DESIGN AND TESTS OF NEW FAST KICKERS FOR THE DAΦNE COLLIDER AND THE ILC DAMPING RINGS

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Abstract

In this paper we illustrate the design of new, fast stripline kickers to inject or extract bunches in electron/positron rings. The kickers have been designed for the injection upgrade of the Φ-factory DAΦNE and as injection/extraction devices for the International Linear Collider (ILC) damping rings. The design is based on tapering the striplines in order to simultaneously obtain low impedance and an excellent uniformity of the deflecting field. The design has been done using 2D and 3D electromagnetic codes such as Superfish and HFSS. High voltage test results on prototypes are also shown.

INTRODUCTION

The injection system is one of the challenging issues of the International Linear Collider (ILC) project [1] and the injection and extraction kickers are one of the most critical issues for the ILC Damping Rings (DR) [2]. In fact the bunch distance in the ring and therefore the choice of the ring circumference are related to the kicker pulse duration; moreover the stability of the beam position at the IP depends also on the kicker pulse stability. R&D programs are in progress in different laboratories at a global level both on the fast pulsers and on the stripline electrodes. The injection and extraction kickers for the positron DR, which has a minimum bunch distance of 6.2 ns, should satisfy the following requirements:

a) ultra short rise and fall time (total pulse duration <12.4 ns);
b) high integrated strength;
c) good uniformity of the deflecting field, within few percent over 90% of the beam stay clear;
d) impedances of the structure as low as possible;
e) 3 MHz repetition rate.

There is a similarity between the ILC injected beam and kicker parameters and the DAΦNE ones, as shown in Table 1. Therefore stripline kickers studied for the ILC damping ring can be used for an upgrade of the DAΦNE injection system. The installation of these new kickers at DAΦNE is an important test for the ILC project, since it should demonstrate with beam measurements the achievement of the kicker performances. These kickers could also be used, in the framework of the ILC collaboration, to test new fast pulsers produced by different laboratories or industry. Compared to the present DAΦNE injection kickers [3] the new ones have:

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

The much shorter pulse allows perturbing only the injected bunch and the two adjacent ones while, at present, a large fraction of the stored bunches (50/110 with 2.7 ns bunch spacing) are affected by the injection kick. This improvement can increase the current threshold of the transverse instability in the positron ring (as it has already been observed experimentally at DAΦNE).

The better uniformity of the deflecting field can increase the injection efficiency at high currents and reduce the background to experiments during injection.

The broadband impedance, according to the calculations, is reduced by a factor 3 with respect to the present kickers. Moreover, since the new kickers have been designed with the same beam pipe cross section of the dipoles, no taper transition are needed between the dipoles and the kicker and this also contributes to the reduction of the machine impedance.

Finally, the possibility of injection at 50 Hz can be useful for future upgrades of the whole injection system.

Table 1: Kicker and beam parameters for ILC DR (*) and DAΦNE.

	ILC DR	DAΦNE
Energy [GeV]	5	0.51
Bunches time spacing [ns]	6.2	2.7
Bunch length [mm]	6	35
Deflection [mrad]	0.7	5
Total defl. voltage [MV]	3.5	2.5
Kicker length [cm]	87	73
Input pulse length [ns]	5.9	5.3
Horizonthal beam stay clear @ kicker (diameter) [mm]	50	50

KICKER DESIGN

A detailed discussion on the kicker design criteria is reported in [4]. The design of the new kickers is based on the idea to properly taper the striplines. The kicker structure is shown in Fig. 1a. Each transverse section has constant 50Ω impedance equal to the output impedance of the high voltage pulse generator. The tapered striplines allow to:

a) reduce the broadband beam coupling impedance of the device;
b) improve the deflecting field quality obtaining a uniform transverse deflection as a function of the transverse coordinate (horizontal in particular);

* Referred to the positron ring with horizontal β-function at the kicker equal to 70 m.

c) obtain a better matching between the generator and the kicker structure at high frequency[†];
d) reduce the beam transfer impedance;
e) have a uniform beam pipe cross section between the dipole region (that has a rectangular cross section) and the kickers region.

Concerning the uniformity of the deflecting field as a function of the transverse coordinates, it should be pointed out that, for a given transverse section of the kicker, the behaviour of the deflecting field depends on the coverage angle. The length of the tapers with respect to the straight section and the internal dimensions of the structure have been optimized using the electromagnetic codes Superfish [5] and HFSS [6] to obtain a uniform integrated deflecting field along the horizontal coordinate. The deflecting field as a function of the horizontal and vertical coordinates is shown in Fig. 2.

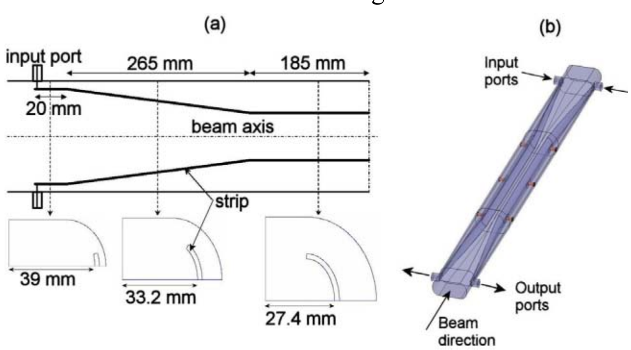

Figure 1: Sketch of the half kicker and HFSS 3D model.

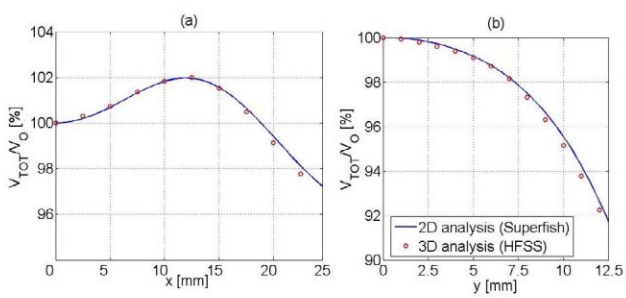

Figure 2: Deflecting field as a function of the horizontal (x) and vertical (y) coordinates.

Better matching between the pulse generator and the kicker structure is assured by reducing the stripline section and placing it very close to the kicker vacuum chamber in the coaxial-stripline transition region. This reduces the longitudinal and transfer impedance of the device also [7].

With a signal of the type sketched in Fig. 3a, which reproduces schematically the input signal from the pulser that we intend to use, the total deflecting field as a function of time is shown in Fig. 3b and the required voltage per strip to reach the desired bunch deflection is ~45kV. As the figure shows the two bunches that are 5.4ns away from the injected one, receive a small kick.

[†] This can avoid multiple reflections of the deflecting pulse in the kicker structure that can perturb the stored bunches especially in the ILC case. Moreover it can allow extracting all the power release to the HOM of the structure by the beam.

The kicker design can be applied, with minor modifications, to the ILC positron damping ring. Assuming a 3 MHz and 5 kV input pulse per strip, the total required number of kicker is ~12.

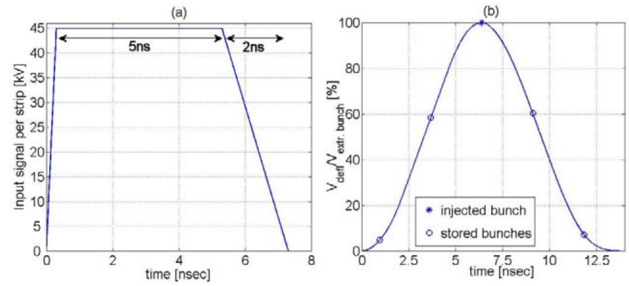

Figure 3: (a) Input pulse signal and total deflecting field (b).

With the code HFSS we have also calculated the longitudinal and transverse beam coupling impedances of the structure and the beam transfer impedance (using the wire method technique [8]). Figures 4a and 4b show, as an example, the calculated longitudinal coupling impedance and the transfer one. From the transfer impedance it is possible to evaluate the peak voltage into the ports and the average power for a given beam current. The maximum induced peak voltage on the upstream port is of the order of 100 V with a 6 nC bunch while the average power induced on the ports is of the order of few tens of Watts with a 2 A beam. No longitudinal and horizontal HOMs are trapped in the structure and the longitudinal loss factor is ~$5 \cdot 10^{-3}$ V/pC for 1 cm bunch length. Concerning the vertical impedance there are four trapped HOM (TE_{11n}-like) with vertical impedance of the order of few tens of kV per meter. These give, in the worst case, growth rates of the order of 1 ms^{-1} at a total current of 2A that are about two orders of magnitude lower than the damping rates provided by the DAΦNE vertical feedback system.

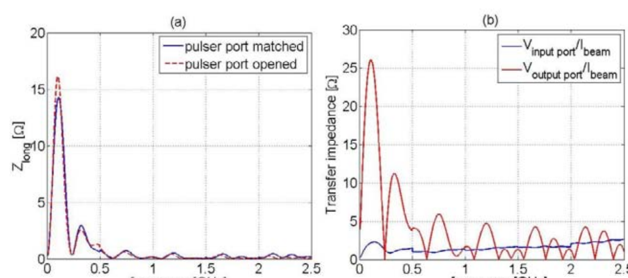

Figure 4: (a) Longitudinal beam coupling impedance and beam transfer impedance (b) calculated by HFSS.

HIGH VOLTAGE TESTS

The mechanical drawing of the kicker is shown in Fig. 5. Since for DAΦNE 45 kV are applied to each strip of the kicker, high voltage (HV) tests on prototypes are necessary to verify if there are discharges on vacuum feedtroughs, connectors or between the strip and the vacuum chamber. To this purpose a small prototype of the kicker has been constructed and is shown in Fig. 6. The device has a uniform strip with a cross section exactly equal to the cross section of the first part of the kicker (where the strip has the minimum distance from the outer chamber and therefore the electric field is higher). The strip is connected to the high voltage pulse generator through vacuum feedtrough of the type that we intend to use in the final structure. First high voltage tests have been performed using a 24 kV 7ns pulse generator courtesy of Fid GmbH Company [9].

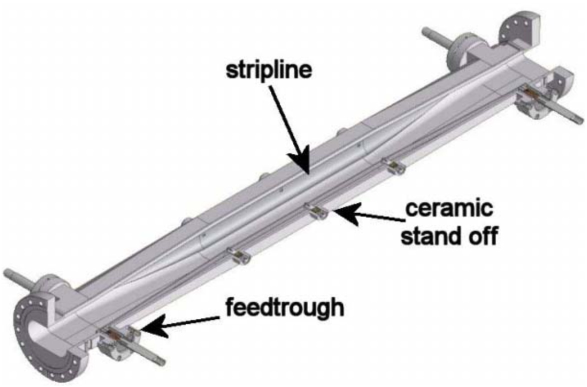

Figure 5: Mechanical drawing of the kicker.

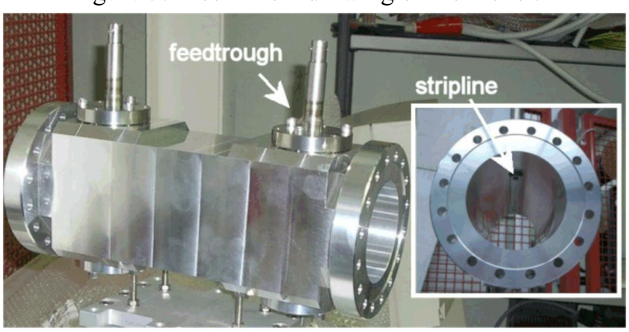

Figure 6: Prototype of the kicker for HV tests.

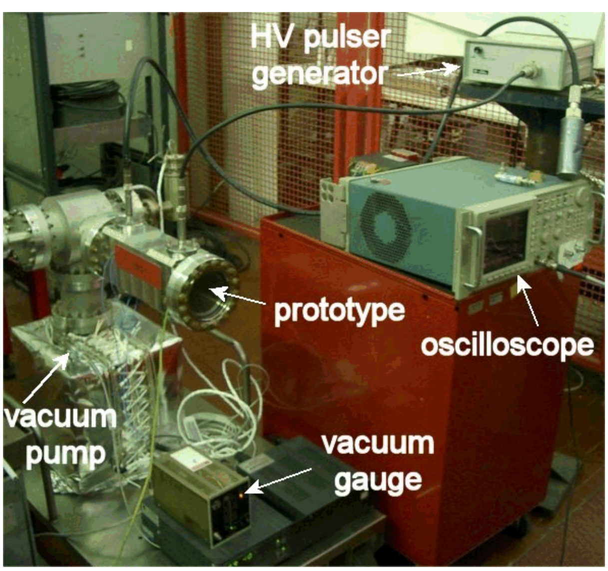

Figure 7: Setup for HV test on prototype.

The prototype test setup is shown in Fig 7. The pulses measured with an oscilloscope at the pulse generator output and at the stripline output are shown in Fig. 8. The difference between the two results is given by the frequency response of cables that we have used. No discharges have been registered.

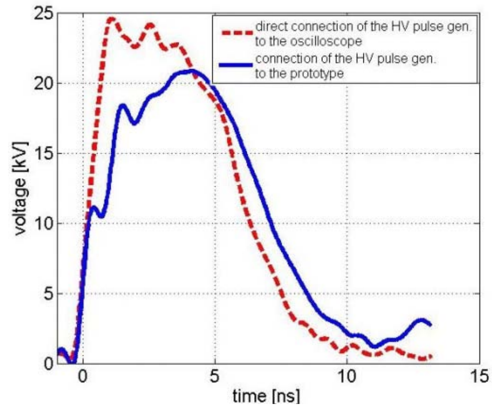

Figure 8: HV pulse measured with an oscilloscope directly connected to the pulse generator and after the prototype.

CONCLUSIONS

We illustrated the design of new, fast stripline kickers to inject or extract bunches in electron/positron rings. The kickers have been designed for the injection upgrade of the Φ-factory DAΦNE and as injection/extraction devices for the International Linear Collider (ILC) damping rings. The design is based on tapering the striplines in order to simultaneously obtain low impedance and an excellent uniformity of the deflecting field. The uniformity of the deflecting field as a function of the horizontal coordinate is of the order of $\pm 2\%$ over the kicker horizontal aperture (± 2.7 cm) while it is less than 10 % over ± 1 cm along the vertical one. The required voltage per strip in the DAΦNE case is ≅45 kV while, in the ILC case, assuming a 3 MHz and 5 kV input pulse per strip, the total required number of kickers is ~12. HV tests on a prototype have been successfully done with a 7 ns 24 kV pulse generator.

ACKNOWLEDGEMENTS

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REFERENCES

[1] S. Guiducci, PAC05, Knoxville, (USA), May 2005.
[2] A. Wolski, et al., LBNL–59449, 2006.
[3] S. De Simone and A. Ghigo, EPAC92, Berlin, 1992.
[4] D. Alesini, et al, DAΦNE tech. note I-17, EUROTeV-Report-2006-025, 2006.
[5] J. H. Billen and L. M. Young, Part. Acc. 7, 1976.
[6] www.ansoft .com.
[7] D.A. Goldberg and G.R. Lambertson, LBL-31664 ESG-160, 1992.
[8] F. Caspers, in Handbook of Accelerator Physics and Engineering, World Scientific, 1999.
[9] http://www.fidtechnology.com