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THE DESIGN AND TEST OF A STRIPLINE KICKER FOR HEPS

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Abstract

A fast stripline kicker is adopted for High Energy Photon Source (HEPS) on-axis injection. The optimization of a prototype 750 mm long kicker has been finished. The 3D simulation results show the final design of wide vane with end cover lowers the beam loss about 31% than the original design does. We develop a feedthrough model with machinable glass ceramic and achieve a VSWR under 1.3 in 0~2 GHz. The assembly of kicker and commercial feedthroughs has been tested with Keysight E5071C. The testing results of S parameters and TDR value show a good agreement with simulation ones.

INTRODUCTION

High Energy Photon Source (HEPS) is a storage ring light source with the beam energy of 6 GeV. The effective dynamic aperture (DA) is about 2.5 mm (horizontal) and 3.5 mm (vertical), which is not large enough for off-axis injection [1]. On-axis swap-out injection or on-axis longitudinal accumulating injection schemes are proposed, and a very fast kicker is required for both on-axis injection systems [2].

In the HEPS test facility (HEPS-TF) project, a stripline kicker of 750 mm long has been designed and tested as one of key hardware techniques. Figure 1 gives the section view of the stripline kicker and high voltage feedthroughs. The design has been optimized to satisfy the specifications of the kicker, such as the matching odd-mode impedance, field uniformity in good field region, and minimizing the local electric field in operation voltage, which are shown in Table 1 [3].

In this paper, we'll first give the detailed optimization of kicker with 3D simulation. Then the preliminary design of feedthrough is presented. Finally, we'll compare the simulation and testing results of the prototype kicker.

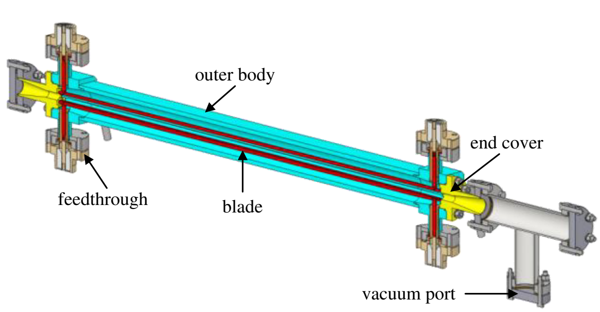

Figure 1: Section view of the stripline kicker.

Table 1: Specifications of the Stripline Kicker for HEPS-TF

Parameters	Value
Length of blades (mm)	750
Gap between the two blades (mm)	10
Good field region (mm)	±2.3 (x) ±1.0 (y)
Field uniformity	2%
Odd-mode impedance (Ω)	50±0.5
Even-mode impedance (Ω)	60±0.5
Operation pulse voltage (kV)	±20
Degree of vacuum (Torr)	1×10^{-9}

KICKER DESIGN OPTIMIZATION

The two-blade stripline kickers have been successfully operating at KEK [4] and DAΦNE [5]. New designs have been developed to achieve high field uniformity, maximum kicker strength, low beam impedance and short pulse width [6-8].

Our kicker design refers to the APS-U design [8-10] because of the similar machine parameters. Figure 2 shows the basic geometry of the kicker body. Robust "D" shape blades are adopted for easily achieving high field homogeneity, where *a*, *b* are the axes of the central ellipse, *blade* is the thickness, *gap* is the half distance, which define the blades geometry. The outer body half shell is composed of 2 connected half ellipses, where X_c, a_0, b_0 defines the central half ellipse, and X_c, a_{00}, b_0 defines the outer half ellipse. Adjusting the *vane* value can improve the mismatching of the even-mode impedance.

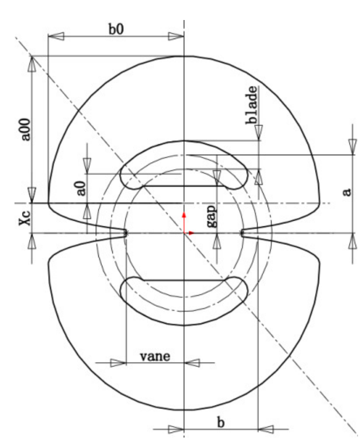

Figure 2: Basic geometry of the cross section.

The whole kicker consists of the main part of 650 mm and two taper parts of 50 mm, as shown in Figure 3. The odd-mode and even-mode impedance are optimized at the section of main part and end section of taper part

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separately. The introduction of taper parts can improve the matching with feedthroughs and lower the beam impedance.

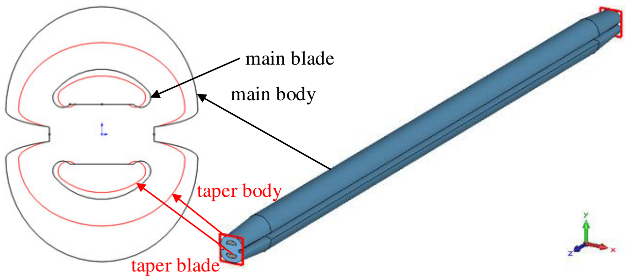

Figure 3: 3D kicker model.

First optimization is extending the vanes to decrease the coupling of the two blades with 3D CST [11]. As shown in Figure 4, the *vane* value changes from *vane* = *b* to *vane* < *b*. The even-mode impedance decreases from ~65 Ω to <60.5 Ω as the odd-mode impedance maintains ~50 Ω. The beam loss factor decreases from 1.042 V/pC to 0.893 V/pC in the Gauss beam ($\sigma_z = 3$ mm), as shown in Figure 5 that means the beam power loss is about 15% lower.

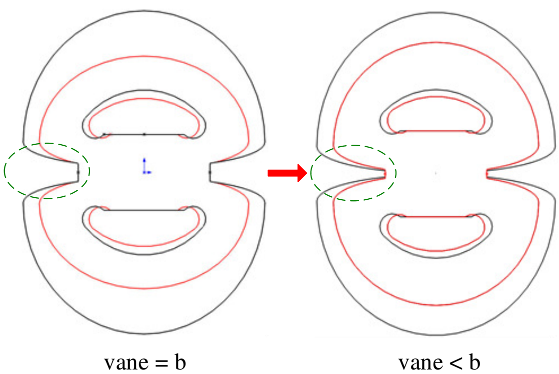

Figure 4: Optimization of the cross section.

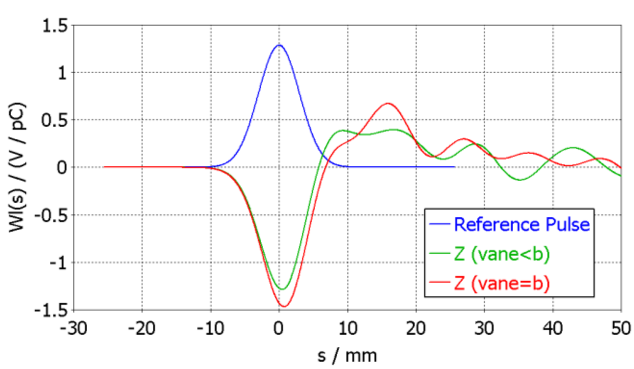

Figure 5: Comparison of the longitudinal wake potential ($\sigma_z = 3$ mm).

Further optimizations mainly focus on improving the taper parts. As shown in Figure 6, we improve the end section of taper parts firstly with increasing the vane width, then add two end covers (shown in Figure 1) at each end of taper parts. The beam power loss decreases 16% after both optimizations.

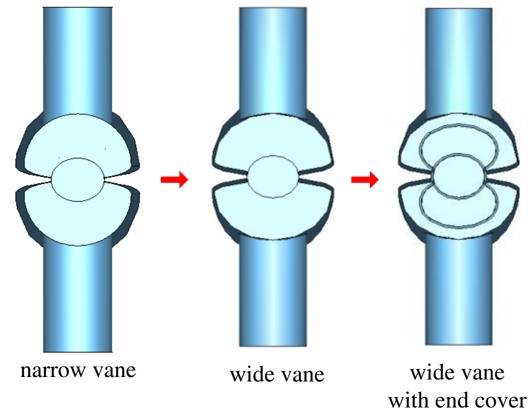

Figure 6: Taper parts improving.

FEEDTHROUGH DESIGN

The requirement of feedthrough is that it must withstand high voltage of above 20 kV, has ultrahigh vacuum degree of less than 1×10^{-9} Torr and enough frequency bandwidth of above 1 GHz.

The commercial FID RF feedthroughs have been assembled with the prototype kicker. The preliminary testing results in RF and high-voltage conditions show that they can meet the request of measurement. But it's very hard to connect to kicker blades because of inner conductor end structure, so it's necessary to develop special ones to satisfy our requirement.

The feedthrough model is shown in Figure 7. The machinable glass ceramic is chosen for the vacuum seal because of the low permittivity ~6, which is easier to achieve good 50 Ω matching. The optimized VSWR value has been below 1.3 up to 2 GHz, as shown in Figure 8.

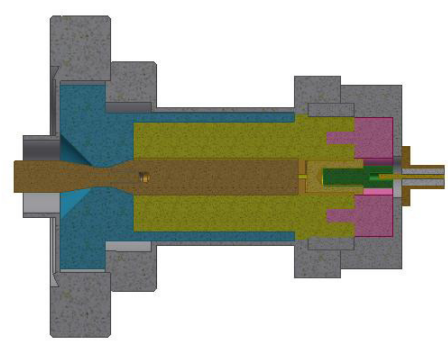
Figure 7: Cross section view of the feedthrough model.

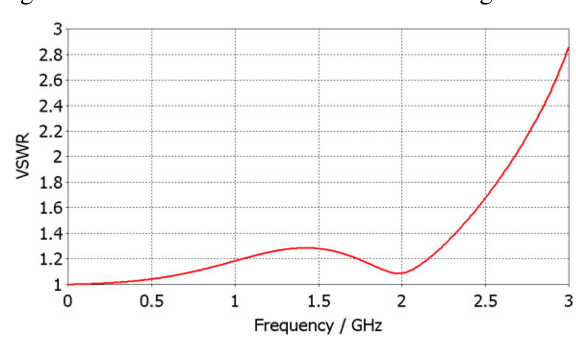

Figure 8: VSWR of the feedthrough.

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RF MEASUREMENT

RF measurement has been done after assembling the 750 mm kicker and FID feedthroughs. The test setup is shown in Figure 9, and Keysight E5071C Network Analyser is used to measure the S parameters and Time-domain reflectometer (TDR) value.

The S parameters comparison is shown in Figure 10. Because we use the perfect coaxial feedthrough in simulation, testing values are worse than simulation ones, especially the insertion loss S21. But we think these values are acceptable.

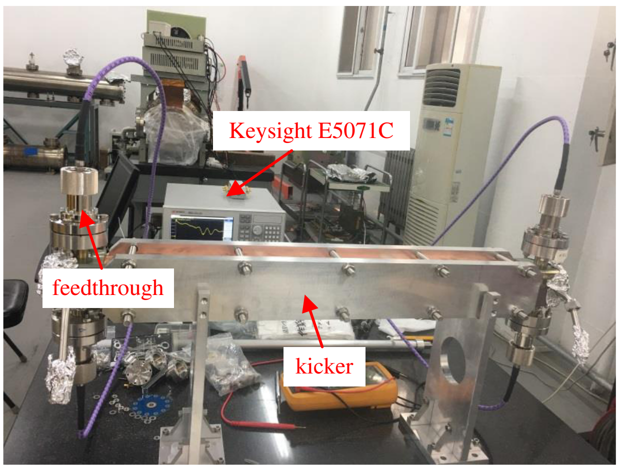

Figure 9: Kicker test setup.

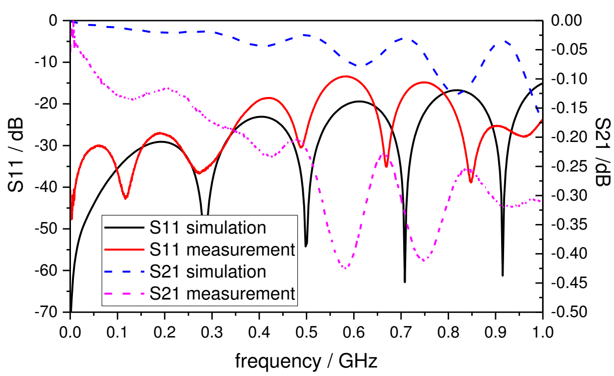

Figure 10: S parameters Comparison between simulation and testing results.

Our feedthrough model is adopted in the TDR simulation, and the TDR comparison is shown in Figure 11. We discover that the odd mode impedance (red line) drops in the middle of the blades and the minimum value is below 48 Ω. The long-blade deflection is thought to be the main reason, which can also lead to a decline of vertical field uniformity. We have considered several solutions, such as adding ceramic supports in the middle of the blades, more bigger and robust blades or lighter alumina blades.

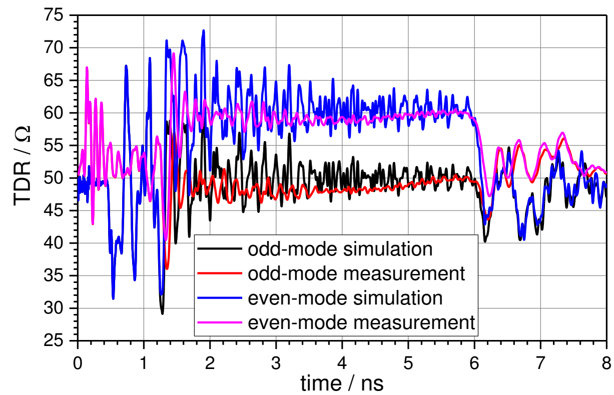

Figure 11: TDR Comparison between simulation and testing results.

CONCLUSION

The stripline kicker design optimization has been done. After extending the vanes, improving the end section of taper parts and adding the end cover at each end of the kicker, the total beam power loss can decrease about 31%.

The preliminary design of feedthrough has been finished and the machinable glass ceramic is adopted. In 0~2 GHz, the VSWR value can be below 1.3.

The kicker and FID feedthroughs have been assembled and tested. The test results of S parameters and TDR value agree well with the simulation ones.

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