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A 300 mm LONG PROTOTYPE STRIP-LINE KICKER FOR THE HEPS INJECTION SYSTEM

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Abstract

In the High Energy Photon Source (HEPS), the dynamic aperture of machine is not large enough for off-axis injection for its baseline 7BA lattice design. So, a group of superfast kickers with about 10 ns pulse bottom width are needed for on-axis swap out injection scheme. The design about a couple sets of 300 mm long strip-line kickers is presented. Five kickers as a module are placed in a stainless steel vacuum vessel to solve the problem of longitudinal space restriction in injection area. So far, the prototype development of strip-line kicker was completed. The results of time-domain reflectometer (TDR) test and high voltage pulse test show that the strip-line kicker can meet the requirement of the HEPS.

INTRODUCTION

The on-axis swap-out injection is the baseline design for the storage ring in the high energy photon source (HEPS) due to its very small dynamic aperture [1-3]. Superfast kicker and pulser are required to minimize the perturbation to stored beam during the injection [4-6]. The traditional kicker magnet can hardly meet the speed requirement of nanosecond magnitude. We adopt the strip-line kicker which is a kind of counter TEM travelling wave kicker. It was also used in APS-U injection system [7-9]. To reserve the possibility of on-axis longitudinal injection in the future, we prefer the shorter kickers. In the final design, the injection section layout of the HEPS storage ring is shown in Fig.1. It is composed by eight strip-line kickers with 300mm long blades and a lambertson. The longitudinal space for kickers is only 2.8m. The specification of injection kicker system for the storage ring is shown in Table 1. The kickers are divided into 2 groups, and installed in 2 separated vacuum chambers. Here, a new kind of prototype strip-line kicker with 5 cell compact structure was developed for the HEPS storage ring.

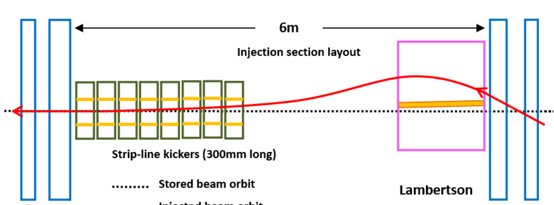

Figure 1: Injection section layout.

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STRIP-LINE KICKER DESIGN

The cross section shape of the strip-line kicker is shown in Fig.2. In the figure, the parameters are used to optimize the impedance of the strip-line kicker. Two D-shaped blades placed vertical are used. Outer body with vanes geometry is adopted to match common-mode impedance. In the longitudinal direction, the kicker cross section is kept consistent, do not have tapered end sections [10-12].

Due to the longitudinal space constraints of the injection straight section, it requires all the kicker units to be placed in two vacuum tanks, which can save some space, instead of separated kicker units with the corrugated connection structure. And it also can contribute to the reduction of beam impedance [13].

Table 1: Specifications of Injection Kicker System

Parameters	Value
Total kick angle (mrad)	2.656
Kick direction	Vertical
Length of strip-line kicker (mm)	300
Gap between two electrodes (mm)	10
Quantity of strip-line kicker	8
Good field region (mm)	±2.3 (x), ±1.0 (y)
Integral field uniformity	<±1%
Odd mode impedance (Ω)	50±1
Even mode impedance (Ω)	<65
Amplitude of electrical pulse (kV)	±17.5
Bottom width of electrical pulse(ns)	10
Repetition rate-CW (Hz)	50
Degree of vacuum (Torr)	10^{-9}

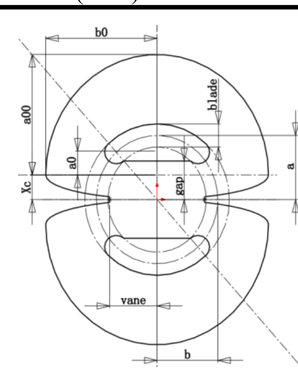

Figure 2: The cross shape of the strip-line kicker.

The prototype we designed was composed of five kicker units placed in a vacuum tank. Every kicker unit has 2 electrodes with 300 mm long that are placed in vertical direction. All the kicker units share the same one long outer

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body that located in a same vacuum tank. The kicker outer body is spilt into 4 pieces to be machined by CNC machining from copper and are fastened together by screw bolts. On the both side wall of the outer body, the water pipes are welded to cooling all the kicker units. The electrodes are also made by CNC machining from copper.

The final 3D mechanical assembly drawing of kickers is shown in Fig.3. All the kicker units are installed in an about 1.5 m long vacuum tank which is made by 316-L stainless steel. The commercial high voltage (HV) RF feedthroughs from FID GmbH are connected to the kicker unit by coaxial bend transition parts. The cooling water pipes welded on the out body are drawn out to the outside of the vacuum tank through cooling water feedthrough. The HV RF feedthroughs and water feedthroughs are connected to the vacuum tank by metal seal ring. All the parts we design can be repeatedly disassembled. It has several ports for pump and assembly on the sides of vacuum tank.

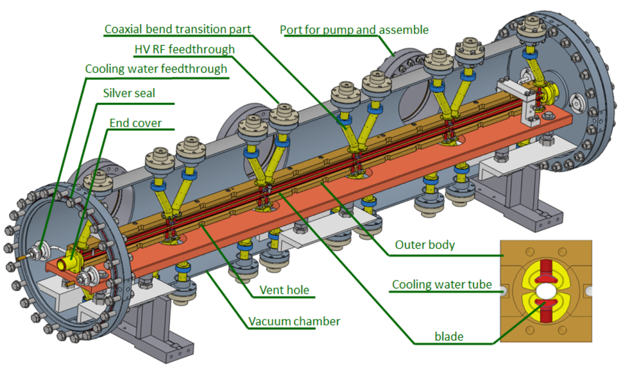

Figure 3: 3D mechanical assembly drawing of kickers.

In order to obtain high vacuum, all parts in the vacuum tank should be considered its air conductance in the design, so as to avoid the relatively independent narrow airtight space. Considering this point, many vent holes are added on out body and coaxial bend.

Coaxial bend transition parts is design for solve the problem of feedthrough space interference. There are ceramic slices in coaxial bend interior as support. The impedance cannot match well at the support point. The slots on the slices are designed to minimize the impedance mismatching, increase creep age distance and air conductance. The simulation analysis shows that the impedance is reduced to 30 Ω. The TDR simulation result of the coaxial bend transition parts is shown in Fig.4.

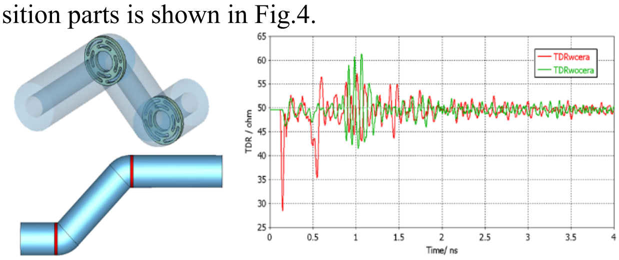

Figure 4: Simulation result of coaxial bend transition part.

The simulation indicates the maximum local electric field intensity reaches 19.73 MV/m inside the kicker units, which is located at the end of the electrode shown in Fig.5.

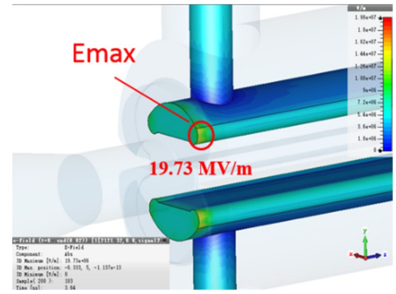

Figure 5: Maximum local electric field intensity distribution.

KICKERS MACHINING AND ASSEMBLY

The prototype of strip-line kicker consists of vacuum tank, blades, outer body, coaxial bend transition parts and sliding support plate. There are 28 flanges on the vacuum tank, in which, 20 ones for installing HV RF feedthroughs. The welding accuracy of these flanges is very important for the final assembling process. Outer body is long and complex, and also need to be welded with water pipe before been machined. Fig.6 is the picture of outer body pieces made by CNC machining. The blades of 300mm long without tapered ends are also made by CNC machining [4], which is shown in Fig.7. Coaxial bend transition parts are also the key parts of the prototype. After many process design adjustments, coaxial bend transition parts were finally successfully processed by CNC machining, as shown in Fig.8.The assembly accuracy reaches 0.05 mm. After 5 kicker units were completely assembled on the table, they were all smoothly pushed into the vacuum tank by using sliding support plate. The final assembly of the prototype kicker is shown in Fig.9.

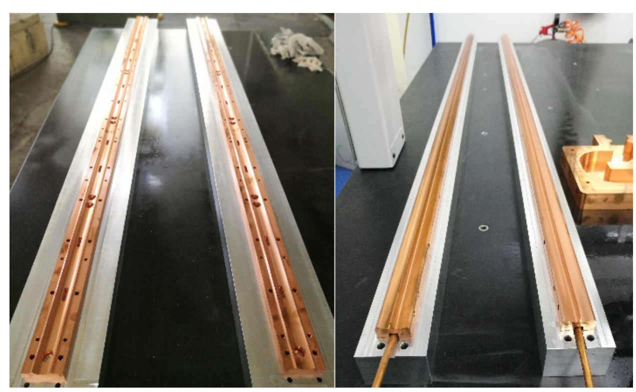

Figure 6: Outer body of strip-line kickers.

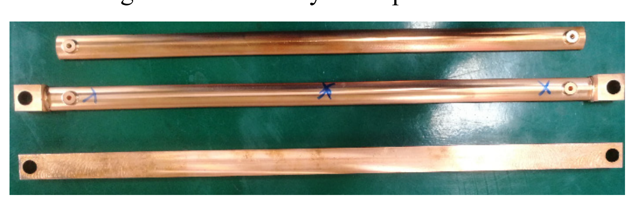

Figure 7: Blades of strip-line kickers.

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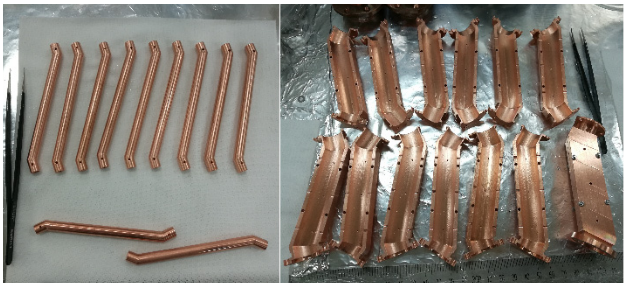

Figure 8: Coaxial bend transition parts.

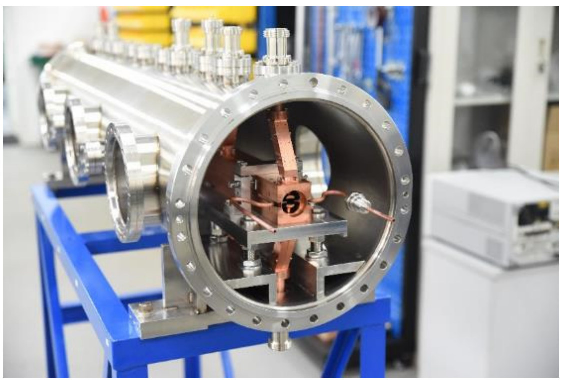

Figure 9: The final assembly of the prototype kicker.

RF MEASUREMENT

Before the high voltage test, the RF test with E5071C NA was performed and the measurement results about time-domain reflectometer (TDR) of prototype kicker is shown in Fig.10 [14]. Compared with the simulation, the testing results agree well and can meet the specifications. It can be seen that the position of the ceramic supporting slices and the interior of the feedthrough are the poor mismatching points.

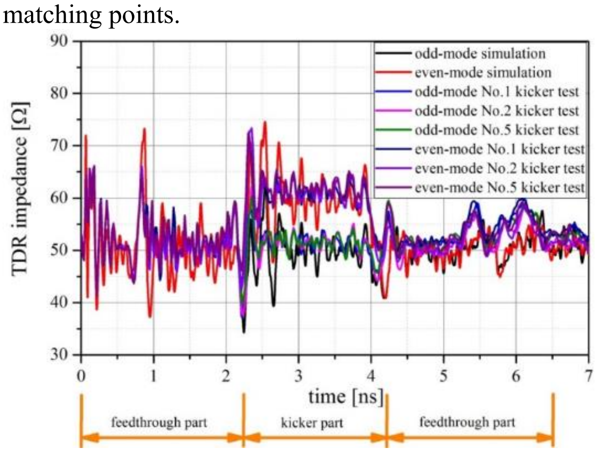

Figure 10: Time-domain reflectometer of prototype kicker.

HIGH VOLTAGE TEST

After vacuum debugging, the vacuum degree of the tank successfully reached 2×10^{-8} Torr without baking in a week. The prototype kicker high voltage test setup is shown in Fig.11. A commercial pulser of ±20kV amplitude, 4 ns pulse width was applied to the all kickers respectively.

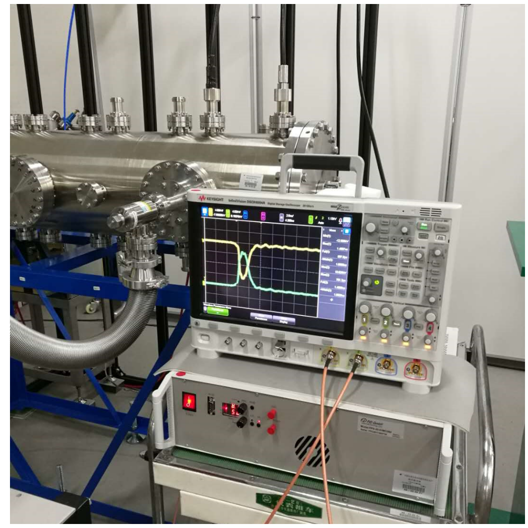

Figure 11: The prototype kicker HV test setup.

Every kicker has similar pulse waveform, and the typical HV test pulse waveform is shown in Fig.12. The bottom width of electrical pulse is less than 4 ns when amplitude of ±20kV. The front edge (10%-90%) of the kicker is less than 650 ps and rear edge (90%-10%) is less than 1.4 ns. It shows that the performance of prototype kicker is good enough for HEPS on-axis injection.

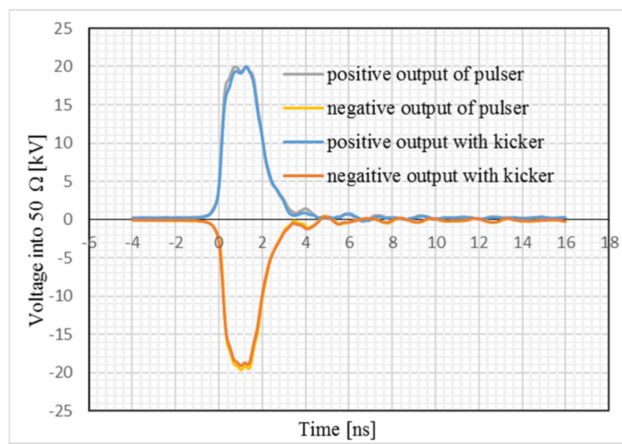

Figure 12: The HV test pulse waveform.

CONCLUSION

A prototype strip-line kicker of 300 mm long for HEPS injection system has been designed and developed. The compact structure of 5 cascaded strip-line kickers hosted in a single vacuum chamber of 1.6m long are demonstrated. We met many difficulties in the process of manufacturing about the prototype, and finally successfully completed it. The prototype kicker passed the test of transmission characteristics, vacuum and high voltage by relevant equipment. The measurement results show that the prototype kicker can meet the HEPS's requirement well.

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