HOM DAMPING IN THE DAΦNE INJECTION KICKERS

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Abstract

The maximum current per beam colliding in the Frascati Φ-Factory DAΦNE was limited by vertical multibunch instability. Investigations with the beam and measurements on the injection kicker prototypes evidenced several high order modes (HOM) trapped in the injection kickers structure, responsible for the instability. The dangerous HOM can be extracted by inserting a couple of wide bandwidth antennas in the kicker structure. The bench measurements on the modified kickers installed in the machine are reported.

1 INTRODUCTION

The operation of the Frascati Φ-Factory DAΦNE needs very high electron and positron currents stored in up to 120 bunches. During the commissioning longitudinal and transverse multibunch instabilities have been observed. The powerful longitudinal bunch by bunch feedback systems [1] are able to damp the longitudinal oscillation at the currents achieved so far (1 A for each beam). A vertical oscillation has been repeatedly observed and damped by keeping the chromaticity strongly positive (at the expence of lifetime shortening). Modal analysis and measurements of the instability threshold as a function of local orbit distortion put in evidence the beam interaction with some parasitic resonant mode trapped in the injection kicker regions. The structure has been studied with a theoretical model and computer simulations based on HFSS code [2]. Measurements on the prototype convinced us that two small antennas placed close to the coils return connections are able to damp the mode impedance to a negligible value without distortion of the kicker pulsed field.

2 INJECTION KICKER

2.1 Kicker Structure

Three fast kickers in each DAΦNE Main Ring allow single turn/single bunch injection. Each kicker is realized with four rods inside the vacuum chamber that has the same inner diameter of the rest of the straight section in order to avoid tapers and relative trapped HOM. The rods distance is compatible with the necessary stay-clear aperture. The two inner and outer rods are connected in series by two copper strips facing the vacuum chamber, as shown in Fig.1, forming two coils. The upper and lower coils are parallel connected to the vacuum feedthrough to halve the inductance presented to the power pulser [3].

The connection between the kicker inner structure, the external high voltage pulser and ground is accomplished by means of two feedthtroughs with low profile ceramic insulators.

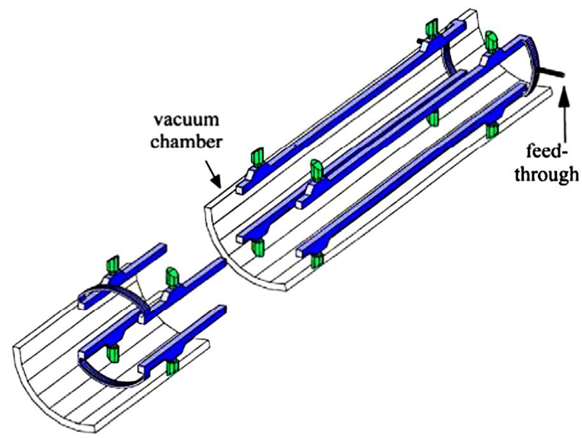

Figure 1: The injection kicker structure

A thyratron switch pulser discharges a capacitor into the kicker coils inductance. The current flowing in the kicker coils generates the pulsed magnetic field necessary to kick the bunch horizontally.

2.2 Kicker Model

A transmission line model has been adopted to study the frequency of the resonant trapped modes in the kicker. The field intensity and distribution have been determined also by computer simulation. The kicker has been considered as a multiconductor transmission line terminated on a reactive load that models the discontinuity between the coils and the vacuum chamber. By choosing a set of independent modes with the same symmetry of the kicker in the transverse plane, the study of the resonances of the complete multiconductor structure is reduced to the study of the resonances of four simple uncoupled transmission lines. The modal analysis is helpful in understanding which trapped mode interacts with the beam. In such a model no feedthrough and external connections are considered; therefore the damping due to the connections with the external device (pulser, ground connection) are not evaluated. The only loads of the multiconductor transmission line are simulated with capacitors permitting the calculation of the resonant frequencies and the distribution of voltage and current along the structure for each mode.

2.3 *Computer Simulations*

The kicker structure has been simulated with 3D-computer electromagnetic code HFSS with proper boundary conditions in order to calculate:

- the configuration of the transverse electric and magnetic fields along the structure;
- the distribution of the longitudinal component of the electric field along the structure, used for the calculation of the coupling impedance;
- the behavior of the electric or magnetic field at any section of the structure.

Figure 2 shows the portion of structure used in the HFSS simulation with the damping antenna and the exciting probe.

The frequencies and shunt resistances for the same resonances calculated with the analytical model and by computer simulations are shown in Table I.

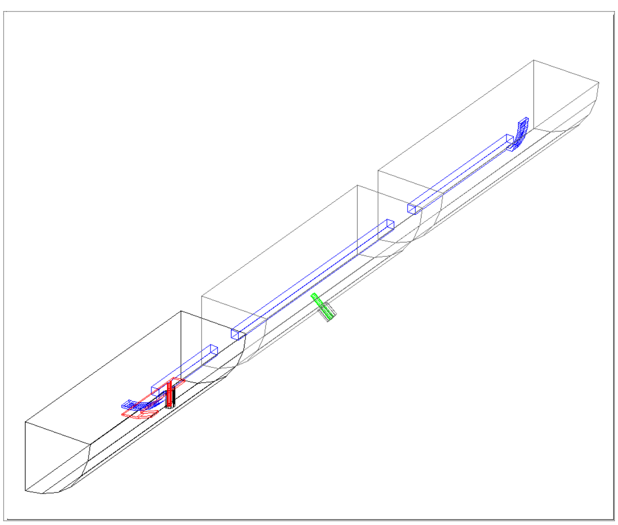

Figure 2: Kicker structure used in the HFSS simulations.

The longitudinal modes have two maxima of electric field at the end of the rods, therefore they are partially coupled and extracted by the connection between the rods and the external devices.

The horizontal modes have a maximum of electric field located at the feedthroughs side and a zero on the other side, then they are strongly damped. Viceversa, in the vertical case the maximum of electric field is in the opposite side where there are no external connection then the modes are completely trapped.

Table I: Results obtained with the transmission line model (t.l.m.) and HFSS simulation.

	freq. (t.l.m.) [MHz]	**freq. (HFSS) [MHz]**	**Q_0 (HFSS)**	**R_s [Ω]**
Longitudinal modes	861.31	838.4	2520	1171
	1005.60	979.3	3124	1459
	1440.14	1406.5	3386	1099
	1731.22	1690.6	3803	1040
	2169.73	2111.3	4611	1173
	freq. (t.l.m.) [MHz]	**freq. (HFSS) [MHz]**	**Q_0 (HFSS)**	**R_s [KΩ/m]**
Transverse modes	73.73	70.9	750	8080.0
	221.21	212.8	1670	1782.7
	368.69	355.1	1693	801.34

2.3 *HOM damping*

A damping antenna has been introduced to extract the dangerous modes trapped in the structure (see Fig. 3). It is realized by means of a strip electrically coupled with the resonant field and positioned under the connecting strips of the rods.

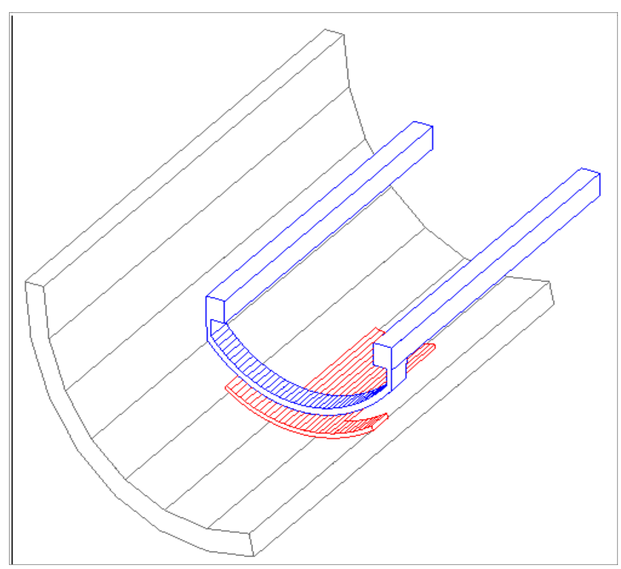

Figure 3: Kicker section in the damping antenna region.

The antenna is made of a copper plate with the same dimension and curvature of the connection strip. The antenna is connected to a 50Ω coaxial cable via a matched strip line connection. The connection strip is necessary to place the 50Ω vacuum feedthrough in a mechanically accessible point.

The antenna is a typical high pass filter because of the capacitive coupling with the field in the structure. In particular, reducing the distance between the antenna and the connection of the coil, and introducing a machined ceramic piece brazed on the antenna, the cut-off frequency shifts down, and the antenna is able to damp also the resonant modes with low resonant frequencies.

3 MEASUREMENTS

Bench measurements were performed, before the installation, on the new kicker with the antenna to verify the damping efficiency. The wire method was employed to estimate the shunt impedance of the longitudinal and transverse modes trapped in the structure. The old kicker was measured before the installation but only the longitudinal modes were taken into account. When these kickers were removed a complete set of measurements on the longitudinal and transverse plane have been performed.

Figure 4 shows the results of the impedance measurement of the longitudinal trapped modes in the damped and undamped case (comparing the impedance of the old and new kickers). Figure 5 shows the same measurements for the transverse (vertical) modes.

Before the installation the high voltage tests were performed on each kicker. A DC voltage up to 25 KV has been applied in order to test the kicker structure insulation after vacuum treatment.

A test with the power pulser has indicated that the introduction of the antennas does not perturb the shape of the kicker current pulse.

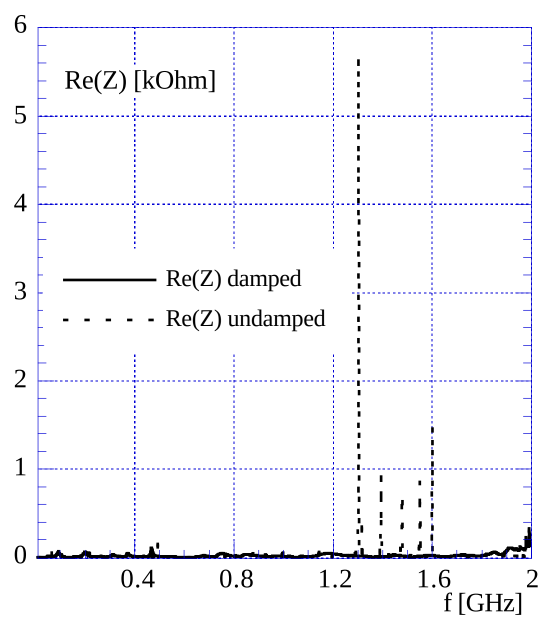

Figure 4: Longitudinal mode impedance with and without damping antenna

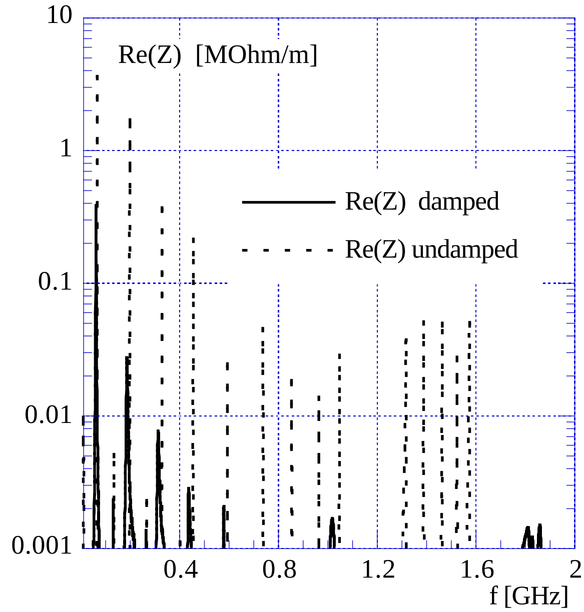

Figure 5: Vertical mode impedance with and without damping antenna

4 CONCLUSION

The bench measurements on the kickers with the damping antennas have shown that the impedances of the dangerous HOM have been reduced to a negligible value. During the machine run some observations of the instability threshold versus the beam displacement in the kicker region have shown the effectiveness of the damping antenna.

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REFERENCES

[1] D.J. Fox et al., “Programmable DSP-based multi-bunch feedback operational experience from six installations”, BIW, 8-11 May 2000, Cambridge, Massachusetts.

[2] D. Alesini, S. De Simone, A. Gallo, A. Ghigo, F. Marcellini, “DAΦNE Injection Kicker: Electromagnetic Analysis of Trapped Modes and Damping Antenna Design”, International Workshop on Performance Improvement of Electron-Positron Collider Particle Factories (e+e- Factories'99), Tsukuba, Japan, KEK Proc. 99-24, p.146.

[3] S. De Simone, A. Ghigo, “DAΦNE Accumulator Kickers”, EPAC 92 Proceedings, p. 1449, Berlin, March 1992.