A NEW KICKER FOR THE TLS LONGITUDINAL FEEDBACK SYSTEM

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Abstract

A new longitudinal kicker will be installed into the Taiwan Light Source (TLS) storage ring in the near future. This kicker is part of the new bunch-by-bunch longitudinal feedback system for stabilization of beam dipole-mode longitudinal coupled-bunch instability in the ring. It will serve to provide fast switching kick voltage to each bunch at 500 MHz bunch crossing frequency. This new kicker employed the Swiss Light Source design with modifications on beam pipe geometry. It has been fabricated, baked out and vacuum tested by FMB-Berlin recently. The kicker has been delivered to NSRRC in November 2004. Longitudinal coupling impedance has been measured in house by coaxial wire method with resistive matching networks at input and output ports. The measured peak coupling impedance of the accelerating mode is 684 Ω with FWHM bandwidth at 280 MHz. It corresponds to a shunt impedance of 1368 Ω at centre frequency. These results agree very well with those calculated by GdfidL.

INTRODUCTION

A prototype longitudinal feedback system has been built for the stabilization of bunch phase oscillations in the TLS storage ring. Preliminary system test using a four-tap FIR digital filter has been performed. As expected, it shows good rejection to DC offset and revolution harmonics embedded in the raw bunch phase error signal. By changing the phase shift provided by the FIR filter, damping and anti-damping of a single bunch beam has been experimentally demonstrated. However, for a multi-bunch beam, the feedback system works well only for beam currents lower than 50 mA. Poor stability of the prototype digital electronic circuits prohibited the system from long term operation that usually required for system fine tuning during beam test. On the other hand, the relatively low efficiency kicker is also a suspect for the inability of the LFB system to damp bunch phase oscillations at higher beam intensity. A second version of digital signal processing electronics for shorter down-sampling period (4 μsec minimum) and better electronic stability is under fabrication. On the other hand, a new longitudinal kicker has been built and will be installed into the storage ring in case higher feedback voltage is required.

Previous version of longitudinal kicker at NSRRC has a wide bandwidth of 280 MHz, but a relatively low shunt impedance of ~80 Ω. It was believed that no harmful higher-order modes. However, no rigorous analysis of such structure has been made. Obviously, a new kicker with higher shunt impedance and maintaining a wide bandwidth is highly desirable. The SLS kicker [1] has the highest shunt impedance and widest operation bandwidth in its type. And most importantly, it can fit easily into our storage ring without much modification of beam pipe geometry or addition of extra transition sections. Note that the TLS storage ring beam pipe transverse geometry is a 38x80 mm ellipse. Figure 1 is a cutaway view of this new kicker to be installed into the TLS storage ring. It has been fabricated, baked out vacuum tested by FMB-Berlin recently. The kicker has been delivered to NSRRC in November 2004.

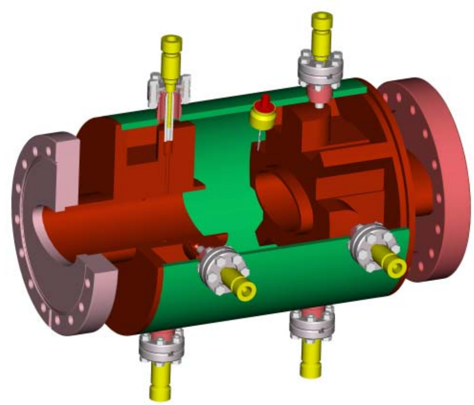


Figure 1: A cutaway view of the new longitudinal kicker to be installed in the TLS storage ring

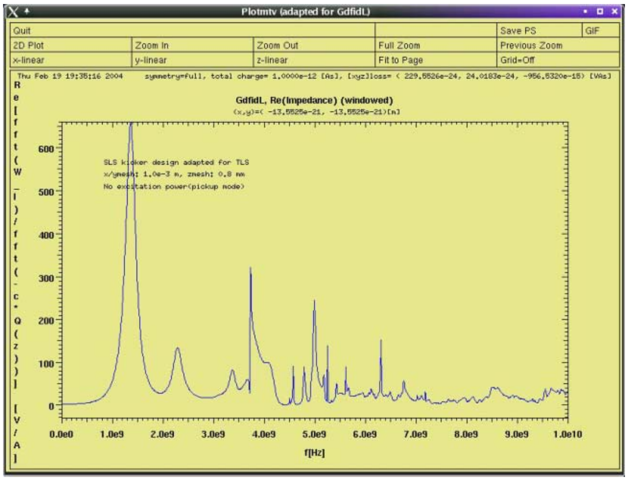
In this work, beam impedance of the kicker have been measured and compared with the result as calculated by GidfidL. Since shunt impedance of the kicker is about twice of the beam impedance, the kicker response can be deduced. The result of longitudinal beam coupling impedance calculation is summarized in section II. The beam impedance and bead-pull measurement setup are introduced in section III. Section IV gives the results of the measurement. From such measurement, some other properties of the kicker can be derived. For examples, a qualitative understanding of the strength of higher order modes, power dissipation on kicker by beam can be obtained

LONGITUDINAL COUPLING IMPEDANCE CALCULATIONS

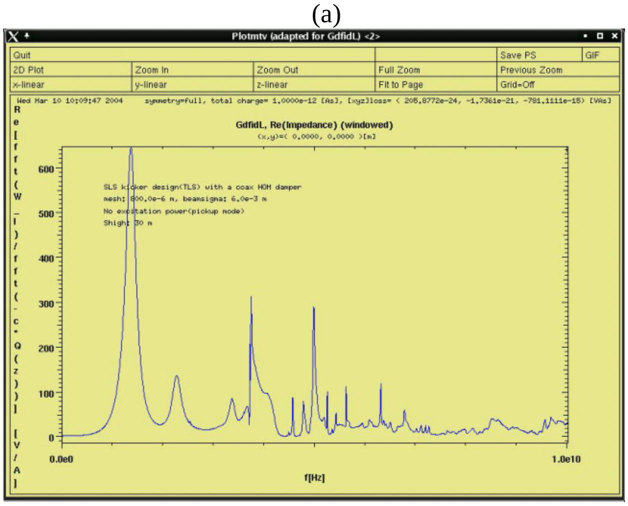
Longitudinal coupling impedance of the kicker has been calculated by the GdfidL code on a cluster of personal computer. Figure 2a is the longitudinal coupling impedance of the kicker without HOM damper. For the fundamental mode, centre frequency is at 1375 MHz and the FWHM bandwidth is 250 MHz. Coupling impedance of fundamental mode at centre frequency is 670 Ω. Figure 2b is the corresponding coupling impedance calculation

0-7803-8859-3/05/$20.00

result with HOM damper. As can be seen from figure 2, the effect of the damper is not obvious in the TLS longitudinal kicker.



(a)



(b)

Figure 2: Calculated kicker longitudinal coupling impedance (a) without higher order mode damper (b) with higher order mode damper

LONGITUDINAL COUPLING IMPEDANCE MEASUREMENT SETUP

Bench measurements have been carried out to verify the design specifications. Basic measurement of rf characteristics includes centre frequency, bandwidth, VSWR at input and output ports and delay variations across the operating frequency range. Another important property of a longitudinal kicker is its shunt impedance. Bead-pull measurement is useful in mapping the longitudinal profile and determining the value of R/Q at centre frequency. And incorporating with Q measurement, shunt impedance at centre frequency can be determined. However, information of shunt impedance versus frequency can only be deduced from beam coupling impedance measurement. A common approach to measure longitudinal beam coupling impedance is the so-called coaxial wire method, or simply wire method. For a multiple coupler structure like this kicker, shunt impedance of the kicker is just two times the longitudinal coupling impedance if output ports are matched to the input ports provide that power dissipation on the kicker cavity wall is much less than the power loss on each coupler.

The coaxial wire measurement setup is schematically shown in Figure 3. The principles and techniques used in this measurement have been described clearly in the papers by H. Hahn and F. Pedersen [2] and Marcellini et al. [3].

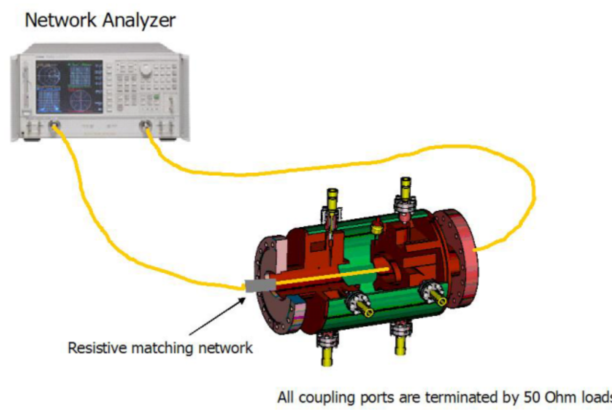


Figure 3: Schematics of the longitudinal coupling impedance bench measurement setup

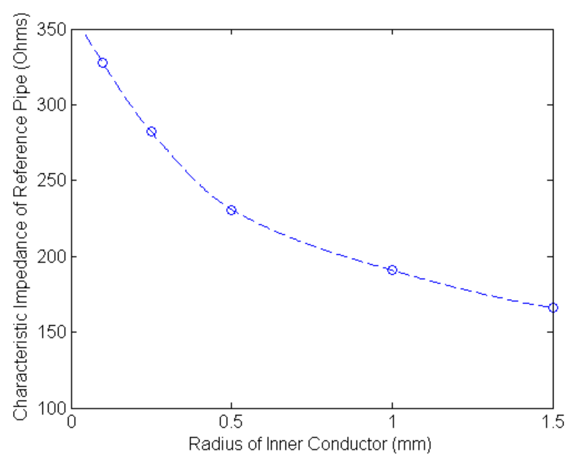


Figure 4: Calculated characteristic impedance of the reference beam pipe at various inner conductor radii for wire measurement

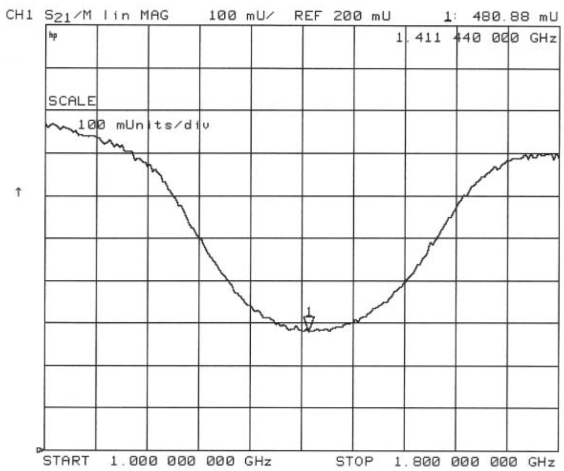
During the measurement, a copper wire (0.25 mm in diameter) placed inside the kicker along the beam axis. Matching resistors are added at both ends to match the 50 Ω coaxial cable with the transmission line formed by the elliptical beam pipe as the outer conductor and the 50 Ω. Longitudinal coupling impedance can be calculated from the measured S_{21} data from the following relation:

$$Z_c = 2Z_{02}\left(\frac{S_{21}^{REF}}{S_{21}^{DUT}} - 1\right) \qquad (1)$$

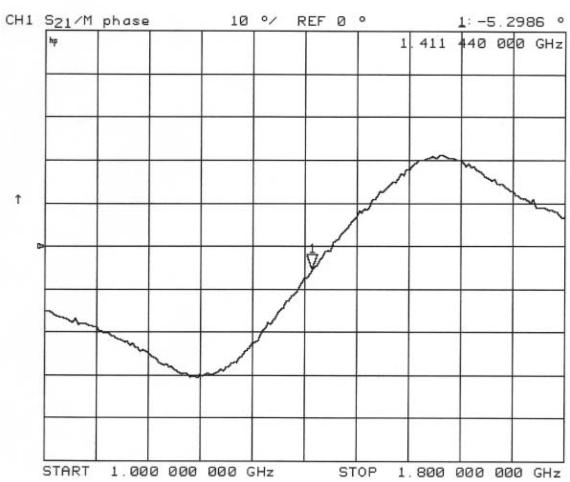
where Z_{02} is the characteristic impedance of the transmission line formed by the wire and the elliptical beam pipe. Since there is no analytical expression of the characteristic impedance such structure, Z_{02} has been calculated by HFSS (Figure 4). The impedance of this "elliptical transmission line" calculated by HFSS is 315 Ω.

MEASUREMENT RESULTS

Figure 5 showed the measured S_{21} that with respect to the S_{21} of the reference beam pipe. The upper diagram (a) is the measured amplitude from 1.0 to 1.8 GHz and the lower diagram (b) is the measured phase.



(a)



(b)

Figure 5: Measured $S^{DUT}_{21}/S^{REF}_{21}$ (a) amplitude (upper picture) (b) phase (lower picture).

From the measured S_{21} data, real part and imaginary part of the longitudinal coupling impedance are calculated and they are shown in figure 6. Although the wire measurement setup is good for frequencies up to approx. 1~2 GHz, we measured S_{21} up to 5 GHz for a qualitative for a quick look at the higher order modes coupling impedance. The result is depicted in Figure 7.

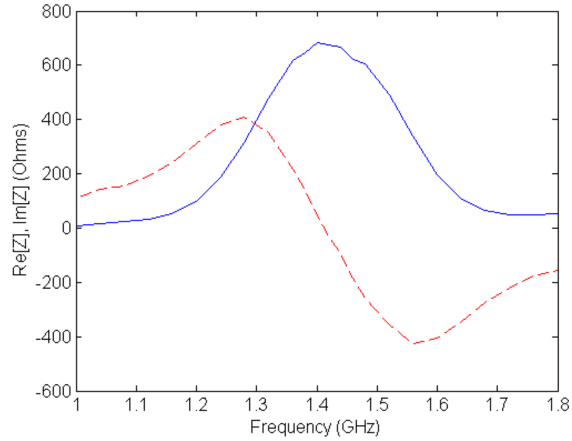


Figure 6: Real and imaginary parts of the longitudinal kicker coupling impedance.

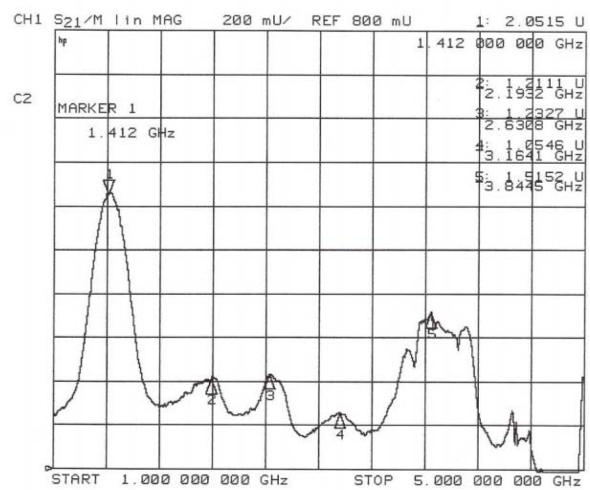


Figure 7: Measured $S^{REF}_{21}/S^{DUT}_{21}$ up to 5 GHz.

SUMMARY

A new kicker for the TLS longitudinal kicker has been fabricated and its fundamental mode coupling impedance has been measured by coaxial wire method. Measured beam coupling impedance is 684 Ω which corresponds to a shunt impedance of 1368 Ω. Bandwidth of the kicker is 280 MHz.

REFERENCES

[1] M. Dehler, "Kicker Design for the ELETTRA/SLS Longitudinal Multi-bunch Feedback", Proceedings of EPAC2002, p.2070-2072.

[2] H. Hahn and F. Pedersen, " On Coaxial Wire Measurements of the Longitudinal Coupling Impedance" BNL 50870, Particle Accelerators and High Voltage Machines TID-4500, April 1978.

[3] F. Marcellini et al., "Beam Coupling Impedance Measurements of the DAΦNE Vacuum Chamber Components", KEK Proceedings 99-24, February 2000, pp.105-113.