KICKER DESIGN FOR THE ELETTRA/SLS LONGITUDINAL MULTI-BUNCH FEEDBACK

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Abstract

The paper reports on the design of the longitudinal kicker for the ELETTRA/SLS longitudinal multi-bunch feedback system. It follows the Daphne/Bessy approach in being a heavily coupled cavity using each four waveguide ports for driver and loads. For minimum broad band impedance effects, the layout adapts to the non circular cross section of the SLS vacuum chamber. The shunt impedance is optimized by additional nose cones in the cavity. Problems with undamped longitudinal and transverse higher oder modes in the kicker are avoided using only one HOM damper, which is designed as a hybrid TE/TM coupler.

1 INTRODUCTION

In addition to the transverse bunch-by-bunch feedback systems, it is planned to set up also longitudinal feedback systems at ELETTRA and SLS. The general setup follows relatively closely that of the transversal systems with the addition of a modulator, since the longitudinal kicker does not work in base band [1].

Design objectives are first a high kick efficiency due to a high shunt impedance, and a tame behavior concerning the beam impedance – low Q higher order modes and a small effective broad band component.

Higher operating frequencies typically lead to physically smaller structures with higher shunt impedances and improved wake fields. The upper limit is given by the cutoff frequency of the beam pipe, which in the case of the SLS injection straight as the kicker location is a chamber with 28 mm height and 88 mm width. The lowest cutoff frequency comes out to be approximately 1.7 GHz, so that an operating frequency band of 1.25-1.5 GHz was chosen for the kicker.

For minimum space requirements, the vacuum chamber cross section was maintained through the kicker, no tapering is required to adapt to some circular beam entrance/exit. As it came out after completing the design, that this cross section together with the nose cones mentioned later gives high shunt impedances due to the small height, no specific design for the ELETTRA chamber geometry was done, an SLS type kicker with matching tapers is going to be used.

2 FUNDAMENTAL MODE OPTIMIZATION

The generic structure is that of the Daphne kicker [2]. Analog to the BESSY [3], four power couplers instead of three are used in order to be able get get to the required loaded Q of approximately 5.5.

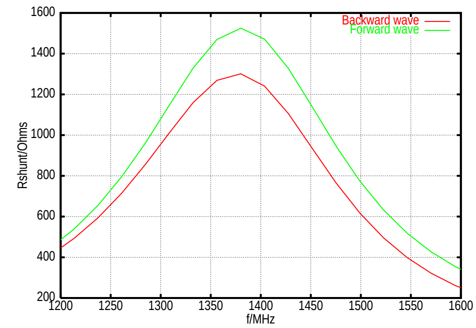

Figure 1: Forward and backward wave shunt impedance as computed with MAFIA-T3.

In order to improve the coupling factor of the fundamental mode, additional nose cones consisting of 10 mm of the vacuum chamber sticking in the cavity on both sides were used. That way, the maximum shunt impedance could be increased to 1500 Ω, which compares well to the theoretical value for the BESSY kicker of 1100 Ω. The variation of the shunt impedance is shown in figure 1, where both the forward wave impedance (RF amplifier connected to upstream RF couplers) and backward wave impedance (RF amplifier connected to downstream couplers) are plotted to demonstrate the slight traveling wave type behavior of the kicker.

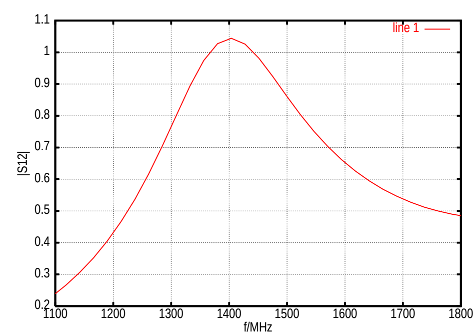

Figure 2: Transmission coefficient from input to output couplers.

The transmission from the input to the output couplers, as seen in figure 2, shows some distortion due to higher order modes. Compared to the shunt impedance, the peak in transmission is shifted toward higher frequencies with a slower roll-off at the upper side band.

An interesting point is the delay between the RF input port and the kick seen by the beam, which was calculated via the group delay of the corresponding transmission function (figure 3). Different from strip-line designs exhibiting no frequency dependency, it by approximately 600 ps in

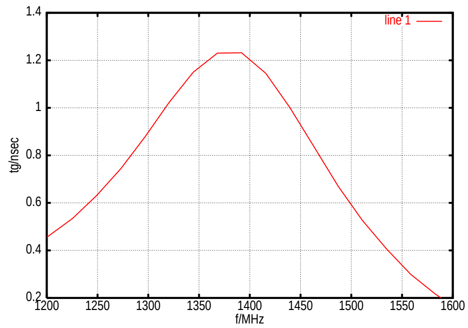

Figure 3: Group delay from input port to kick seen by the beam.

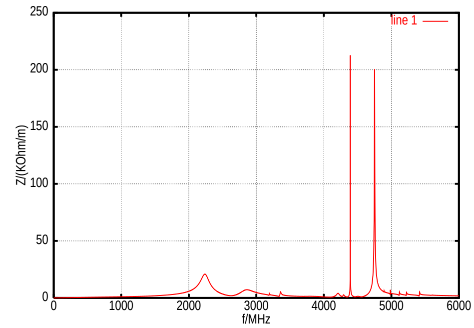

Figure 4: Horizontal Impedance without HOM coupler.

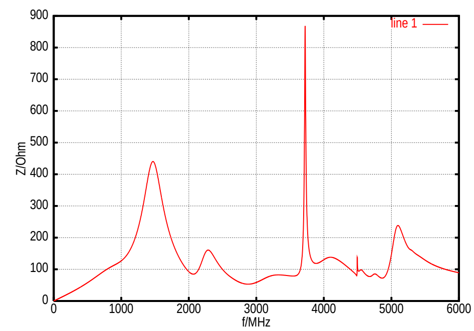

Figure 5: Longitudinal Impedance without HOM coupler.

the 1.25-1.5 GHz operating band. The corresponding phase shift of ± 180 degrees would give an anti damping behavior of the feedback for certain frequencies, which is clearly unacceptable. For the compensation of this delay variation an FIR filter with filter function

$$H(j\omega) = \left(1 + ae^{-j\omega\tau}\right)^2, a = 0.65,\ \tau = 360psc \quad (1)$$

is going to be used, which also compensates for the amplitude dependency.

3 HIGHER ORDER MODES

For the calculation of the beam impedance due to higher order modes in the structure, a set of frequency domain calculations using MAFIA were used. The structure (actually a quarter of it due to symmetries) was computed with magnetic shorts on the coaxial couplers. With V_{ij} the voltage of mode i seen at the magnetic short of port j and W_i the total magnetic energy in the structure, coupling coefficients can be calculated:

$$k_{ij} = \frac{V_{ij}^2}{4W_i} \quad (2)$$

The impedance seen at port j is then:

$$Z_j = \sum_i \frac{2j\omega k_{ij}}{\omega^2 - \omega_i^2} \quad (3)$$

Given this relation, the additional damping introduced by the 50 Ohms impedance seen at the port can easily be computed. With the beam pipe cutoffs being approximately 5.5 GHz for longitudinal and horizontal dipole modes, only resonances up to these frequencies have to be computed, requiring only the first 34 longitudinal modes and horizontal modes. Due its low cutoff of approximately 1.7 GHz for vertical dipole modes, only two modes were found in the relevant band being standing waves in the power coupler without any big influence on the beam impedance.

The resulting spectra are shown for the horizontal dipole impedance in figure 4 and for the longitudinal beam impedance in figure 5. In both cases, there are trapped modes at higher frequencies, which do not couple to the power couplers.

Particularly interesting is the trapped longitudinal mode at 3.8 GHz shown in figure 6. In reality, this is a dominantly TE type quadrupole mode. The non circular beam pipe cross section distorts the field lines so, that a small longitudinal monopole field is created. In the dipole spectrum, one of the trapped dipole modes shows mainly TE (4.8 GHz) behavior and is in reality a degenerated sextupole mode. The other dipole resonance (4.4 GHz) exhibits mainly TM characteristic.

Trying to damp these modes via dedicated higher order mode couplers in the longitudinal symmetry plane would require the following setup: With magnetic coupling loops, the TE type horizontal dipole requires a coupler at the top of the chamber, with the loop being longitudinally (along the beam axis) oriented. The TM dipole coupler would sit

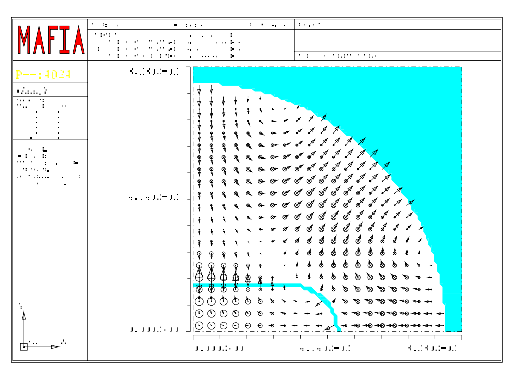

Figure 6: Electric field of a degenerated quadrupole mode near beam pipe.

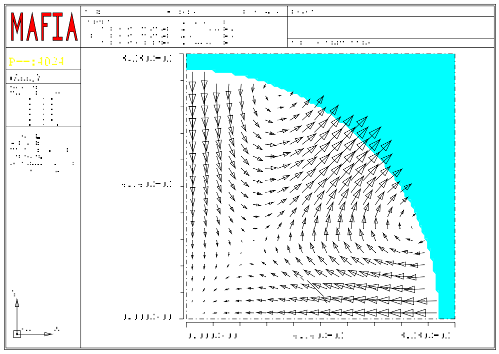

Figure 7: Electric field of a degenerated quadrupole mode in the symmetry plane of the kicker.

in the same location, the loop being oriented azimuthally. As shown in figure 7, the longitudinal mode would not couple to any of these and would require its own coupler at 22.5 degrees from the top with the loop longitudinally oriented.

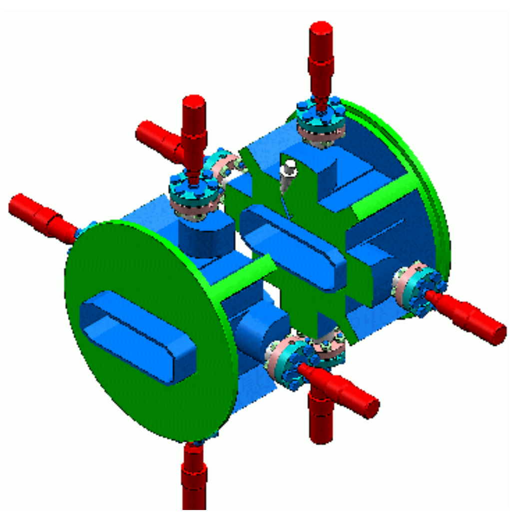

Figure 8: Kicker cavity with the higher order mode coupler.

Figure 9: Transverse impedance with HOM coupler.

This would mean the use of at least three or, if trying to preserve structure symmetry, six HOM couplers. Instead a location and orientation for only one coupler was chosen to simultaneously coupling to all modes. The best combination, as shown in figure 8, was found to set the coupler at 23 degrees off the vertical axis and to orient the loop 30 degrees out of the longitudinal axis, that way having twice as much TE than TM coupling. Total power into the coupler induced by the beam is slightly above 10 Watts, with the feedback amplifier adding another 3 Watts.

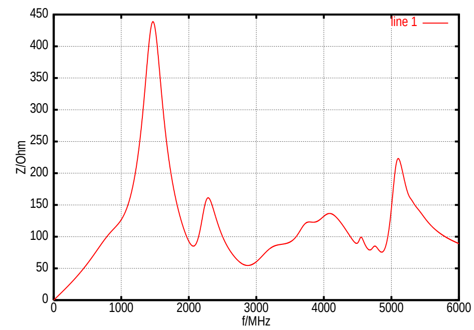

Figure 10: Longitudinal impedance with HOM coupler.

The effect of the HOM coupler on the resulting beam spectrum has been computed analog to that of the power couplers, the result is shown in figures 9 and 10. The longitudinal high Q resonance at 3.8 GHz has more or less vanished, in the horizontal dipole spectrum, the mode at 4.4 GHz vanishes, whereas the impedance at 4.7 GHz drops by a factor three. In reality, an even stronger effect can be expected, since the coupler is destroying the symmetry of the structure, leading to a small coupling of these modes to the vertical dipole spectrum, so that the low beam pipe cutoff for vertical dipole fields introduces additional damping.

4 SUMMARY

For the ELETTRA/SLS longitudinal multi-bunch feedback, a heavily loaded cavity type kicker has been designed. The shunt impedance has been improved by introducing nose cones in the cavity. The group delay between input ports and beam voltage show strong variations, which have to be corrected by an additional filter. The eight power coupler do not suffice to damp all eigen modes, so that a hybrid TE/TM type coupler has been introduced. The kicker has been built and is included in the SLS storage ring. First commissioning results are expected in the next few weeks.

5 REFERENCES

[1] D. Bulfone, V. Forchi, M. Lonza, L. Zambon, M. Dehler, ”The ELETTRA Digital Multi-Bunch Feedback Systems”, contribution THPRI035, this conference.

[2] R. Boni, A. Gallo, A. Ghigo, F. Marcellini, M. Serio, M. Zobov, “A waveguide overloaded cavity as longitudinal kicker for the DAPHNE bunch-by-bunch feedback system”, Part.Accel.52:95-113, 1996.

[3] S. Khan, T. Knoth, A. Gallo, F. Marcellini, B. Sparato, M. Zobov, “Longitudinal and transverse feedback kickers for the BESSY II storage ring”, pp. 1147, proc. of the 1999 Particle Accelerator Conference PAC, New York, USA, 1999.