AN OVER-DAMPED CAVITY LONGITUDINAL KICKER FOR THE PEP-II LER*

P. McIntosh, R. Akre, D. Anderson, S. DeBarger, M. Dormiani, J. Fox, K. Jobe, H. Schwarz, D. Teytelman, U. Wienands, A. Young, SLAC, Stanford, CA 94025, USA. F. Marcellini, INFN-Frascati, Italy. M. Tobiyama, KEK, Japan

Abstract

Both rings of PEP-II use drift tube kickers in the longitudinal bunch-by-bunch feedback system. Efforts are now underway to increase the stored beam currents and luminosity of PEP-II, and beam-induced heating of these structures, particularly in the Low Energy Ring (LER) is of concern. An alternative kicker design based on the over-damped cavity kicker, first developed by INFN-Frascati is being built for PEP-II. This low loaded Q (or wide bandwidth) structure is fed by a network of ridged waveguides coupled to a simple pill-box cavity. Beam induced RF power is also coupled out of the cavity to external loads, so that the higher order modes (HOMs) excited in the structure are well-damped. This paper details the kicker design for PEP-II and discusses some of the design trade-offs between shunt impedance and bandwidth, as well as the influence of the feedthroughs on the kicker parameters. Estimates of the expected power deposition in the cavity are also provided.

INTRODUCTION

The longitudinal bunch-by-bunch feedback systems at PEP-II use wide-band drift-tube kickers [1] that have performed very well at beam currents up to 1.9 A and 6.3 ns bunch spacing and roughly 1000 bunches in the LER. However, with plans to substantially increase the beam currents, with bunch currents much higher than originally anticipated, the thermal stresses in these kickers will become quite high. The drift tube kickers are difficult to cool since the drift-tubes are supported only by rather thin electrodes. In order to prevent these kickers from becoming a beam current limit we are building new feedback kickers based on the successful design of an over-damped cavity developed at INFN-Frascati [2] and used elsewhere [3][4] to replace the existing feedback kickers in the LER. The new structure is easily cooled from the outside and expected to more than double the current capability of the LER kickers.

THE NEW LFB CAVITY KICKER DESIGN

The bandwidth requirement for the new kicker derives from the spectrum of modes in the beam. At PEP-II, every 2nd RF bucket can be filled, the bandwidth required to perform efficient damping is then equal to $f_{RF}/4$, or 119 MHz. A bandwidth of ~ $f_{RF}/2$ or 238 MHz has been chosen to provide more linearity over its operating band. The cavity fundamental TM_{010} mode therefore has to be very broadband with a low loaded Q, which is contrary to traditional RF cavity design requirements. A simple pill-box cavity is employed, strongly coupled to which are four large waveguides (see Figure 1) which are terminated externally to 50 Ω, reducing the Q to give a $Q_L \sim 5$.

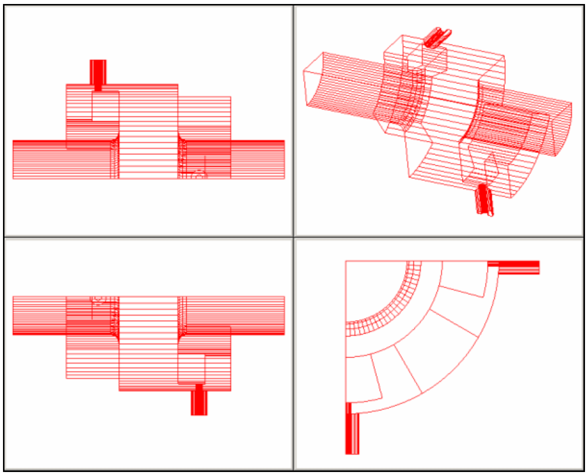

Figure 1 HFSS Longitudinal Feedback Kicker Geometry

The frequency chosen for the new kicker is 9/4 f_{RF} or 1.071 GHz as this gives the highest shunt impedance solution of the options available (13/4 and 9/4 f_{RF}) [5]. The existing longitudinal feedback system also operates at 1.071 GHz and has enough power to drive the new kickers, so infrastructure modifications are minimal. The HOM spectrum of the kicker is shown in Table 1 and the fundamental mode shunt impedance is ~ 1.5 times as much as the drift-tube kicker so that some voltage kick increase is expected from the same amplifier power. The TM_{01} mode cut-off frequency of the 89 mm beam pipe is 2.6 GHz and modes above that are highly damped as confirmed by MAFIA simulations.

Table 1 Kicker Fundamental and HOM Characteristics

Mode	Freq (GHz)	Q_L	BW (MHz)	R_s (Ω)
TM_{010}	1.071	4.8	224	626
TM_{110}	1.5151	22	69	16.7 k
TE_{111}	1.7114	210	8	19.2 k
TM_{011}	2.0507	13	157	65
TM_{020}	2.4117	116	21	76

The new kicker cavity has been developed using the Ansoft finite element, electro-magnetic solver – HFSS [6]. A bandwidth response of 224 MHz, centered at 1.071 GHz (see Figure 2), has been achieved by optimization of the waveguide profile and coupling transitions.

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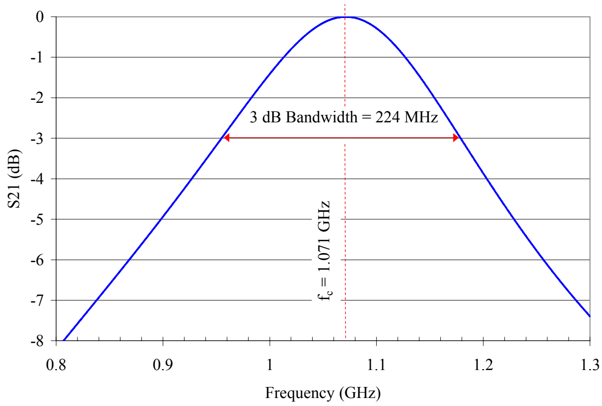

Figure 2 Transmission Frequency Response of Kicker

The kicker structure (see Figure 3) is being fabricated from OFHC copper for efficient cooling and to avoid multipactor problems that can arise in aluminium structures without Titanium Nitride coating.

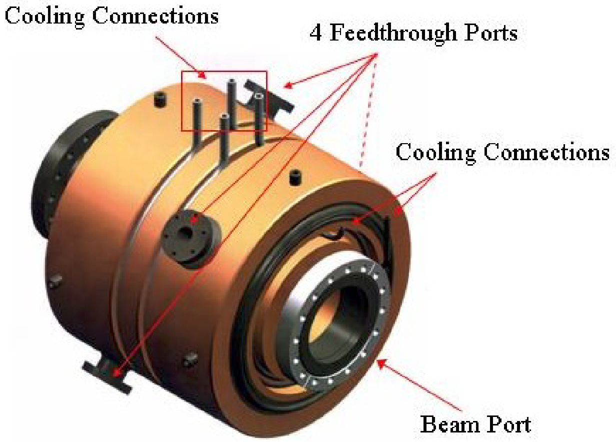

Figure 3 New Kicker Mechanical Assembly

KICKER BEAM INDUCED POWER

Both the existing drift-tube and cavity kickers present impedances that absorb power from the circulating beam. The center frequencies of both designs are selected to minimize the impedance at multiples of the RF frequency for which there are very strong harmonic content in the circulating current. However, due to gaps in the filling patterns and unequal charges in the stored buckets, there is significant power deposited by the beam in both structures. As seen in figures 4 and 5, the 3A nominal fill in the LER would deposit roughly 14 kW in the cavity kicker and 12 kW in the drift-tube kicker.

One important difference between the structures is seen in the periodic impedance of the drift tube, which absorbs power from the beam at high frequencies as well as in the operating band. The drift-tube structure has a finite directivity in the 1 - 2 GHz band, so that the bulk of the power in this band is coupled out of only two load ports. Therefore the power to the drift tube load ports is higher, by almost a factor of 2, than in each of the 4 symmetric ports on the cavity kicker.

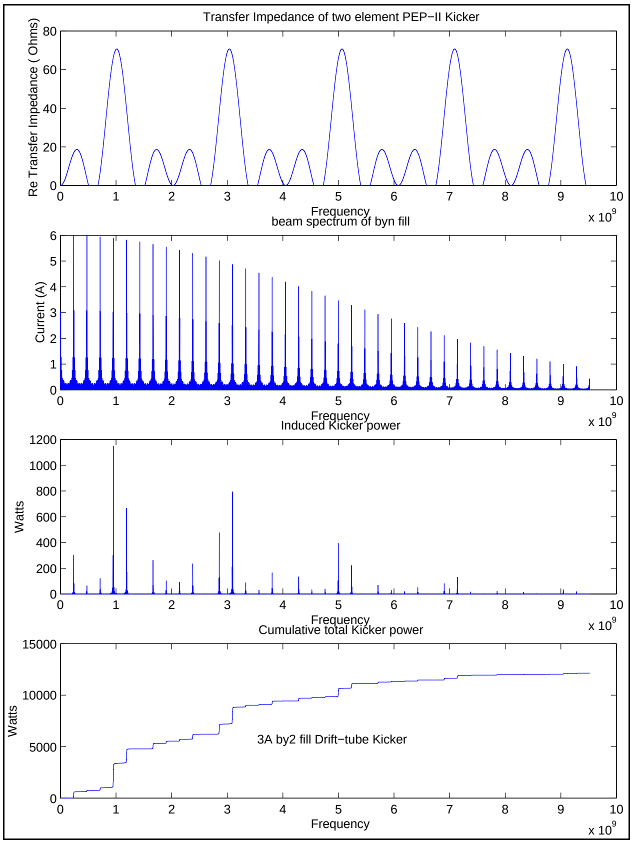

Figure 4 Beam Induced Power for Existing Drift-tube Kicker

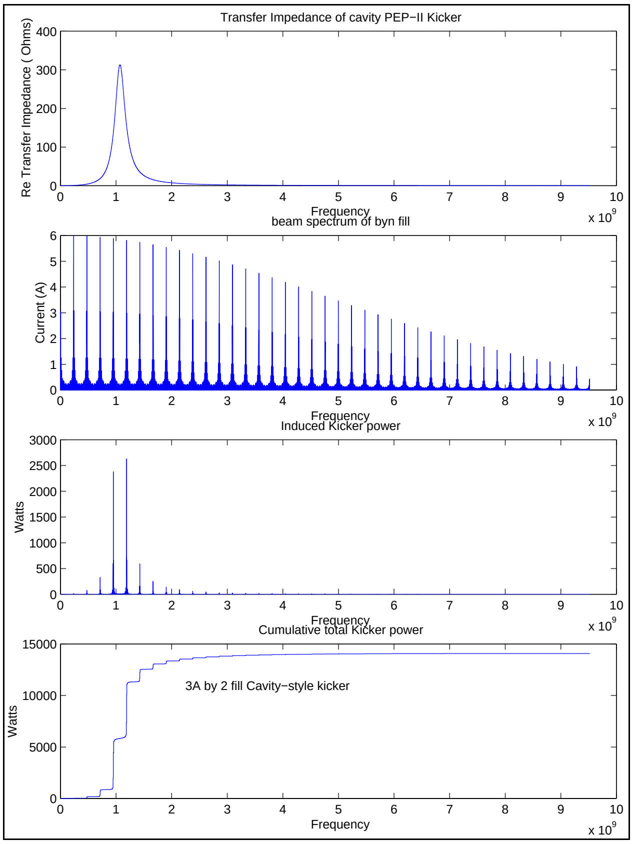

Figure 5 Beam Induced Power for New Cavity Kicker

On the other hand, the cavity kicker requires the installation of high power circulators between power amplifier and kicker. The most important advantage of the cavity kicker is thermal management, as it has no internal structure, and the cavity itself can be water-cooled on surfaces outside the vacuum chamber.

A NEW RF FEEDTHROUGH

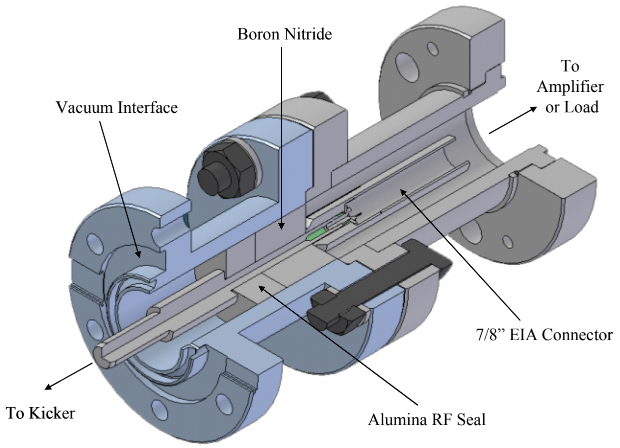

Figure 6 The New High Power RF Feedthrough Design

Each feedthrough has to be able to handle at least ¼ of the total beam induced power (plus ~¼ of the amplifier power). To have some safety margin in the power handling capability and allow beam current increases to 4.5 A in the future, a new high power RF feedthrough has been developed at SLAC. The design may also be an attractive solution for other high power feedthrough applications. The feedthrough is being built by industry (see Figure 6) and is specified to handle 10 kW at 1 GHz, although we expect some leakage of frequencies up to 8 GHz due to excitation of HOMs.

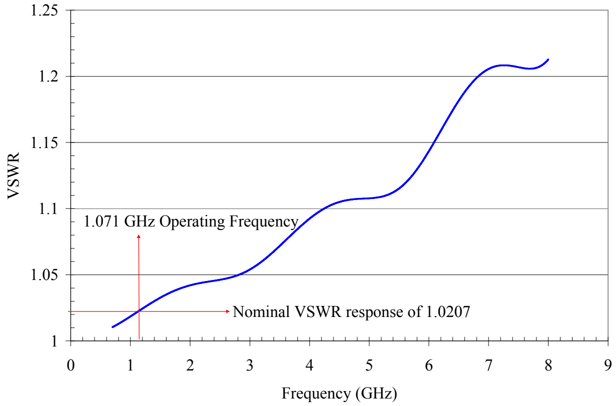

Figure 7 HFSS RF Feedthrough Frequency Response

HFSS has again been utilized to optimize the feedthrough to have a good VSWR response over a wide bandwidth, extending up to 8 GHz (see Figure 7). The new feedthrough comprises a 7/8" EIA interface and incorporates an alumina ceramic vacuum seal; it also has a boron nitride ceramic which is used to dissipate some of the thermal energy generated in the inner coax. There are optimized impedance transformations at either side of the ceramics which control the VSWR response up to this high frequency. The output coax then has a smooth 50 Ω impedance transition to the cavity kicker.

Attaching the feedthroughs to the cavity kicker has the effect of perturbing the fundamental mode bandwidth. The magnitude of the perturbation is intrinsically related to the mismatch the feedthrough presents. Experience at both DAΦNE and KEK, who also use this type of cavity kicker and feedthrough configuration, albeit with different operating characteristics, has shown that the operational bandwidth perturbation can be as much as 20% [7][8]. With this in mind, by having a low VSWR at its fundamental operating frequency, HFSS simulations predict that when attached to the new kicker, the induced perturbation from this new feedthrough is only ~5% (see Table 2).

Table 2 TM_{010} Mode Perturbation Due to Feedthroughs

TM_{010}	Freq (GHz)	Q_L	BW (MHz)	R_s (Ω)
w/o f/thru	1.071	4.8	224	626
with f/thru	1.071	4.6	235	620

CONCLUSIONS

This collaboration has developed a new 4-port longitudinal feedback kicker which should not limit the LER operation on PEP-II up to 4.5 A. The increased shunt impedance of the structure enables a larger voltage kick to be applied to the bunch than with the present drift-tube kicker, for the same amplifier power. Operation of the LER at 4.5 A will generate more beam-induced power which is extracted from the structure through the RF feedthroughs. A new high-power feedthrough design will be able to fulfill this requirement. Two kicker cavities are currently being manufactured at SLAC and the associated feedthroughs manufactured by industry, for installation on the PEP-II LER this summer.

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[7] Private communication M. Tobiyama, KEK.
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