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IMPEDANCE AND HEAT LOAD ANALYSIS OF THE STRIPLINE KICKER IN HEPS

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Abstract

In the High Energy Photon Source (HEPS), stripline kickers are adopted for beam injection and extraction. Beam coupling impedance contribution from the stripline kicker is calculated. Detailed studies on the heat load dissipation have been performed. The peak electric field on the blade and the induced voltage on the feedthroughs due to the beam passage are also calculated.

INTRODUCTION

A new photon source HEPS [1] is proposed in the Institute of High Energy Physics (IHEP). The baseline design has a 7BA lattice structure with circumference of 1360.4 m. On-axis injection scheme is adopted due to the restricted dynamic aperture in the low emittance ring. To minimize perturbation on adjacent bunches during injection, fast stripline kickers with rise time of 4 ns will be used. Therefore, a prototype stripline kicker of 750 mm long is fabricated and tested in the experimental lab [2]. The kicker has two “D” shaped electro blades and an ellipse outer body with vanes. The Cross-sectional view of the stripline kicker is shown in Fig. 1. The impedance and heat loading is a major concern due to the restrict beam pipe dimension.

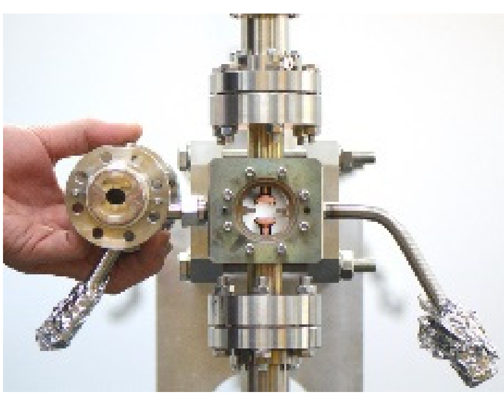

Figure 1: Cross-section view of the stripline kicker.

In this paper, the beam coupling impedance and heat load analysis of the stripline kicker in HEPS is studied numerically. The simulations are studied with rms bunch length of 3 mm. The heat load dissipation due to the beam parasitic power loss in the kicker will be discussed in detail. The electric field induced on the blade and the voltage induced on the feedthrough due to the beam passage are also discussed.

LONGITUDINAL AND TRANSVERSE IMPEDANCE

The stripline kicker is one of the main contributions to the total beam coupling impedance of the ring. The longitudinal and transverse impedances are calculated numerically with the code CST [3]. The impedances and wakes are obtained with rms bunch length of 3 mm. The geometrical model used in the following simulation studies is shown in Fig. 2. The kicker has a stripline structure with two electro blades in parallel. For the model studied, the main part of the outer body is made of copper, and two block of stainless steel welded at both ends. The electro blade is made of stainless steel with copper coating to reduce the heat load dissipation. Here, four ideal feedthroughs with characteristic impedance of 50 Ohm have been used in the simulation.

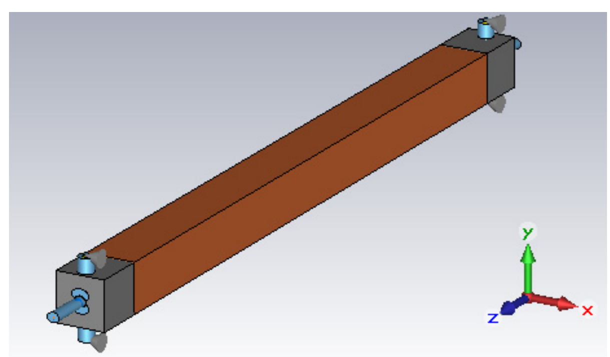

Figure 2: The simplified model used in the simulations.

The real part of the longitudinal impedance spectrum of the kicker up to 20 GHz is shown in Fig. 3. The impedance spectrum shows resonances every ~200MHz, which corresponds to twice the length of the kicker. This is mainly induced by the resonant structure formed between the metal plates and the vacuum tank. The transverse impedance spectrum is shown in Fig. 4. Similar resonances as in the longitudinal impedance can be observed in the transverse plane.

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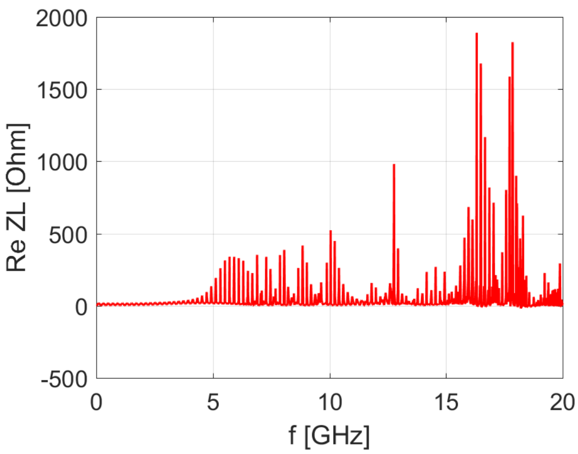

Figure 3: The real part of the longitudinal impedance.

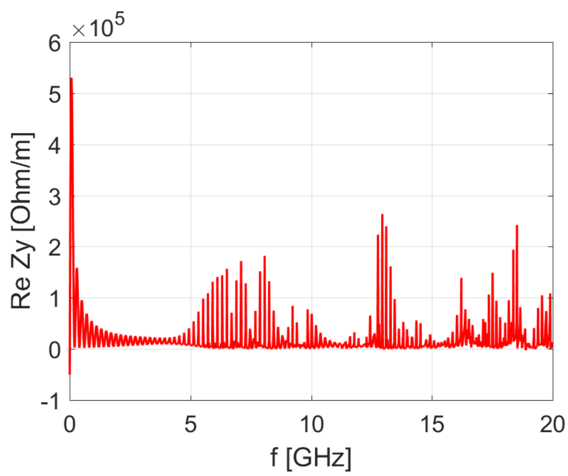

Figure 4: The real part of the transverse impedance.

The broadband effective impedances are also evaluated with bunch length of 3 mm. The total contribution of one kicker to the longitudinal effective impedance is considerably small. The contribution to the transverse kick factor per kicker is 314 V/pC/m. The transverse impedance is considerably high due to the small gap between the kicker blades.

The simulation gives total longitudinal loss factor of 0.72 V/pC per kicker. If we consider a total beam current of 200 mA with bunch number of 63, the loss factor corresponds to a total parasitic power loss from the beam is around 2.1 kW. This is quite high for such a small volume of kicker. However, when consider the bunch manipulation by introducing the harmonic RF cavity and bunch lengthening due to the longitudinal impedance at high beam current, the power dissipated in the kicker should be largely reduced. Figure 5 shows the dependence of the longitudinal loss factor on the rms bunch length.

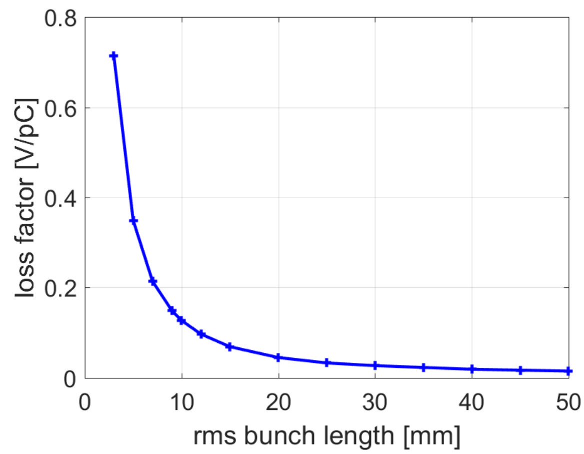

Figure 5: Dependence of the longitudinal loss factor on the rms bunch length.

HEAT LOAD DISSIPATION

The heat load dissipation in the structure is studied numerically. The simulations show that, with total power loss of 2.1 kW, about 233 W will be dissipated on the kicker plates and about 288 W will be dissipated on the outer body. The other part of the power will mainly be transported to the upstream feedthroughs (~ 838 W) and downstream feedthroughs (~ 625 W), and finally be absorbed by the terminal matching resistances.

Figure 6 indicates the power loss dissipated on the blades and the outer body during and after the passage of one bunch. The red curve corresponds to the power dissipated on the kicker blades, while the green and blue curve represents the power dissipated on the middle and end part of the outer body. The peaks in the blue curve indicate higher loss when the beam passes through the gap between the blade and the outer body. The power dissipation decreases rapidly after the bunch passage, since the wakefield left by the beam has transported out the feedthroughs or turned to ohmic loss on the metal surface.

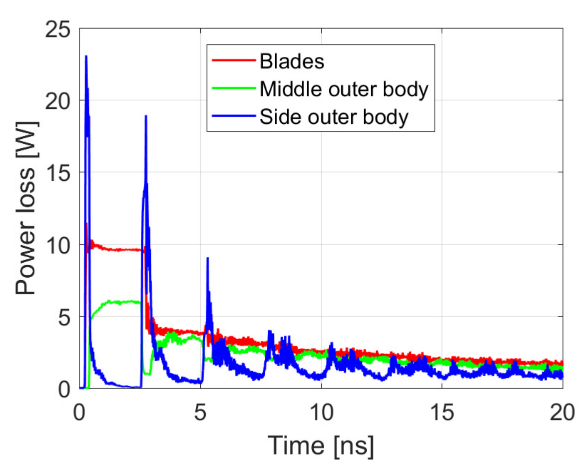

Figure 6: Energy dissipated on the blades during and after the bunch passage.

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PEAK ELECTRIC FIELD ON THE ELECTRO BLADES

When the beam passes through the kicker, electric and magnetic field can be induced on the blade and the outer body. The electric field on the surface of the structure is monitored during the simulation, and the peak electric field during the beam passage is analysed. Figure 7 shows the variation of the peak field on the blade and on the outer body during a single passage of one bunch. The peak electric field on the outer body is 13.4 MV/m, which arise when the beam passes through the upstream gap. The peak electric field on the kicker blades is 19.4 MV/m when the beam passes through the downstream gap. The peak electric field on the blade locates at the end edge of the blade, as shown in Fig. 8.

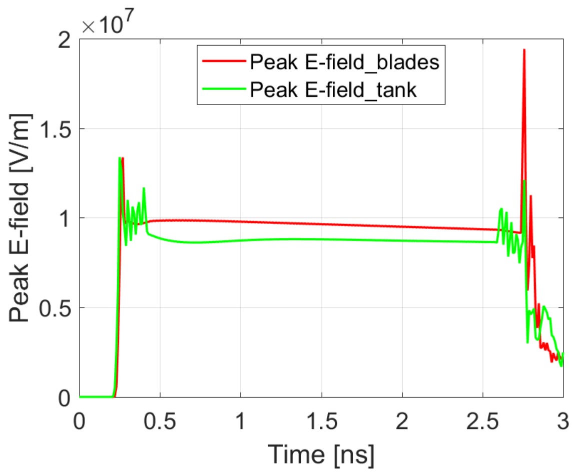

Figure 7: Maximum electric field on the blade and on the outer body. The red curves presents the peak electric field on the kicker blades and the green curve shows the peak electric field on the outer body.

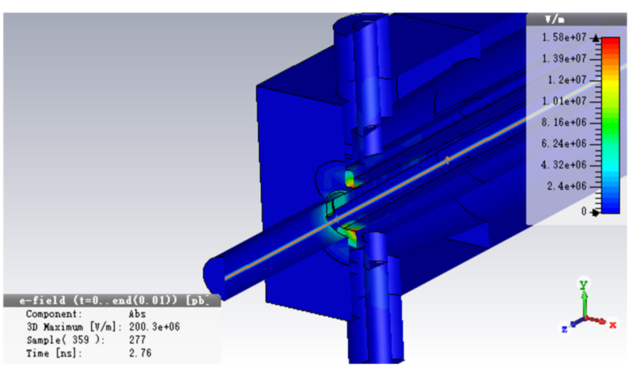

Figure 8: Distribution of the electric field at the condition of peak electric field on the kicker blades.

INDUCED VOLTAGE ON THE FEEDTHROUGHS

The wakefield generated by the beam can also transport to the feedthroughs and induce additional voltage on the terminals. Considering ideal feedthroughs with characteristic impedance of 50 Ohm, the induced voltages on the upstream and downstream feedthroughs are shown in Fig. 9. Peak induced voltage on the upstream feedthroughs is around 370 V and on the downstream feedthroughs is around 290 V. The induced voltage decays rapidly after the bunch passage.

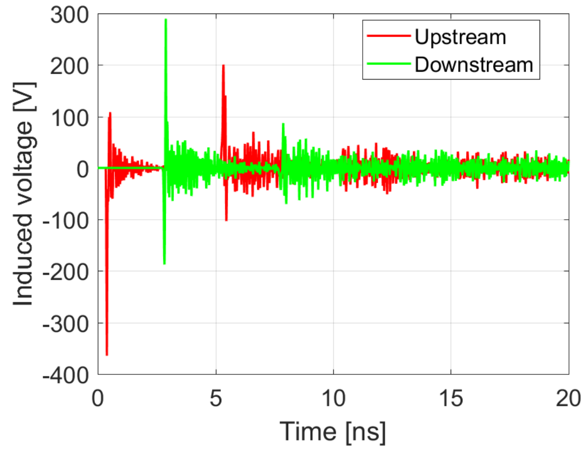

Figure 9: Voltage induced on the upstream and downstream feedthroughs during and after the bunch pass through the kicker.

CONCLUSION

Detailed discussion of the impedance and rf-heating associated with the 750 mm stripline kicker in HEPS is presented. The longitudinal and transverse beam coupling impedances of the stripline kicker is studied numerically. The heat load dissipation due to the parasitic power loss of the beam is discussed in detail. Numerical simulations show that the peak electric filed on the blades is around 19.4 MV/m. The voltages induced on the feedthroughs due to the beam passage are also given. When considering bunch lengthening induced by introducing the harmonic RF cavity and the longitudinal impedance at high beam current, the heat load and electric field induced on the blade due to the beam can be largely reduced.

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[3] CST, `https://www.cst.com`