Development of the RF Kicker for the Longitudinal Feedback System at SRRC

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Abstract

SRRC is currently developing a RF kicker for the longitudinal feedback system. The kicker is a pill-box cavity with nine pieces of striplines. The resonant frequency is tuned to the designing value 1125 MHz by adjusting the length of the striplines. Excited by a single stripline, cold test results indicate that the full 3 dB bandwidth exceeds 250 MHz and the shunt impedance deduced from bead-pull measurement is about 80 Ω

1 INTRODUCTION

In a longitudinal feedback system, the RF kicker is used to apply an energy correction, an electromagnetic kick, to a passing bunch. It provides the beam bunch with a damping force to decay its longitudinal oscillations around the synchrotron phase. To damp all the dipole mode oscillations, the kick force must change its phase from a passing bunch to the next bunch. The phase change required by the successive bunches may range from in phase (i.e. the same magnitude and same sign) to out of phase (i.e. the same magnitude but alternative sign), implying that at least half the bunch frequency is necessary for the bandwidth of a longitudinal feedback kicker. For our machine, the revolution frequency is 2.5 MHz. In addition, 200 buckets can be filled, so that the bandwidth of at least 250 MHz is required for our kicker to damp all the dipole mode oscillations. In addition to the bandwidth requirement, the damping time constant introduced by the feedback system is proportional to the ratio of the maximal energy deviation to the kick voltage. For constant RF power, the kick voltage is proportional to the number of kickers which are installed. However, the space in length available for our kicker is only 26 cm, the available kicker number is limited due to the space constraint. Producing a sufficient kick voltage to overwhelm any longitudinal anti-damping force within the limited space is an another requirement for the kicker. To fulfill the requirements of wide bandwidth and high kick voltage, some special designs for the RF kicker have been proposed by the laboratories such as ALS, KEK and DAϕNE [1, 2, 3]. The kicker developed at SRRC provides a different type of designs, in which a pill-box cavity and striplines is combined. In this paper, we present the basic design concept and cold test results.

2 BASIC CONCEPT

The basic concept for the kicker design is to combine the wide bandwidth of the striplines and the high impedance of the E010 cavity.

2.1 Wide bandwidth of the stripline

The bandwidth of the stripline with a matching load can be obtained by the description for the transfer impedance of the stripline[4],

$$Z_p = Z_L \cdot g \cdot e^{j(\pi/2 - k_0 l)} sin(k_0 l) \quad (1)$$

where $k_0 = \omega/c$, ω is the frequency, c is the speed of light, g represents a factor of geometry and Z_L is the characteristic impedance of the output. According to Eq.1, the 3 dB bandwidth is 1125 MHz for the stripline with the mid frequency of 1125 MHz. This bandwidth is much wider than 250 MHz, the requirement for the kicker bandwidth with the mid frequency of 1125 MHz.

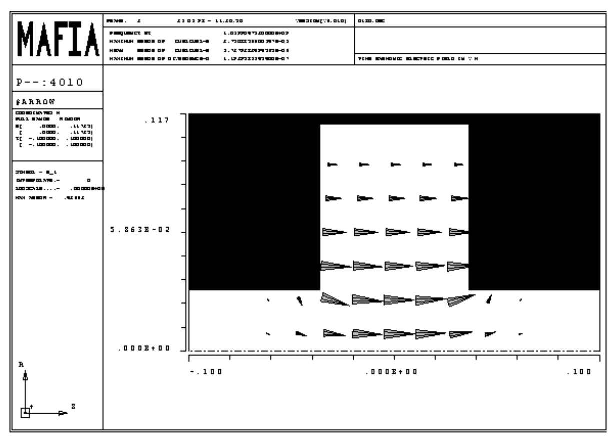

Figure 1: Electric field distribution for the E010 cavity.

2.2 High impedance of the E010 cavity

The field distribution of the E010 cavity, as shown in Fig.1, has high shunt impedance. For example, the shunt impedance can be higher than 1 $M\Omega$ for a simple type of E010 cavity, e.g. a pill-box cavity, with the resonant frequency of 1125 MHz. However, its bandwidth is only about 1 KHz, which is too narrow for the kicker.

2.3 Combination of the E010 cavity and striplines

For the kicker which combines the E010 cavity and the striplines, the RF power is coupled into the kicker by the stripline, a portion of the RF power is absorbed directly by the matching load of the stripline. It make the kicker to have a strong external coupling, which can broaden the bandwidth. The excited kick fields, as shown in Fig.2, are intensive on the beam axis due to the boundary condition of the E010 cavity. The field intensive on the axis can increase the shunt impedance.

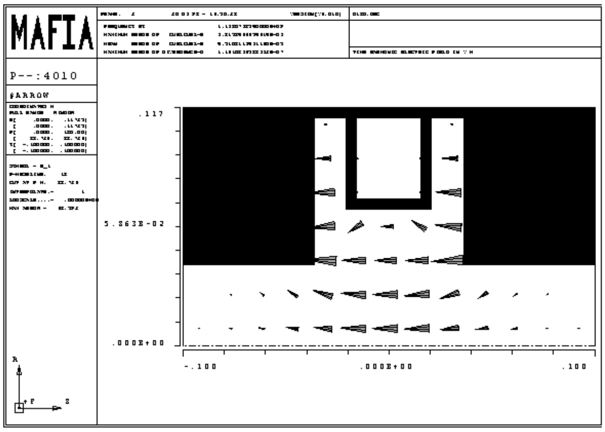

Figure 2: Electric field distribution for the fundamental mode of the kicker. The matching loads in the calculation are replaced with short circuits for simplicity.

3 REAL KICKER

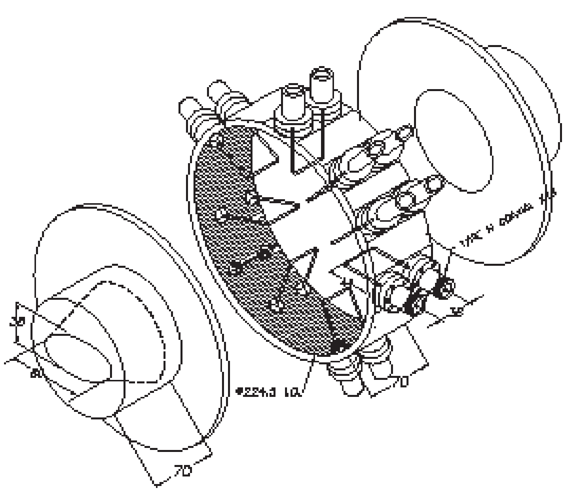

Figure 3: Sketch of the actual kicker.

The real kicker, as depicted in Fig.3, is a pill-box cavity with nine pieces of striplines around the pill-box cavity symmetrically. The pill-box cavity has a radius of 224.5 mm and a length of 70.0 mm. To decrease the broadband impedance unwanted, the section between the pill-box cavity and the beam pipe is a transition from the elliptical to the circle. We adopt the N type coaxial feed-through for isolating the vacuum in the kicker from the air and for the connection ports of the striplines. The connection ports are terminated with matching loads except for three of those used for RF power coupling. The tree striplines used for RF coupling are symmetrically around the kicker. The transverse components of the kick fields can be canceled on the axis if the fields excited by the three striplines are tuned to in phase. The additional six striplines can damp some of the high order modes and broaden the bandwidth. Because the quality factor of the kicker is very low, we do not install any frequency tuner and only tune the center frequency to the designed value by adjusting the length of the striplines.

4 COLD TEST RESULTS

4.1 Bandwidth and loaded Q

Excited by a single stripline with a network analyzer, the measurement results in Fig.4, indicate that the reflection coefficient at the center frequency (1125 MHz) is -24.8 dB, the bandwidth for 3 dB return loss is 280 MHz and the loaded Q is about 4. The frequency of the high order mode shown in Fig.4 is 1492 MHz, which is discussed later.

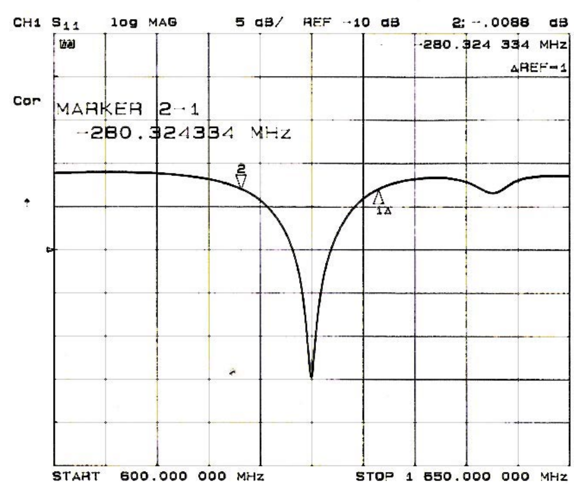

Figure 4: Reflection signal from the kicker, measured by network analyzer.

4.2 Electric field profile on the axis

As well known, the field profile can be determined by introducing a perturbation into the cavity [5]. A previous study [6] has demonstrated that the shift of the resonant frequency caused by a metal bead perturbation with radius r_{bead} can be expressed by

$$\frac{\triangle\omega}{\omega} = -\frac{\pi r_{bead}^3}{U}[\epsilon_0 E_0^2 - \frac{\mu_0}{2} H_0^2] \tag{2}$$

If the magnetic field is known to be zero, for example on the axis of a mono-pole mode, the strength of the electric field can be obtained from

$$E_z(z) = [-\frac{\triangle\omega}{\omega}\frac{U}{\epsilon_0 \pi r_{bead}^3}]^{\frac{1}{2}} \tag{3}$$

where U is the stored RF energy in the cavity. Based on

Eq.3, we obtain the electric field profile on the axis and compare the measure result with the program calculation, as illustrated in Fig.5.

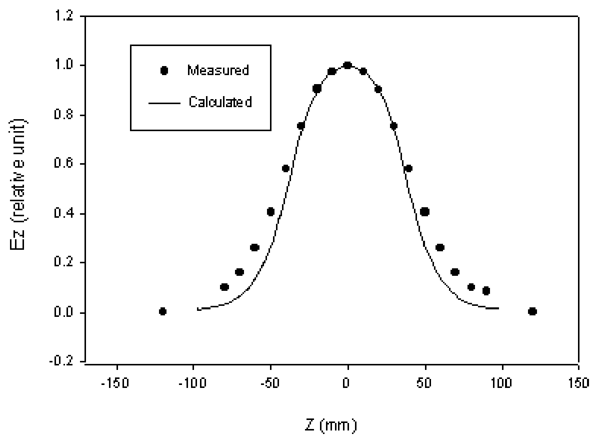

Figure 5: Electric field profile on the axis for the fundamental mode of the kicker.

4.3 *Shunt impedance*

According to the definitions, the ratio of the shunt impedance to the loaded Q can be expressed as

$$\frac{R_s}{Q_l} = \frac{[\int E_z(z)e^{j\omega z/v}dz]^2}{2\omega U} \tag{4}$$

where E_z can be obtained by Eq. (3) for mono-pole modes. According to Eq.4 and the measurements in Fig.4 and Fig.5, the shunt impedance is about 80 Ω.

4.4 *The high order mode of 1492 MHz*

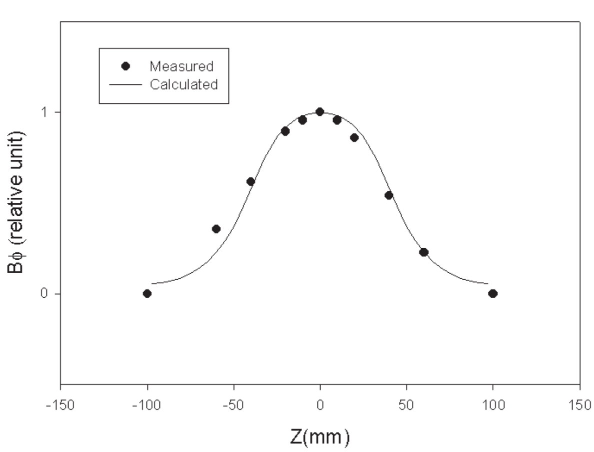

Figure 6: Magnetic field profile on the axis for the high order mode of 1492 MHz.

To identify the high order mode of 1492 MHz shown in Fig.4, we measure the field profiles on the axis with the bead-pull method. Fig.6 shows that the field profiles measured is in agreement with the program calculation on the boundary condition of the dipole modes. According to the program calculation, the electric field of this high order mode is zero on the axis, it implies that this mode is not to be excited by the beam current, so that this high order mode cause no harm to the beam stability.

5 CONCLUSION

This study has demonstrated that the kicker, under the space constrain of 26 cm in length, fulfills the bandwidth requirement (great than 250 MHz), and has good matching to the RF source, the return loss is 24.8 dB at the designed frequency 1125 MHz. The electric profile on the axis is reasonable agreement with the program calculations.

However, the program calculation indicates that the ratio of the shunt impedance to the quality factor is about 53, which is larger than 20 obtained from the measurements. A possible reason to induce the difference may be the simplification of the model for calculation; the matching loads are replaced with the short circuits because the matching loads are too complicated for the program. And the matching loads absorb portion of the RF energy directly, which can reduce the shunt impedance.

6 REFERENCES

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