TESTS AND OPERATIONAL EXPERIENCE WITH THE DAFNE STRIPLINE INJECTION KICKER

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Abstract

New injection stripline kickers are operating since December 2007 at the DAFNE collider. They are designed to operate with very short pulse generators to perturb only the injected bunch and the two stored adjacent ones at 2.7 ns and are a test for the design of the fast kickers of the damping ring (DR) of the International Linear Collider (ILC). Stripline frequency response and impedance measurements have been performed to characterize the structure and are compared to the simulation results. Operational performances are also described, pointing out the problems occured and the flexibility of the stripline structure that worked with both the short and the old pulse generators and has been used as an additional damping kicker to improve the efficiency of the horizontal multibunch feedback system.

INTRODUCTION

New kickers have been realized for the injection upgrade of the Φ-factory DAFNE. They have been conceived to operate with new fast pulse generators recently available on the market [1]. Compared to the previous devices, the new system has as main features:

a) much shorter pulse (≈12 ns instead of ≈150 ns);
b) better uniformity of the deflecting field;
c) lower beam impedance;
d) higher repetition rate (max. 50 Hz).

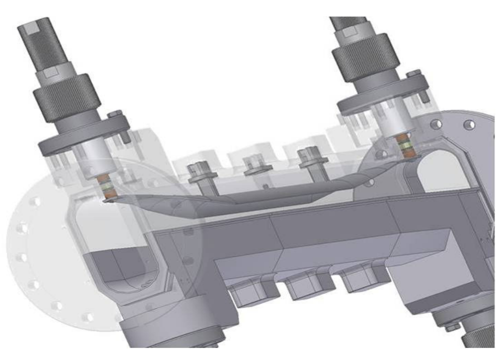

Figure 1: The two stripline kicker structure.

The kicker is basically a two stripline structure (see Fig.1), where both the striplines and the surrounding chamber have been tapered. Each transverse section has constant 50Ω impedance to match the output impedance of the high voltage pulse generator. The field flatness has been obtained with a proper choice of the ratio between the length of tapered and straight sections, while the beam impedance reduction is the result of an accurate shaping of every single kicker component[2]. From measurements presented in the following section, the structure turns out to be HOM free and the broadband impedance is 3 times lower than the previous kicker .

The new injection system at DAFNE represents also a test and a R&D activity of one of the most challenging issues of the ILC, i.e. the injection/extraction kickers for the DR [3]. ILC/DR and DAFNE kickers have common requirements: short pulse length (this minimizes the bunch distance and hence the DR circumference), good uniformity and high strength of the integrated deflecting field, and impedances of the structure as low as possible.

HV TESTS AND RF MEASUREMENTS

Before installation, the new kicker was tested and measured in laboratory: high voltage tests were performed on the kicker fully equipped with feedtroughs, cables and loads. Both the old 250ns long 25kV pulse generator, already used with the previous DAFNE kicker, and a fast 5ns - 45kV pulse generator produced by FID GmbH[1] have been tried successfully.

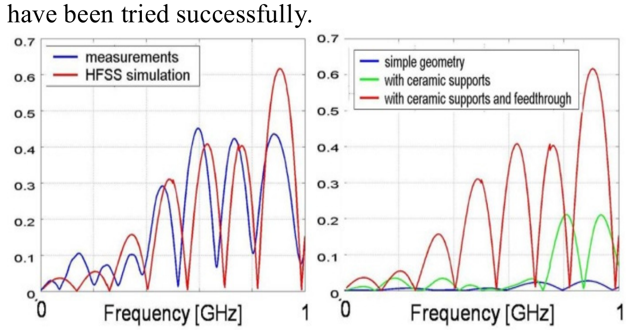

Figure 2: Reflection coefficient (S_{11}) at the input port.

The kicker frequency response has been measured as reflection coefficient (S_{11}) at the input port of the stripline. S_{11} is quite small up to ≈400MHz (the pulse frequency spectrum does not extend beyond), but increases at higher frequencies. This result is confirmed both by measurements and simulations (see the left plot in Fig. 2). The deterioration of S_{11} is mainly due to the feedthroughs contributions, as the simulations of the structure with and without feedthroughs demonstrate (see plot on the right).

The wire method technique of measurement has been used to fully characterize the kicker impedance. The longitudinal coupling impedance has been measured with several different terminations at the 4 kicker ports. Only 3 cases are reported in Fig. 3, and in particular: when 50Ω matches each port, when the 2 input ports are closed on short circuits and the output ports are on 50Ω, and when the 50Ω are replaced by the real HV load built to be used for the operation. The first of these measurements give the impedance of the stand-alone kicker, while the other two take account of mismatches introduced by connecting the pulsers (a short circuit is used to simulate the pulser in the worst possible condition). The same 3 sets of port terminations have been considered in the horizontal impedance measurements.

With dashed lines are also plotted the HFSS [4] simulations of the wire measurements. Only the case of ideal port matching was considered. The comparison shows a very nice agreement between measurements and simulations. The transverse impedance in the vertical plane was not measured because the kicker chamber is too narrow to place two wires and the related matching networks. In all the coupling impedance plots the red lines refer to the real part and the blue lines to the imaginary part of Z. Finally, the measured and simulated transfer impedances (i.e. the output voltage per beam current unit) of the input (downstream) and output (upstream) ports are reported. Also in this case the results agree quite well.

Since, above the TE_{11} frequency cut-off of the coaxial line formed by the kicker chamber and the wire(s), coaxial TE_{11n} resonances are usually measured, all the wire measurements have been limited at 2 GHz [5].

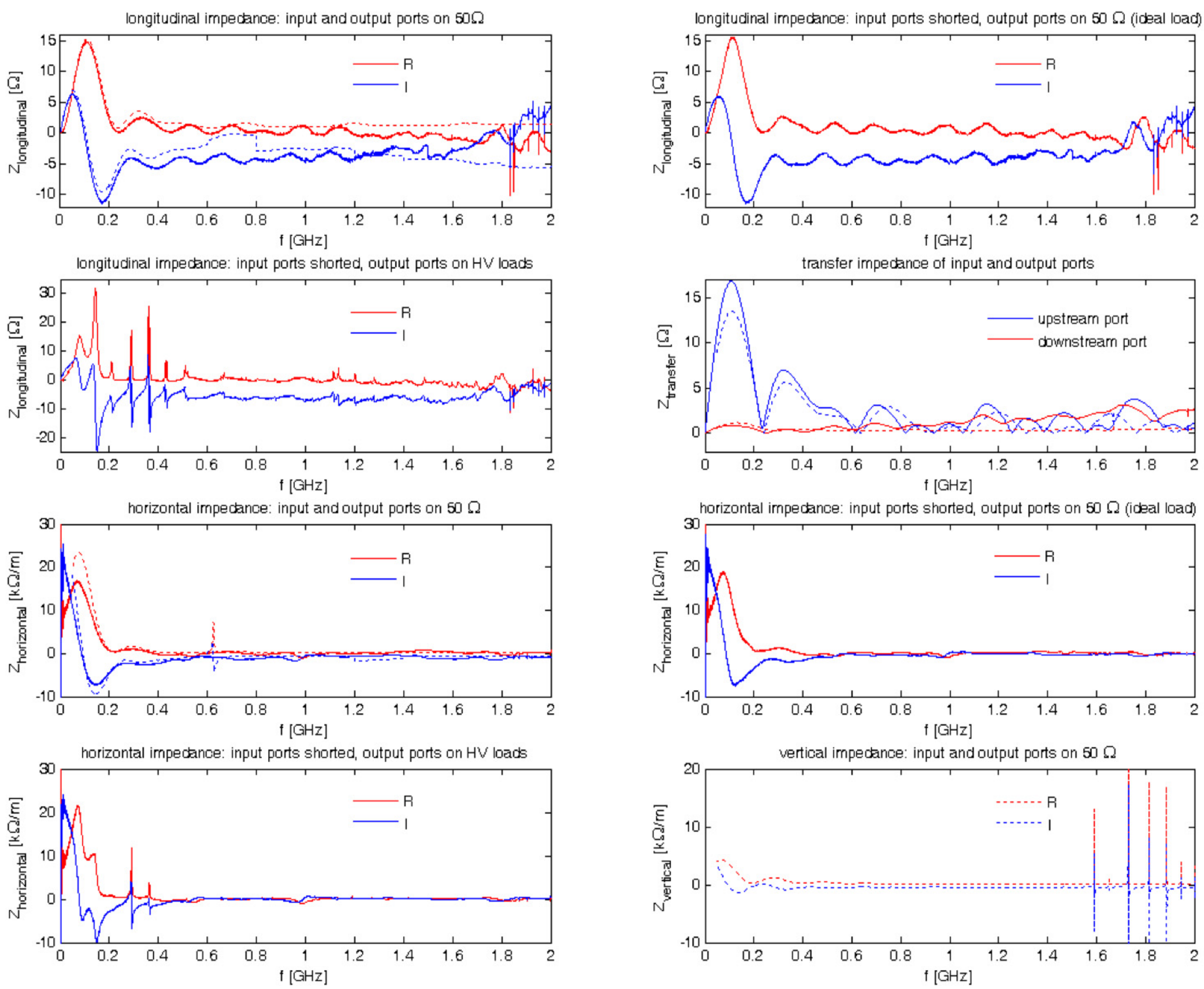

Figure 3: results of impedance measurements (solid lines) and simulations (dashed lines).

The coupling impedance measurements and simulations have pointed out the absence of trapped HOMs in the longitudinal and horizontal planes when at least 2 ports are loaded on 50Ω. Only with the input ports short circuited and the output ports terminated with HV loads some resonances have been measured. In the vertical plane 4 trapped HOMs (TE_{11n}) were found even in ideal matching conditions. All these resonances (Z_l<30Ω in longitudinal plane, Z_t<20kΩ/m in transverse planes), even in full coupling with beam spectrum lines, could give instability growth rates well below the damping rates provided by the DAΦNE feedback systems.

The transfer impedance allows the evaluation of the peak voltage and the average power induced by the beam into the kicker ports for a given beam current. The maximum induced peak voltage on the upstream (output) ports is of the order of 50 V with a 6 nC bunch while the average power induced on the ports is of the order of about ten watts with a 2A beam.

KICKER OPERATIONAL EXPERIENCE

Four new kickers have been installed since November 2007 in the DAFNE storage rings. They always worked properly and never gave problems. For great part of the operation time, they worked with the old long pulse generators in both the rings.

As a matter of fact, the new fast pulse generators has shown very poor reliability, even after repair and substitution of damaged parts with upgraded ones. For this reason we never had the possibility to use, at the same time, the four fast pulsers on the two kickers of the positron ring as scheduled for 2008.

Nevertheless, a different "hybrid" configurations was tested, where the two kinds of pulsers were used together on the same kicker, connecting each one to a different stripline. Each trace in the display snapshot of Figure 4 is the sum of the signal detected at the two stripline outputs of each kicker installed in the positron ring. The difference in length between the fast and long pulses results very clearly, while their relative amplitude is meaningless because of the different attenuations on the two channels.

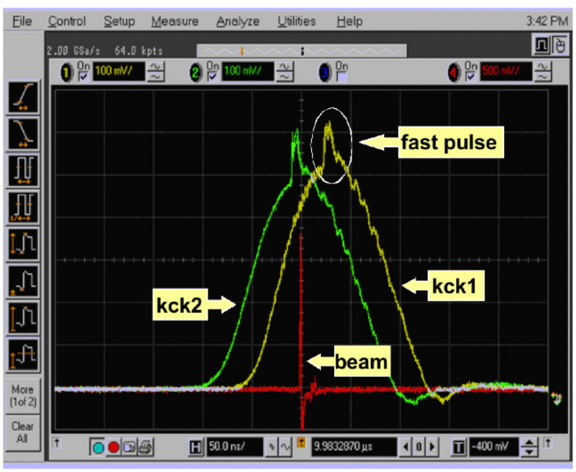

Figure 4: "Hybrid" injection: long and fast pulses, from two striplines of e+ ring kickers, observed in sum at the scope.

Tests with the hybrid configuration allowed to successfully prove the injection with this system and to measure the perturbation of the fast pulse on the stored beam.

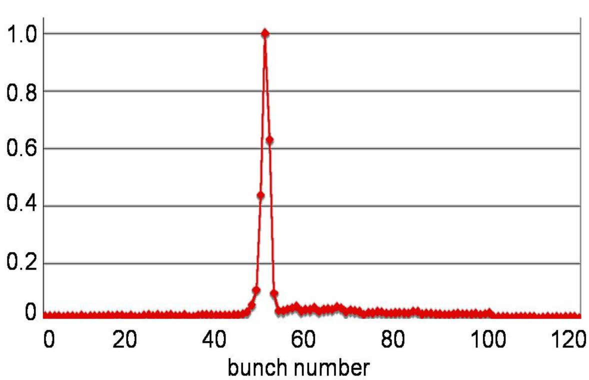

Figure 5: 100, of 120, stored bunch r.m.s. oscillation amplitude with kicker pulse centred on bunch 50.

Figure 5 is the plot, obtained with the horizontal digital feedback diagnostics, of the r.m.s. oscillation amplitude of 100 stored bunches with the kicker pulse centered on bunch 50. As expected [2] the bunches 49 and 51 takes approximately half the kick maximum amplitude, while bunches 48 and 52 are only very little perturbed.

With the aim to overcome the problems related to the fast pulser reliability, it was then decided to try a different and more compact model always fabricated by FID. It produces an output pulse having the same shape but a reduced amplitude from 45kV to 24kV. In spite of the lower kick voltage, increasing ß function in the kicker region and changing the beam orbit in the septa, the injection was possible as well. Two 24kV units were installed in the electron ring according to the hybrid scheme. Unfortunately, after a month of successfully operation, they also broke. At the moment FID is working on an upgraded version of this pulser that will be tested on DAFNE as soon as possible.

The new stripline kicker has been also used as an additional kicker for the horizontal feedback. Both the kickers of the DAFNE positron ring have, at present, one stripline connected with the old pulser for beam injection and the remaining stripline connected to the amplifiers of the feedback system. Thanks to this configuration it is possible to inject the beam and to improve the feedback performance at the same time.

CONCLUSIONS

The design of the new, fast stripline kickers for the injection upgrade of the DAΦNE Φ-factory is based on stripline tapering to obtain a low beam impedance device and an excellent uniformity of the deflecting field in the transverse plane. These characteristics are essential also for the Damping Ring of the ILC, then the experience done with the new DAFNE injection system is an R&D on the Damping Ring injection system as well.

In DAFNE the injection with the new kickers has been demonstrated, both using the old long pulse generator and a hybrid system where fast and old pulser are combined together.

The only not yet solved question concerns the reliability of the fast pulse generators. Works to substantially increase it are in progress.

REFERENCES

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