DESIGN AND SIMULATION OF THE TRANSVERSE FEEDBACK KICKER FOR THE HLS II*

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Abstract

In order to suppress the coupled bunch instabilities in the HLS II storage ring, a transverse feedback system is required. The vital component of the system is the kicker that is the feedback actuator. We design a stripline kicker for the HLS II. The horizontal and vertical electrodes are combined in a structure on account of the space limit. In addition to the design issues, this paper focuses on the simulation results for the kicker using the computer codes. By the 2D code POSSION, we calculate and optimize the characteristic impedance of the stripline kicker to match the 50Ω external transmission lines so as to reduce the reflected power. The reflection coefficient and the shunt impedance in the working frequency range are obtained by the 3D code HFSS. The simulation results provide many important supports for the structure design.

INTRODUCTION

In the upgrade project of the Hefei Light Source (HLSII), to obtain a better performance of the light source, the more efficient new transverse and longitudinal digital bunch-by-bunch feedback system need to be developed to cure the coupled bunch instabilities. This paper mainly introduces the design and simulation of the transverse feedback kicker.

As a transverse kicker, the way of the power coupled to the beam should be the odd mode. In this mode, two voltages which are of equal magnitude but 180° out of phase drive the downstream ports of the beam direction, with the upstream ports terminated on matched loads, see Fig.1. When the kicker is driven from the downstream ports, the contributions of the transverse electric and magnetic fields to the deflecting force **F**=q(**E**+**v**×**B**) add up, while the two forces cancel out if the power is applied to the upstream ports.

The horizontal(X) and vertical(Y) electrodes are combined in a structure because of the space limit. The C-shaped electrodes are for the X-plane and the flat electrodes are for the Y-plane, referring to the designing of BESSY II stripline kicker [1], shows in Fig.2. For the HLS II, with a 204MHz RF system and every buckets filled, the bandwidth of the kicker should be 102MHz so that all possible coupled-bunch modes can be feedback. The stripline length is 183mm and the overall length of the kicker is 300mm.

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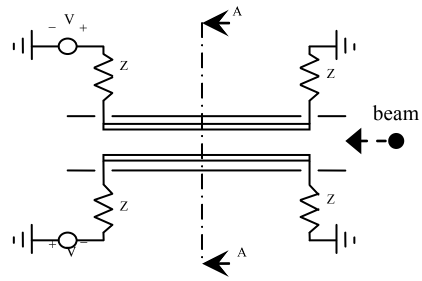


Figure 1: Schematic of a pair of stripline electrodes as a transverse kicker.

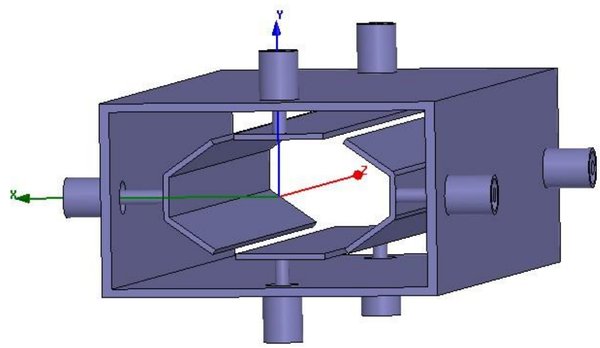


Figure 2: The transverse kicker model in the HFSS.

IMPEDANCE MATCHING

Each of the stripline electrodes with its adjacent vacuum pipe forms a transmission line of characteristic impedance Z_c. In order to maximize the amplifier power transfer to the kicker, each stripline should be matched to the external transmission lines to reduce the reflected power at the coaxial feedthroughs, and this requires $Z_c=50\Omega$.

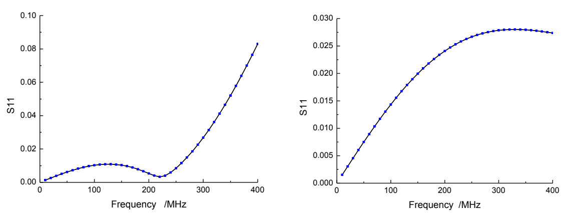
Because of the existence of the capacitance C between the stripline electrodes and the vacuum pipe, the electromagnetic energy E can be stored. The formula to calculate the characteristic impedance can be deduced by

$$\begin{cases} Z_c = \dfrac{1}{\upsilon C} \\ E = \dfrac{1}{2}C(V_1 - V_2) \end{cases} \Rightarrow Z_c = \frac{(V_1 - V_2)^2}{2\upsilon C} \qquad (1)$$

where υ is the speed of light, $V_1$and V_2 are the respective electric potential of the stripline electrodes and the vacuum pipe. When $V_1=\pm1$V and $V_2=0$V, the simplified formula is $Z_c=1/(2\upsilon E)$

The simulation results by the Poisson code of the characteristic impedance for the horizontal and vertical excitation modes are $Z_{cx}=49\Omega$ and $Z_{cy}=50.2\Omega$.

Fig.3 shows the reflection coefficients (S_{11} parameter) vs. frequency at the input ports: the reflection power is very small in the both horizontal and vertical excitation modes.

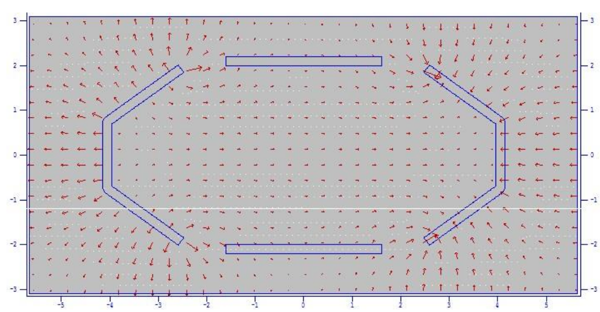


a. horizontal b. vertical

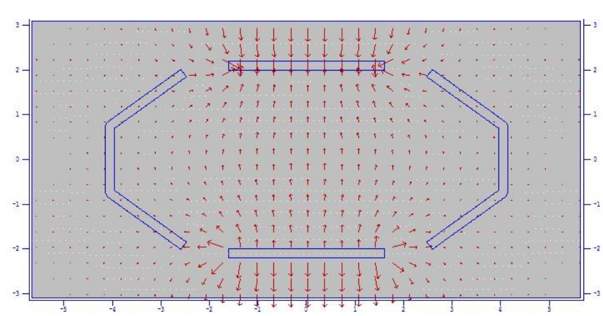
Figure 3: Reflection coefficient vs. frequency.

ELECTRIC FIELD SIMULATION

Using the 2D Poisson code, we simulate the electric field distribution when the horizontal or the vertical electrodes are at opposite unit potentials. Fig.4 shows the electric field line distributions of the both direction excitation modes.



a. horizontal excitation



b. vertical excitation

Figure 4: 2D electric field line distributions in the kicker.

a. Horizontal Excitation

Around the center beam line, the electric field only has the E_x component of 0.028V/mm (E_y≈0).The E_x increase peak and then decrease from the X-axis center to the two sides , while gradually increase on the Y-axis, and within ±0.0007V/mm change on the X and Y axis in ±5mm from orbit center, see Fig.5

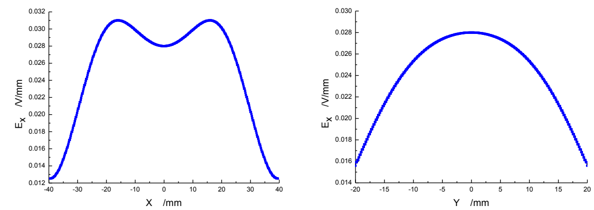


Figure 5: E-field along the X and Y axis when horizontal excitation.

b. Vertical Excitation

Around the center beam line, the electric field only has the E_y component of 0.046V/mm (E_x≈0).The variation of the E_y to the two sides of the X-axis is gradual decrease, while is gradual increase on the Y-axis, and within ± 0.001V/mm change on the X and Y axis in ± 5mm from orbit center, see Fig.6.

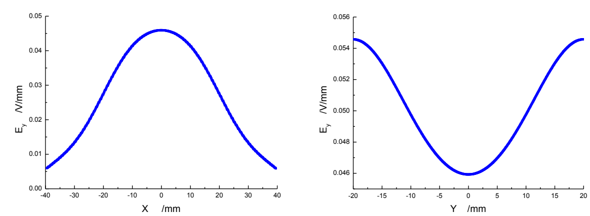


Figure 6: E-field along the X and Y axis when vertical excitation.

SHUNT IMPEDANCE

The other important parameter R_s is the transverse shunt impedance describing the kicker's efficiency:

$$R_s = \frac{V_\perp^2}{2P} \quad (2)$$

where $V_\perp$ denotes the transverse deflecting voltage, defined as the integral of the transverse component of the Lorentz force per unit charge along the beam Z axis.

$$V_\perp = \int_0^l (\vec{E} + \vec{v} \times \vec{B})_\perp dz \quad (3)$$

The transverse shunt impedance of a stripline transverse kicker driven in the odd mode can be calculated by the following formula [2]:

$$R_s = 2Z_c (g_{x,y} \frac{2}{kh_{x,y}})^2 \sin^2(kl) \quad (4)$$

where Z_c is the characteristic impedance of the transmission line, $g_{x,y}$ is the respective geometric coverage factor, k is the wavenumber, l is the electrode length, $h_{x,y}$ is the respective distance between opposite electrode.

We can also calculate the shunt impedance by the integration along the kicker axis of the electric and magnetic fields obtained by the simulation code [3, 4]. The results can be compared with the previous formula. The HFSS code treats the time-varying fields as phasors and computes the field values for a given frequency and a given phase. At the vertical excitation mode, for example, we can get

$$\begin{aligned} E_y(x=0,y=0,z,\omega t=0) &= E_1(z) \\ B_x(x=0,y=0,z,\omega t=0) &= B_1(z) \\ E_y(x=0,y=0,z,\omega t=\pi/2) &= E_2(z) \\ B_x(x=0,y=0,z,\omega t=\pi/2) &= B_2(z) \end{aligned} \quad (5)$$

We can define:

$$\begin{aligned} E_y(z) &= \left[E_1^2(z)+E_2^2(z)\right]^{1/2} \quad \Phi_E(z)=\arctan\left[\frac{E_2(z)}{E_1(z)}\right] \\ B_x(z) &= \left[B_1^2(z)+B_2^2(z)\right]^{1/2} \quad \Phi_B(z)=\arctan\left[\frac{B_2(z)}{B_1(z)}\right] \end{aligned} \quad (6)$$

Then the deflecting electric field and magnetic field, including the magnitude and the phase, are given by

$$\begin{aligned} E_y(z,t) &= \mathrm{Re}\left\{E_y(z)e^{j[\omega t-\Phi_E(z)]}\right\} \\ B_x(z,t) &= \mathrm{Re}\left\{B_x(z)e^{j[\omega t-\Phi_B(z)]}\right\} \end{aligned} \quad (7)$$

The maximum transverse deflecting voltage applied to the beam at a given frequency is

$$V_\perp(\omega)=\left|\int_0^L E_y(z)e^{j\left[\omega\frac{z}{c}-\Phi_E(z)\right]}+cB_x(z)e^{j[\omega\frac{z}{c}-\Phi_B(z)]}\right| \quad (8)$$

where L is the length of the kicker, ωz/c is the transit time factor. The comparison between the formular and simulation results is shown in Fig.7.

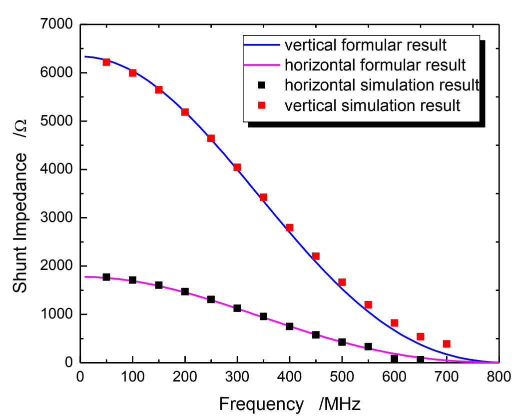


Figure 7: Transverse shunt impedance.

At 102MHz, the horizontal R_s is 6 kΩ and the vertical R_s is 1.7kΩ.And the kick voltage we require can be calculated by

$$V_\perp = 2\frac{1}{\tau_u}T_0(E_0/e)\frac{1}{\sqrt{\beta_m\beta_j}}\Delta_{x,y} \quad (9)$$

where τ_u is the transverse damping time constant, T_0 is the revolution period, E_0 is the beam energy, β_m and β_j are the values of the β function at the BPM location and the kick location, $\Delta_{x,y}$ is the maximum transverse oscillation amplitude at the BPM location.

For the storage ring of HLS II, the kick voltage exceeds 249V horizontally and 223V vertically. On the condition of the good reflection at the input ports, we can calculate the power value that is enough to suppress the coupled bunch instability from the equation (2).

Table 1: Transverse Kicker Parameters

Parameter	Value
bandwidth	102MHz
length of electrodes	183mm
overall length	300mm
electrode thickness	2mm
electrode separation (x,y)	79mm, 40mm
coverage factor (x,y)	0.91,0.87
shunt impedance at 102MHz(x,y)	1.7kΩ, 6kΩ
kick voltage at 102MHz(x,y)	249V, 223V

CONCLUSION

For the HLS II, We have designed the kicker of the transverse feedback system. The table 1 shows the some main parameters of the kicker. The simulation results fulfil the goals of the feedback damping. So the manufacture and test of the kicker should be our next work in near future.

REFERENCES

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