-Microtron

Extractable energy	22.5	MeV
Energy gain per turn	535	keV
Energy spread (FWHM)	35	keV
Magnetic field	0.112	T
Magnet diameter	2.220	m
Pole piece diameter	1.800	m
Gap height	0.110	m
Magnet width	0.450	m
Microwave frequency	3.0	G c/sec
Microwave peak power	2.0	MW
Pulse duration (max.)	4	μs
Pulse repetition rate	10	c/sec (max.250 c/sec)
Working vacuum	10^{-6}	mbar
Pulse current	15	mA
Vertical emittance	≤ 8	π mm mrad
Horizontal emittance	≤ 3	π mm mrad

FIG 4
Design Parameters of one Unit Cell

ρ = 2.670 m	Q_x = 2.220
L = 6.400 m	Q_y = 1.310
l_M = 1.398 m	α = 0.180
l_Q = 0.250 m	K_1 = 1.690
l_1 = 1.025 m	K_2 = -1.530
l_2 = 0.210 m	E = 800 MeV

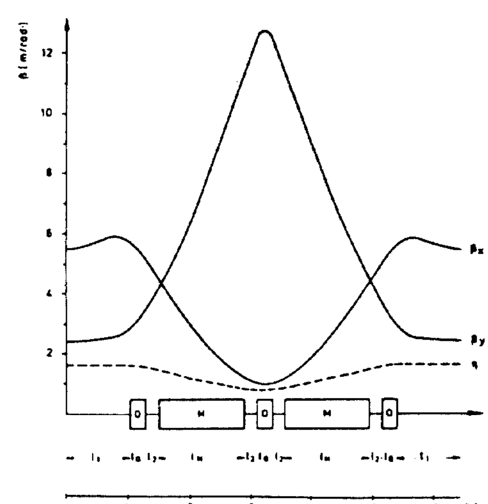

FIG 6

The relative Deviation $\frac{\Delta K}{K}(t)$ as Function of Time

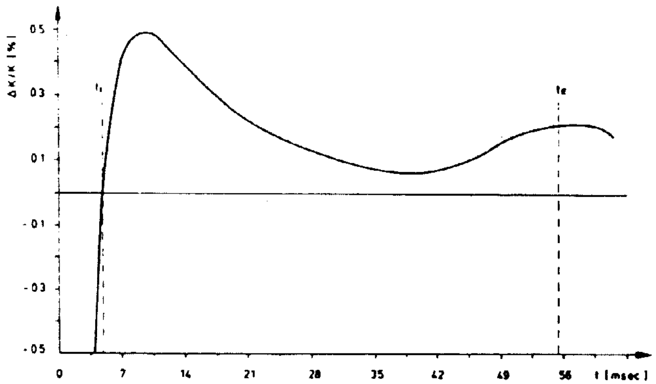

FIG 5 Control of the White-Circuits

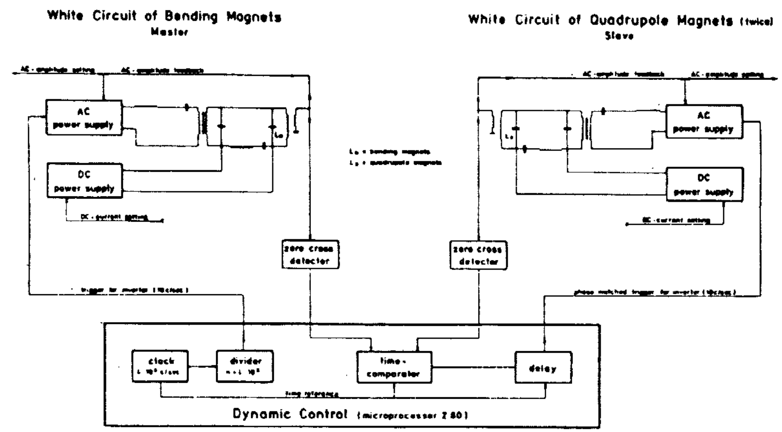

FIG 7

The Q-Value as Function of Time

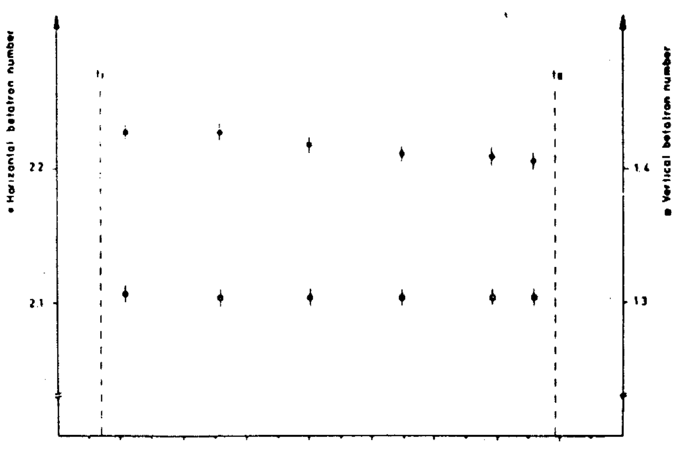

FIG 8

The vertical Emittance as Function of Energy