DESIGN OF A BROADBAND KICKER CAVITY FOR THE TLS LONGITUDINAL FEEDBACK SYSTEM

W.K. Lau, T.T. Yang, M.S. Yeh, SRRC, Hsinchu, Taiwan

Abstract

The broadband kicker cavity has been re-designed for the TLS longitudinal feedback system for higher efficiency of rf power usage. In order to meet the constraint in kicker length imposed by the available room for installation in the storage ring, it employs a simple pillbox cavity loaded with many coaxial magnetic field couplers for broader bandwidth and symmetrical excitation. Design of this new kicker cavity and results a test of such coupling scheme in a pillbox cavity are presented.

1 INTRODUCTION

A longitudinal feedback system has been built for the TLS storage ring for 200 mA operation [1]. The system, especially the digital signal processing electronics, has been tested and characterized. A four taps FIR digital filter that provides significant gain and 90º phase shift at synchrotron frequency has been implemented. As expectation, it shows good rejections to DC offset and harmonics of revolution frequency of the raw bunch phase error signal. Damping and anti-damping of a single bunch beam has been successful. However, for a multi-bunch beam, the feedback system works only for beam current below 80 mA. The relatively low efficiency longitudinal kicker [2] is also a suspect for the inability of the LFB system to damp bunch phase oscillations at higher beam intensity. Therefore, a new longitudinal kicker is being constructed for the generation of higher feedback voltage.

2 DESIGN CONSIDERATIONS

Based on the system requirements and data for the existing designs, expected performance of the kicker cavity is listed in Table 1.

Table 1: Expected performance of the new TLS longitudinal kicker

Center Frequency [MHz]	1125
Bandwidth [MHz]	250
Shunt impedance [Ω]	860
Loaded Q	4
Damping time [nsec]	1.25
Number of input ports	4
Available rf power[W]	250
Max. voltage [V]	1312

In the 120 meters TLS storage ring that has many components, available room is a main limitation of kicker design. Also, a longitudinal kicker with simple mechanical structure is highly desirable.

2.1 R/Q versus Cavity Length

The center frequency was set at about 1125 MHz. To allow damping for all of the 200 coupled-bunch dipole modes in the TLS storage ring, the bandwidth of the kicker is set at 250 MHz. Since the shunt impedance and unloaded quality factor of an ideal pillbox has analytical expressions, a coarse estimate of dimensions of the kicker cavity can be done. At fixed pillbox cavity radius, it is well known that the transit time factor decreases with cavity height d, while the shunt impedance (without transit time correction) and unloaded Q increases with d. Therefore, there exists a maximum value of R/Q at certain cavity height (Figure 1). In our case, for a pillbox cavity with radius at 11.27 cm, the maximum value of R/Q is at a height of 11 cm. However, due to the physical constraint and higher order mode distribution, one may not be able to use this optimum value and some tradeoff has to be done.

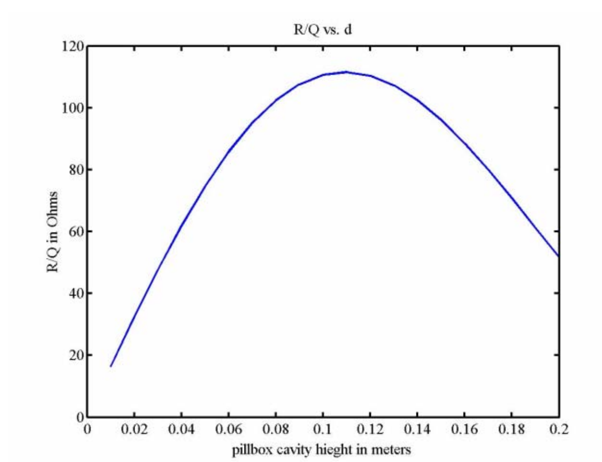

Figure 1: The calculated R/Q versus cavity height d.

2.2 Magnetic Field Coupling

Radio frequency power will be fed into the kicker cavity via coaxial transmission lines at one of the end wall (Figure 2) to excite TM_{010} mode. The rf current of the coaxial transmission line flowing on the cavity sidewall along the direction of the traversing beam will induce a magnetic field that matches the magnetic field of TM_{010} mode in the pillbox cavity. However, due to the high cavity impedance, rf power will in general be reflected back to the generator. In order to couple rf power into the cavity such that the maximum of the transmission current wave is located near the half height of the cavity, some impedance matching circuit is required. There are several ways to implement this matching circuit. One simple way is to bridge the coaxial transmission line with a stub tuner at half wavelength from the cavity center. Other side of the cavity can be terminated with an rf absorber.

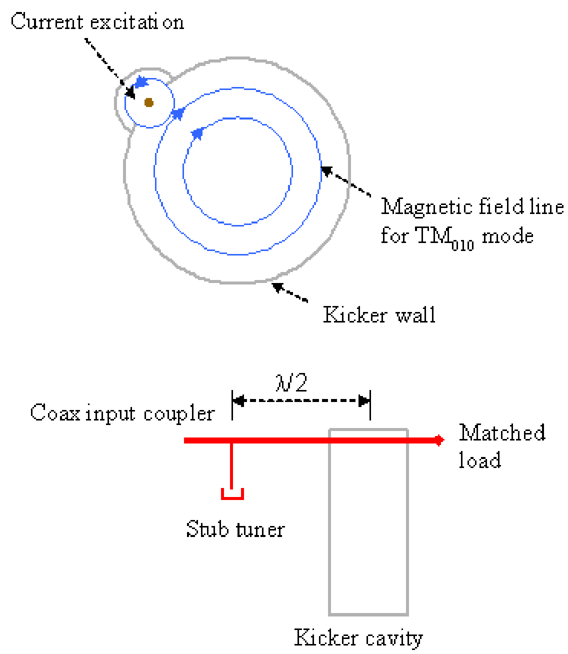

Figure 2: An illustration of the magnetic field coupling scheme for the kicker cavity.

2.3 Symmetric Excitation

To excite a TM_{010} mode symmetrically to avoid a field gradient across the cavity, more input couplers can be employed. For broader bandwidth, one could add more couplers of the same type (without a stub tuner) and load them with rf absorbers at both ends.

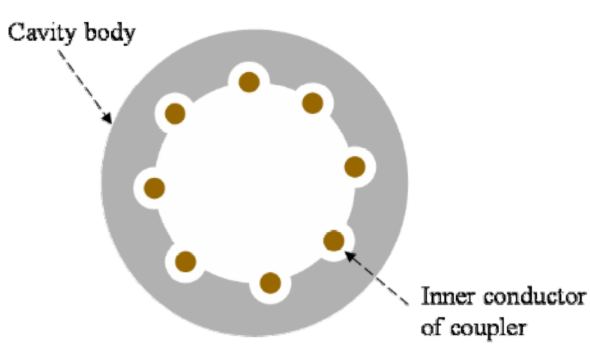

Figure 3: Cross section view of a kicker cavity with eight couplers.

Figure 3 shows a conceptual drawing (cross section view) of a kicker cavity with eight coupler structures. Four of them are input couplers that each one has matching circuit at the end which is connected to the power sources and the other end terminated by a dummy load. The other four couplers are loaded with rf absorbers at both ends. A prototype of such structure is being fabricated.

3 TEST OF THE COUPLING SCHEME

A pillbox cavity with one coupler has been built to check the magnetic field coupling scheme as described in section 2.2. With an excitation electric probe, six cavity resonant modes can be observed from the signal picked up by the coupling circuit up to 3 GHz (Figure 4). Fundamental mode has been found to be at 1.056 GHz.

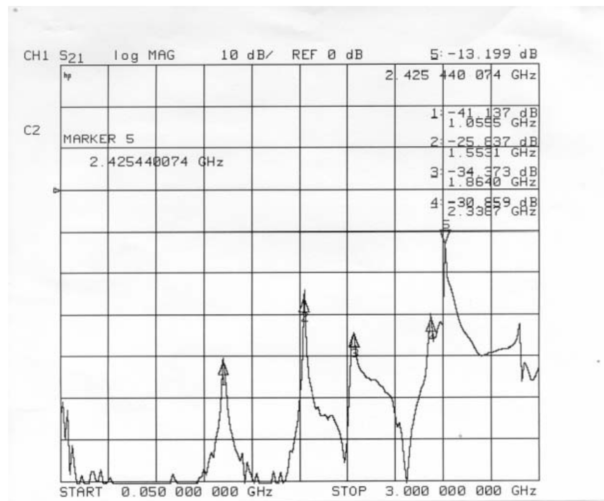

Figure 4: Cavity resonant modes as observed from signal picked up by the coupler

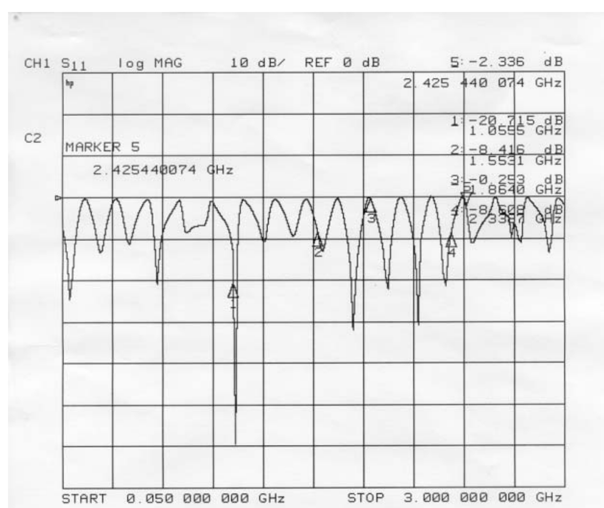

Figure 5: Return loss measured at the one end of the input coupler with properly adjusted matching stub

By putting a properly adjusted stub tuner at ~λ/2 away from the cavity center, strong resonance can be observed at the resonant frequencies corresponds to the previously observed fundamental mode (Figure 5). One can see that excitation of modes other than the fundamental is less effective by using this coupling scheme.

4 SOME CALCULATION RESULTS

Simulations are being done to optimize cavity dimensions for higher shunt impedance and better HOM characteristics. The effectiveness of using magnetic coupling scheme as discussed above will also studied with HFSS simulations. Some preliminary results for cavity dimensions as depicted in figure 6 show acceptable predictions of resonant frequency and unloaded quality factor of fundamental mode. i.e. f_{010} = 1.066 GHz and Q_0 = 3125 for a stainless steel cavity with conductivity at 1.1×10^5 S/m.

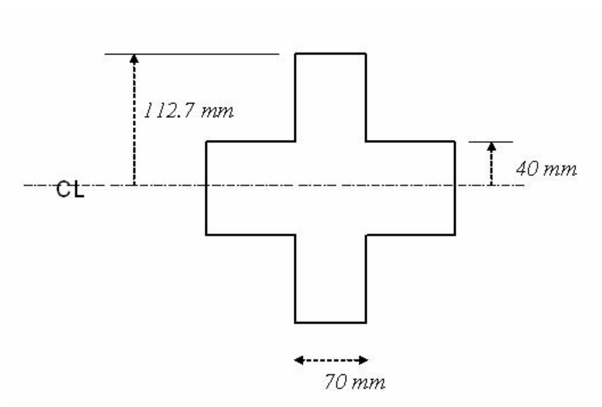

Figure 6: Dimensions of the kicker cavity for preliminary calculations

Resonant frequencies of several higher order modes have been calculated and in good agreement with the observed results in Figure 4.

5 TRANSMISSION SYSTEM LAYOUT

The rf transmission system should be a low loss and broad bandwidth circuit to allow fast amplitude switching of rf power at 2 nanoseconds. It should also allow symmetrical excitation of the longitudinal kicker for higher efficiency and provide good isolation between the power amplifier and the longitudinal kicker at each port. Figure 4 is a schematic layout of the rf transmission system for the longitudinal kicker. Output of the 250 MHz broadband power amplifier is split into two channels at 90 degrees phase difference. Each channel is further split into another two. As a result, the power amplifier output is split into four channels. For symmetrical excitation of longitudinal kicker, each channel has to be adjusted to have the same electrical delay by trimming the length of each low loss feeder transmission line that connect to feeder and the kicker. Most of reverse power from the kicker cavity will be absorbed by the 50 Ω rf loads at each of the hybrids.

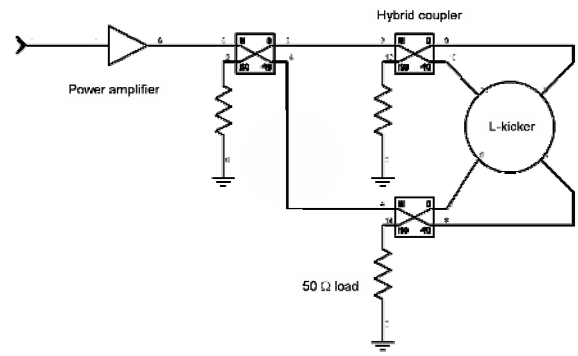

Figure 7: Schematic layout of the rf transmission system for the longitudinal kicker.

6 CONCLUSION AND DISCUSSION

A new design of broadband kicker cavity for longitudinal feedback system is under studied. A magnetic field coupling scheme has been proposed to excite the fundamental mode. This coupling scheme has been tested in a simple pillbox cavity. A prototype with four input couplers and four dummy couplers are under fabrication. The transmission circuit has also been re-designed for excitation of this new kicker. Further study will includes optimization of kicker cavity dimensions for higher shunt impedance, verification of the coupler by HFSS calculations and shunt impedance measurement of the multi-coupler prototype kicker etc.

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7 REFERENCES

[1] W.K. Lau et al., “Preliminary Beam Test Results of the TLS Longitudinal Damper with High Performance DSP Modules,” EPAC’2000, Vienna, June 2000.
[2] L.H. Chang et al., “Development of the RF Kicker for the Longitudinal Feedback System at SRRC,” EPAC’98, June 1998.