LONGITUDINAL AND TRANSVERSE FEEDBACK KICKERS FOR THE BESSY II STORAGE RING[*]

S. Khan, T. Knuth[†], BESSY, Berlin, Germany

A. Gallo, F. Marcellini, B. Sparato, M. Zobov, INFN, Frascati, Italy

Abstract

This paper presents an overview of the bunch-by-bunch feedback kickers designed for the BESSY II storage ring. Simulation results for the longitudinal kicker cavity and for the transverse stripline kicker are discussed.

1 INTRODUCTION

Bunch-by-bunch feedback systems are required to cure multibunch beam instabilities at high currents in the BESSY II storage ring [1]. The present status of the longitudinal feedback system (LFB) and the transverse feedback system (TFB) is reported in [2]. As longitudinal correcting element, a waveguide-overloaded cavity was favored over a drift-tube structure. The kicker cavity designed for DAΦNE [3] was modified to meet the requirements for BESSY II. A shunt impedance of 960 Ω and effective damping of higher-order modes (HOMs) has been achieved. For the TFB, stripline electrodes will be used. The stripline pairs for each transverse plane will be combined in one structure.

This paper describes the design issues and focusses on simulation results for both kickers using the computer codes MAFIA [4], POISSON [5] and HFSS [6]. The parameters used in the simulations are given in Table 1.

Table 1: Simulation parameters for BESSY II.

f_{rf}	rf frequency	499.65 MHz
n	harmonic number	400
E	beam energy	1.7 GeV
I	assumed beam current	400 mA
P	total rf power (LFB)	220 W
	total rf power (TFB)	2×150 W

2 LONGITUDINAL KICKER

2.1 Geometry and Performance

The LFB kicker is based on a pillbox cavity design as shown in Fig. 1. In order to achieve the desired bandwidth of [7]

$$f_{\mathrm{bw}} = 0.53\, f_{\mathrm{rf}} = 265 \text{ MHz}, \tag{1}$$

eight waveguides are attached to provide suitable damping. Four waveguides are used as power inputs, the four other waveguides are connected to loads.
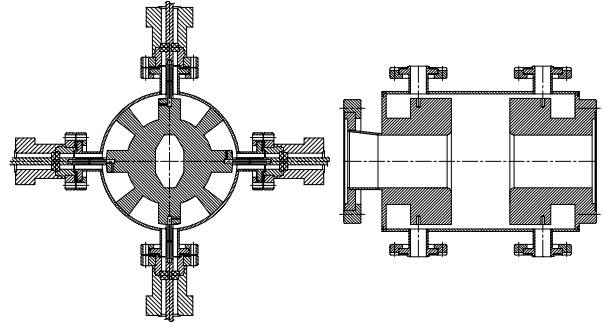
Figure 1: Longitudinal kicker structure.

MAFIA calculations yield an optimum R/Q-value of 87 Ω at a cavity length of l=72 mm. The center frequency has to fulfill the condition [8]

$$f_c = (p \pm 0.25) f_{rf} \tag{2}$$

where p is a positive integer. In order not to deviate too much from the original design, a center frequency of 1374 MHz (i.e. 2.75 f_{rf}) was chosen, leading to a theoretical pillbox radius of 83 mm. Extensive simulations were performed using the 3D-code HFSS in order to check the HOM content of the structure, to obtain the required Q-value of 5.2, and to optimize the transition from the coaxial feedthrough to the waveguide. Fig. 2 shows 1/8th of the kicker structure. The reflected power up to the cut-off frequency does not exceed 6%. The port-to-port frequency response is shown in Fig. 3. With a center frequency of 1380 MHz and a bandwidth of 270 MHz, a Q-value of 5.1 is obtained.
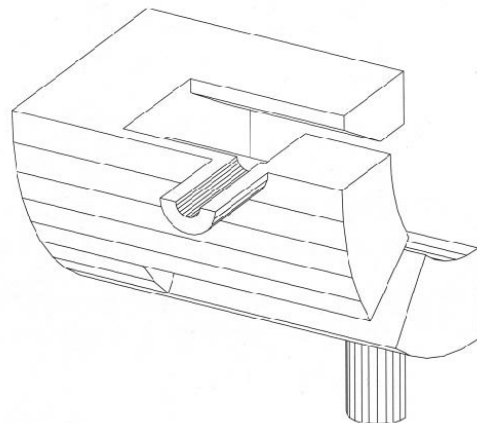

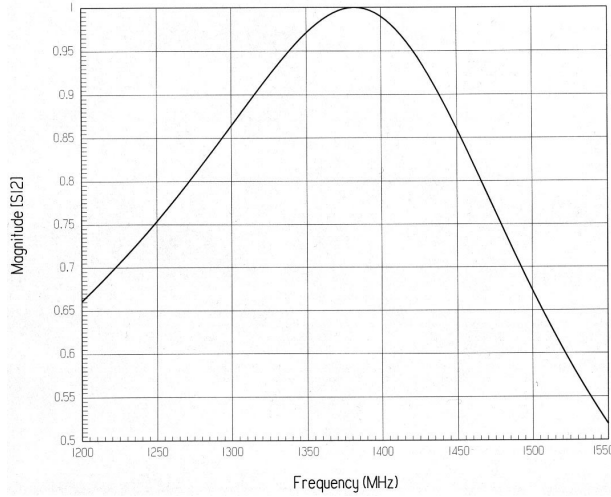Figure 2: HFSS model as 1/8th of the whole structure.

Figure 3: Frequency response of the fundamental mode.

For a given input power P, the simulation yields an electric field amplitude $E_z(z)$ and phase $\Theta_z(z)$ on the cavity axis, from which the accelerating voltage

$$V_{\text{acc}} = \int_{-l/2}^{l/2} E_z(z) \exp(i[2\pi f_c z/c - \theta_z(z)]) dz \quad (3)$$

is obtained. The resulting shunt impedance, given by

$$R_s = \frac{|V_{\text{acc}}|^2}{2P}, \quad (4)$$

is 1100 Ω. An independent method to obtain R_s by simulating a wire along the beam axis yields a slightly lower value of 960 Ω. Table 2 summarizes the kicker parameters.

Table 2: Longitudinal kicker parameters.

pillbox length	72 mm
length including waveguides	260 mm
overall length	310 mm
pillbox radius	82 mm
number of waveguides	8
center frequency	1380 MHz
bandwidth	270 MHz
Shunt impedance	960 Ω

2.2 HOM Characterization

Monopole and dipole HOMs were selected using 2D MAFIA calculations, and their center frequencies were verified by 3D runs. In the vicinity of these frequencies, HFSS runs were performed to obtain the Q-values and shunt impedances listed in table 3 and table 4. The power generated by the monopole modes was computed up to the cut-off frequency of 5.2 GHz, where each mode contributes a power of

$$P_G = \sum_i \frac{1}{2} \text{Re}[R_c(\omega_i)] I_i^2 \quad (5)$$

with I_i representing the beam spectrum and R_c the coupling impedance, which turned out to be twice the shunt impedance. Table 5 lists the total power contribution of the fundamental mode and the total power of all HOMs for beam currents of 200 mA and 400 mA in 320 buckets. Since the cavity is a non-directional device, about half of the generated power is seen by the amplifier i.e. 130 W at 400 mA. A circulator for protection is not immediately needed, since the amplifier is capable of absorbing up to 100% of its output value (220 W).

Table 3: Monopole modes of the kicker cavity.

Mode	$f_{\text{MAFIA}-3D}$ [MHz]	R_s/Q [Ω]	f_{HFSS} [MHz]	Q	R_s [Ω]
0	1405.8	86.9	1382	5.2	887
1	2518.5	13.9	2250	7.1	99
2	3231.1	2.6	3257	65	169
3	3872.5	13.6	3849	149	2026
4	4379.7	2.6	4195	32	83

Table 4: Dipole modes of the kicker cavity.

Mode	$f_{\text{MAFIA}-3D}$ [MHz]	$R_s^\perp/Q$ [Ω]	f_{HFSS} [MHz]	Q	$R_s^\perp$ [Ω]
1	2190.5	4.32	2176	15	64.8
	2082.8		2062	18	77.8
2	2279.7	0.07	2257	30	2.1
	2108.0		2085	97	6.8
3	2968.4	3.3	3019	18	59.4

Table 5: Total beam induced power with 320 buckets filled.

I	$P_{\text{fund.}}$ [W]	$P_{\Sigma\text{HOM}}$ [W]	P_G [W]
200 mA	35.5	29.9	65.4
400 mA	142.0	119.5	261.5

3 TRANSVERSE KICKER

3.1 Geometry and Performance

For the transverse kicker, a stripline geometry will be employed. The horizontal (x) and vertical (y) electrodes are combined in a single structure to minimize space requirements and to obtain a moderate loss factor. Each pair of electrodes is driven in differential mode using a $180°$ power divider connected to a 150 W linear amplifier.

Fig. 4 shows the model of the kicker for MAFIA calculations. C-shaped electrodes for the x-plane and flat electrodes for the y-plane match the octagonal shape of the adjacent vacuum chamber without tapering, leaving only a 5 mm wide gap in longitudinal direction. The electrode length of 300 mm maximizes the shunt impedance. To improve radiative heat dissipation, the outside surface is increased by adding cooling vanes. Using the 2D code POISSON, the electrodes and the surrounding chamber were shaped to meet the line impedance requirement of $R_L = 50$ Ω. A model was built and TDR (time domain
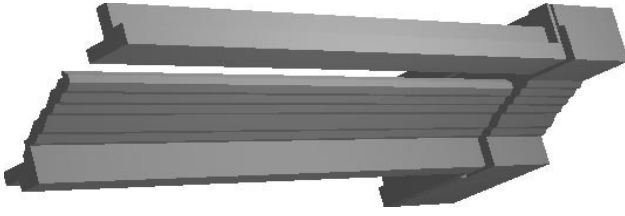
Figure 4: MAFIA model of the transverse kicker (1/8th of the full structure).

reflectometry) measurements were performed to verify the line impedance of the electrodes, which agrees well with the calculations, and to minimize reflections at the transition to the coaxial feedthroughs. The different geometry of the electrodes in x and y leads to a different transverse shunt impedance $R_s^\perp$ [9]

$$R_s^\perp = 2R_L \left(g_{x,y} \frac{2}{kh} \right)^2 \sin^2 \theta, \qquad (6)$$

where $g_{x,y}$ is the respective geometric coverage factor, k is the wavenumber, l is the electrode length, h is the distance between opposite electrodes and $\theta = k\,l$. Fig.5 shows the frequency dependence of the shunt impedance in both planes.
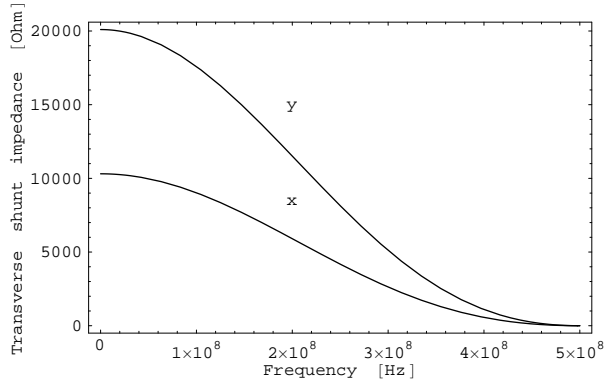

Figure 5: Shunt impedance of the transverse stripline kicker.

A higher vertical shunt impedance is prefered because of the larger vertical resistive wall impedance of a flat vacuum chamber. Over the entire mode spectrum (DC to 250 MHz), the kick voltage exceeds 1.7 kV vertically and 1.2 kV horizontally.

3.2 HOMs and Power Losses

HOMs found by performing MAFIA calculations in the frequency domain are trapped behind the electrodes and couple only weakly to the beam. Even though HFSS calculations show that most of the HOM power dissipates through the feedthroughs, at least one damping loop will be installed to further damp the the strongest modes.

Ohmic losses from the image currents passing the electrodes were calculated for a beam current of 400 mA. A total power loss of 5 W for stainless steel (specific resistivity $\varrho_{St} = 0.71 \cdot 10^{-6}\ \Omega$m) and 0.8 W for copper electrodes ($\varrho_{Cu} = 0.017 \cdot 10^{-6}\ \Omega$m) was obtained. On the other hand, using the Stefan-Boltzmann law and the emission coefficients for steel ($\epsilon_{St} = 0.29$) and copper ($\epsilon_{Cu} = 0.03$) electrode temperatures of $T_{St} = 80°$C and $T_{Cu} = 105°$C were found. In order to decrease the electrode temperature, the possibility of blackening the electrode surfaces is being considered.

Table 6: Transverse kicker parameters.

line impedance	50 Ω
length of kicker structure	310 mm
overall length (incl. bellow and pumping port)	600 mm
electrode separation (x, y)	65 mm, 35 mm
Coverage factor (x, y)	1.1, 0.83
Kick voltage at DC (x, y)	1.7 kV, 2.4 kV
Kick voltage at 250 MHz (x, y)	1.2 kV, 1.7 kV

4 ACKNOWLEDGMENTS

5 REFERENCES

[1] R. Bakker for the BESSY team: 'Status and Commissioning Results of BESSY II', this conference.

[2] S. Khan, T. Knuth: 'BESSY II Feedback Systems', this conference.

[3] R.Boni et al.: 'A Waveguide Overloaded Cavity as Longitudinal Kicker for the DAΦNE Bunch-by-Bunch Feedback System', Part. Acc. Vol.52 (1996), p.95.

[4] 'MAFIA User's Guide', CST, Darmstadt.

[5] J. H. Billen: 'The Superfish Manual', Los Alamos LA-UR-96-1834.

[6] Hewlett-Packard Co.: 'HFSS, the High Frequency Structure Simulator HP85180A^{TM}'.

[7] A. Gallo et al.: 'Efficiency of the Broadband Rf Cavity Longitudinal Kicker in DAΦNE', internal note.

[8] M.Bassetti et al.: 'DAΦNE Longitudinal Feedback', Proceedings of the 3rd Europ. Part. Acc. Conference (1992), p.807.

[9] D. Goldberg, G. Lambertson: 'Dynamic Devices: A Primer on Pickups and Kickers', AIP Conf. Proc. No. 249 (1992), p. 537.