THE DESIGN AND PRELIMINARY TEST OF A STRIPLINE KICKER FOR HALS*

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Abstract

Stripline kicker is an important component of both on-axis longitudinal accumulation [1] and on-axis swap out injection schemes in HALS(Hefei Advanced Light Source). After more than one year of R&D, construction of the first prototype is completed. The kicker performance is simulated by CST. The results show that in the range of 0~1 GHz, on differential mode, S11 is less than - 20 dB. In order to facilitate installation, the extension part and PTEF bracket were designed. The assembly of kicker and commercial feedthrough has been tested with pulse generator and network analyzer.

INTRODUCTION

Hefei Advanced Light Source (HALS) aims to be a diffraction-limited storage ring (DLSR). On-axis injection is a feasible scheme. As the crucial component, the R&D of stripline kicker is very important. Length, geometrical structure of cross section and transition part are crucial in kicker physical design. They directly affect the transmission of high-voltage pulse, integrate field and perturbation to adjacent stored bunches. We can estimate simulation results by referring to transmission parameters, differential/common mode impedance and TDR.

DESIGN METHOD

The maximum length of a stripline module L_{mod} depends on operating mode and the shape of pulse [2]. One optional operation mode of HALS is 100 MHz RF system with a bunch separation of $T_g = 10$ ns. Here we consider a trapezoidal pulse signal as shown in Fig. 1. The total width of the pulse is $T = T_r +_{top} +T_f$.
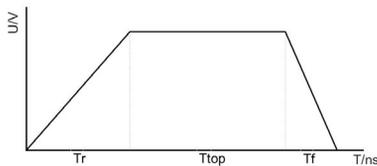

Figure 1: Simplified input pulse profile.

In on-axis longitudinal accumulation injection scheme, deflection field should be completely transparent to the circulating bunches adjacent to injected bunch, so the profile of pulse should satisfy Eq. (1).

$$T < T_g - 2T_p \qquad (1)$$

The propagation time of pulse signal on electrode is $T_p = L_{mod}/c$. The maximum length for stripline electrodes in each module is given by Eq.2.

$$L_{mod} \le (\frac{T_g}{4} - \frac{T_r}{2})c \qquad (2)$$

To reach this conclusion, the following point need to be considered. The direction of pulse propagation on electrode is opposite to that of beam motion, so the deflecting force is twice the electric force. Otherwise, the deflecting force of electric and magnetic components will cancel each other. We chose FPG 20 Pulse Generator from Germany FID Company. Table1 summarizes the relevant machine parameters and kicker requirements.

Table 1: The Relevant Parameters

Parameter	Value
Beam energy(E)	2.4GeV
Bend Angle(Θ)	3.5mrad
Total Kicker Length	1.2m
Stripline Length(L_{mod})	0.4m
T_g	10ns
Voltage(V)	±17.5kV
T_r	<0.7ns
T_{top}	1~1.2ns
T_f	<1.5ns

Stripline kicker consists of two electrodes and a vacuum chamber, operating in differential mode. Two pulses with opposite polarity and equal amplitude from generator are input to the downstream ports of electrodes through connection cables and feedthrough simultaneously, and the upstream port of electrodes are terminated by 50 Ohm load, which can absorb pulse to prevent reflection [3].
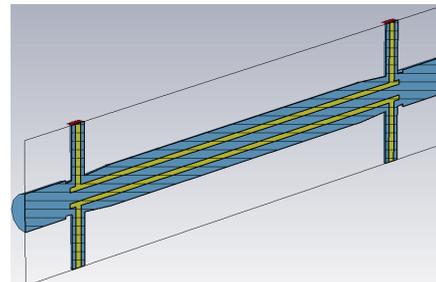

Figure 2: Overall structure of kicker.

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Because the impedance of generator, cables and network analyser are all 50 Ohm, the differential mode impedance of kicker on operation should be 50 Ohm. When a bunch pass through kicker, it will induces images charges on both electrodes, which can affect subsequent bunch. So, the common mode impedance should be as close as 50 Ohm to reduce beam coupling impedance. Furthermore, a transition tapered part was designed to better match electrodes with feedthrough.
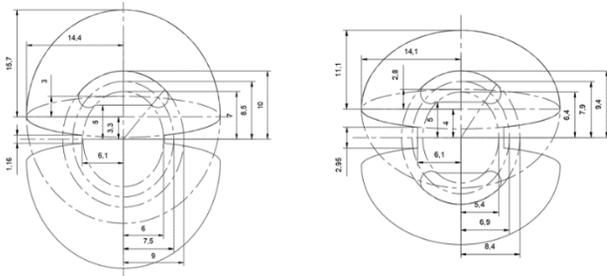

Figure 3: Geometric structure of cross section, main part(left) and transition part(right).

The overall structure and cross section of kicker are showed in Fig. 2 and Fig. 3. The geometric structure of blades referred to the design of APS-U [4] [5]. The position of electrodes and vacuum chamber are determined by three similar ellipses, the gap between electrodes and two ellipses with same central position, parameter x, respectively. Using the parameter sweep function of CST, each parameter was optimized step by step until appropriate simulation results were obtained.

The inner conductor of commercial feedthrough vacuum end is too short to be connected to electrodes, so we re-designed an extension part, as shown in Fig. 4.
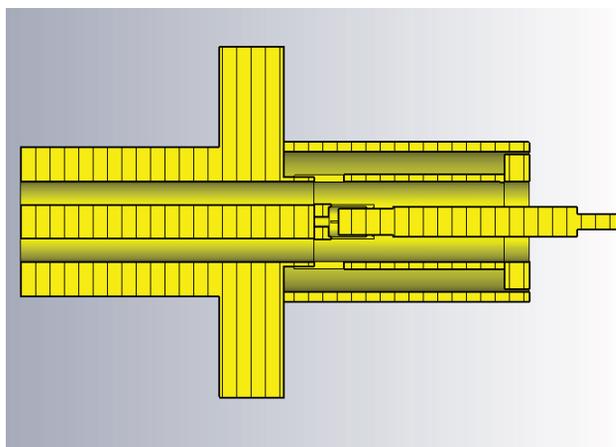

Figure 4: Extension part.

SIMULATION RESULTS

In simulation, feedthrough and extension part were replaced by 50 Ohm coaxial line, as shown in Fig. 2.

Pulse generator has a high repetition rate, so it is necessary to simulate transmission and reflection parameters. As shown in Fig. 5, in the range of 0~1 GHz, on differential mode, S11 is less than - 20dB and S21 is greater than - 0.03 dB. On common mode S11 is less than - 13.3 dB and S21 is greater than - 0.2 dB. The reflection is very small.

TDR(Time Domain Reflection), evaluates the impedance profile along a TEM or similar structure based on the reflected time signals at a port (mode). It is the only possibility to "look into a structure" and locate mismatches. As shown in Fig. 6, differential mode impedance is around 50 Ohm, and common mode impedance is around 60 Ohm. There is mismatch, where feedthrough (coaxial in simulation) connected to electrode. The effect of mismatch is weakened when the transition tapered part is adopted.
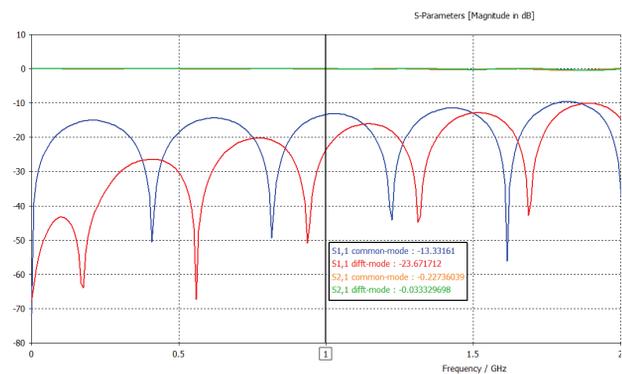

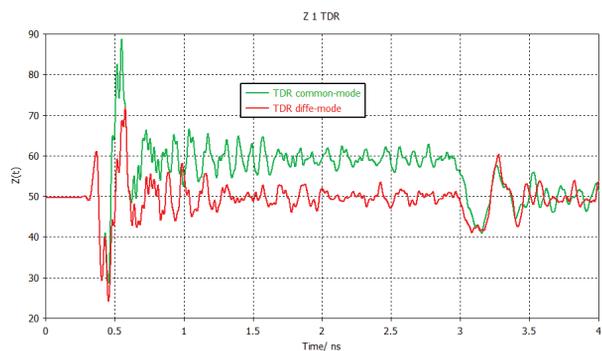Figure 5: S-parameters in simulation.

Figure 6: TDR in simulation.

TEST RESULTS

After more than one year of design and research, the first generation prototype has been processed. Special technology was adopted in vacuum chamber processing. It was divided into two halves along the longitudinal section, processed separately, then welded together. Weld seam is on the front of prototype. Assembly prototype with feedthrough is showed in Fig. 7. The installation and fixing of electrodes is a great challenge. In order to solve this problem simply and effectively, a set of PTEF fixed bracket was designed, which can locate and fix electrodes during installation.

Figure 7: The prototype assembled with feedthrough.

Feedthrough air side, connection cables, and high voltage pulse generator output ports are all FC26, not commonly used standard connector. So we cut two cables provided by FID company into four cables. Two ends of each cable are FC26 and standard N-type respectively, as shown in Fig. 8.

Figure 8: Fixed bracket(left) and processed cable(right).

Assembled kicker is connected to Keysight E5071C Network Analyzer by processed cables and be measured S-parameters. The test setup is showed in Fig. 9.

Figure 9: The test setup.

The result of measurement is slightly worse than that of simulation. Possible reasons are analysed. Firstly, in simulation, coaxial line was used instead of feedthrough and extension part. Secondly, the connector between cable and feedthrough is FC26, which can not be calibrated. So measurement results include the loss on connecting cables. Thirdly, the connection between feedthrough and extension part and electrodes was not stable enough.

Figure 10: Single electrode TDR test by two port NA.

A two-port network analyzer with TDR function was used to test the TDR of a single electrode. Impedance mismatch can be observed at the connection point on feedthrough, extension and electrode, as shown in Fig. 10

Test with high voltage pulse generator was also done. Before connecting oscilloscope, three attenuators were connected with a total of -72.26 dB. Fig. 11 shows the comparison between direct output pulse of generator and output pulse after kicker. Voltage amplitude decreased by 6%.
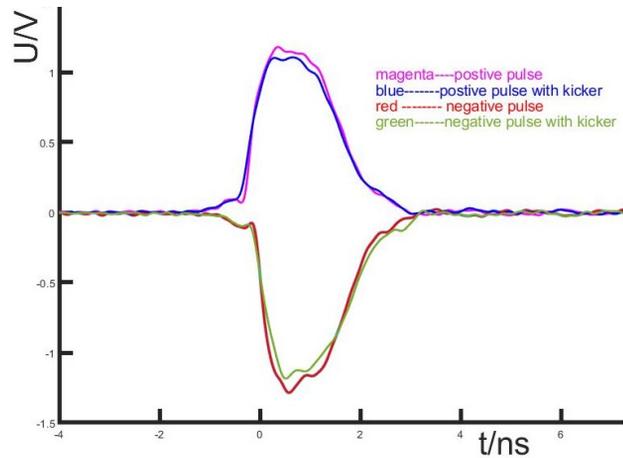

Figure 11: High voltage pulse test.

CONCLUSIONS

Based on measurement results, the following work need to be improved. Firstly, the adapter from FC26 to N type should be designed, then cables can be calibrated. Secondly, the method of more accurate electrode installation need to be explored. Thirdly, extension part should be further optimized to reduce mismatch and reflection. Next, we need to perform vacuum test. The measurement of beam coupling impedance by wire method is also in progress. The related components are being processed.

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