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DEVELOPMENT OF FAST KICKERS FOR THE APS MBA UPGRADE*

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Abstract

The APS multi-bend achromat (MBA) upgrade storage ring will support two bunch fill patterns: 48 singlets and a 324 singlets. A “swap out” injection scheme is adopted. In order to minimize beam loss and residual oscillation of the injected beam and to minimize perturbation of the stored beam during a swap-on injection, the rise, fall, and flat-top parts of the kicker pulse must be held within a 22.8-ns interval. Traditional ferrite-core-type kickers can’t meet the timing requirements; therefore, we decided to use stripline-type kickers. We have completed a preliminary design of a prototype kicker geometry. Procurement of the pulser supply and other components of an evaluation system is under way. We report the specification and design of the fast kicker and current status.

2-D KICKER MODEL

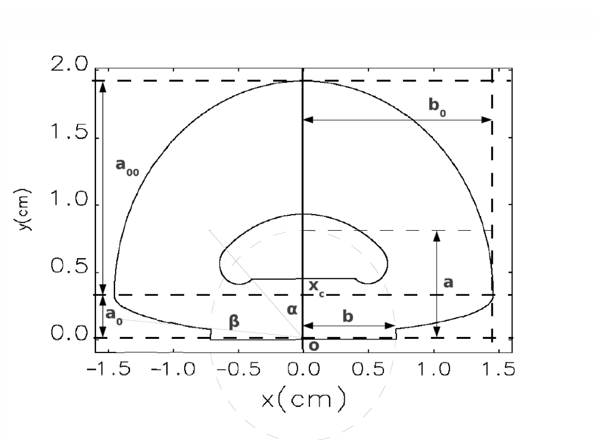

Figure 1: Geometry of the stripline kicker 2-D model.

The basic shape of the kicker stripline is shown in Figure 1. Specifications of the MBA injection/extraction kickers are listed in Table 1. Two-blade stripline type kickers with a line impedance of 50 Ω are selected, mainly due to fast rise and fall time, high voltage requirement and commercial availability of vacuum feedthroughs, connectors and cables. Similar devices have successfully been developed at KEK [1] and DAΦNE [2]. Impedance-matching plays an essential role in achieving maximum kicker strength, reducing local high-voltage concentration that can lead to breakdown, and minimizing beam impedances. Our optimization strategy is to match the differential impedance as close as possible to 50 Ω while allowing some mismatch in the common-mode impedance. A “vaned” outer body geometry is adopted to ease common-mode impedance-matching, while “D” shaped blades are used to improve field-uniformity in the good field region. The kicker has tapered end sections for matching impedance to the feedthroughs. Optimization is performed by running a multi-objective sddsoptimize [3] process with a 2-D simulation program [4]. Figure 1 shows the parametrization of geometry. The outer shell consists of two connected half-ellipses defined by the half axes (a0; b0) & (a00; b0), the center xc and the vanes on the horizontal axis. The inner blade is defined by an ellipse with axes (a, b), and by the thickness of the blade. Table 2 lists optimized parameters, and Figure 2 shows the 2-D E-field distribution. Results of the optimized parameters are shown in Table 2.

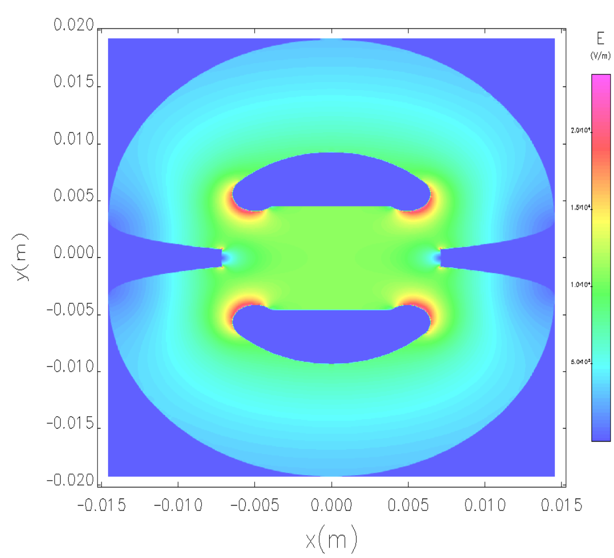

Figure 2: Field distribution of 2-D optimized model.

3-D MODELING

A 3-D simulation was performed with CST studio [5] in order to further verify 2-D result and to optimize the tapered part of the stripline kicker. The tapered parts are shown in Figure 3. Both the dimension of the body cavity and the width of the blades reduce gradually. The interface between the blade and the inner conductor of the feedthrough is under development. Optimization is performed on the blade width and the shape of the interface to minimize reflections. Figure 4 shows the TDR

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results and Figure 5 shows the S-parameters results, respectively.

Table 1: Specifications for the Fast Kickers

Total kick	2.88 mrad
Number of kickers	4
Length per kicker	0.72 m
Field uniformity	2%
Residual kick	2.5%
Aperture at kicker	9mm
Blade voltage	±15KV

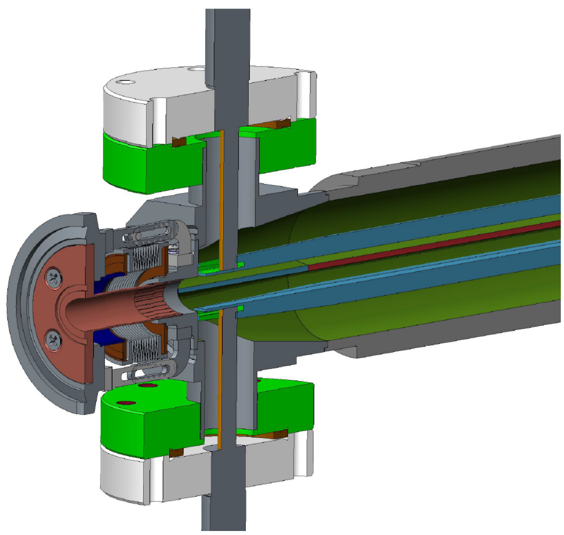

Figure 3: Tapered section of the stripline kicker model.

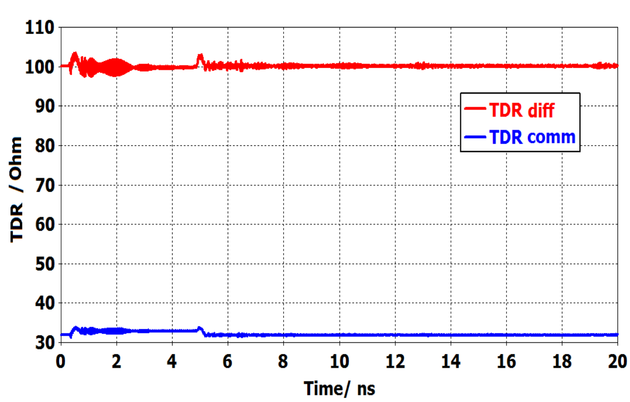

Figure 4: TDR of common and differential modes.

Table 2: Optimized Kicker Parameters

a	7.8 mm	b	7.15mm
α	43.83 deg	β	84.27 deg
a0	2.87 mm	a00	15.91mm
b0	14.54 mm	xc	19.19 mm

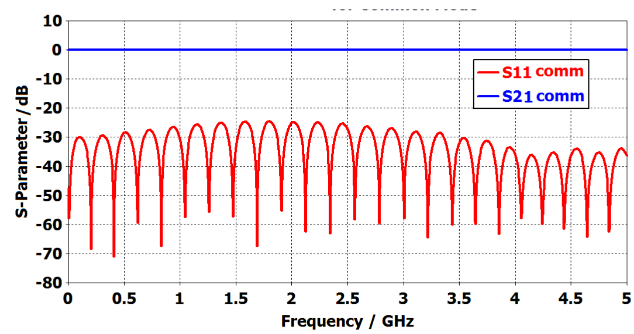

Figure 5: Common-mode S-parameters.

HIGH VOLTAGE FEEDTHROUGH

A survey of commercial rf feedthrough products showed that the majority of products have a voltage rating of less than 10kV. The few with higher voltage ratings do not meet our bakeout temperature and radiation resistance requirements.

We decided to work with Cosmotec to develop a special feedthrough that meets our requirements. The specifications for the feedthrough are listed in Table 3 and a simulation model is shown in Figure 6 [6].

Al_2O_3 ceramic is used for the insulation and vacuum seal. OFE copper is used for the inner conductor. On the air-side the insulation consists of both ceramic and PEEK material. The PEEK is part of a special connector supplied by Cosmotec.

The feedthrough design is simulated with CST MW Studio. Figure 7 shows the TDR result after optimization.

Table 3: High Voltage Feedthrough Specifications

Max. voltage	25 kV	Pulse rate	2Hz
Impedance	50±0.5 Ω	Max. Pulse width	30 ns
Bandwidth	1GHz	Peak current	500A

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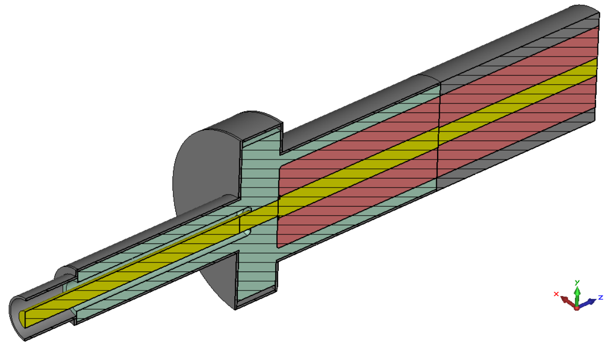

Figure 6: High voltage feedthrough model.

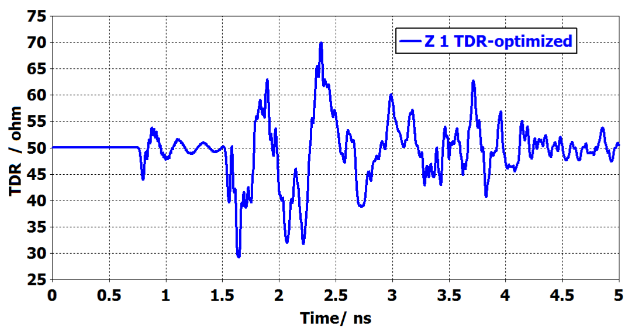

Figure 7: TDR result of the high voltage feedthrough.

BEAM IMPEDANCE SIMULATION

The fast kickers with a total length of 2.88 m and a blade distance of 9mm contribute a non-trivial part of beam impedance. The longitudinal impedance is estimated to 33Ω per kicker and the vertical impedance at low frequency is estimated to 0.9 MΩ/m [7]. These estimations do not include the effect of the tapered part and the feedthrough interface. Simulation will be performed on the final geometry to produce more accurate impedance data.

FORCE ON THE BLADES

An analysis of the force on the blades found that electric force and magnetic forces cancel each other in TEM mode, and net force exists only when there is reflection in the stripline. Based on the impedance matching of the kicker model the force is estimated at less than 100 g for a 15kV blade voltage, which is not a concern for the 3-mm thick blades. The feedthroughs are specified to sustain a maximum force of 9 kg and can support such a deflecting force.

TOLERANCES

Tolerances were assessed by performing 2-D simulation with variation of several geometry parameters. We concluded that a 25 um cross section tolerance would meet our needs. Further assessment with 3-D simulation will be performed.

POWER LOSS

Our simulation indicates power loss of 22.4 W into the kicker for a circulating beam of 200 mA in 48 bunch mode. The heat loss on the blade itself is estimated at 9 W per blade. The heat loss on kicker body is estimated at only 2.4 W. Our main concern is heating of the blades. We may decide to plate the blade surface with a more conductive material to reduce loss.

TEST PLAN

We plan to perform bench test of the kickers with a dual output FID pulser and high voltage attenuators. We also plan to install the kicker in the beam dump transport line (BTX) and use the Booster beam for a beam test. A beam profile monitor will be designed and installed to characterize the kicker with the beam.

CURRENT STATUS

We completed the simulation of the kicker geometry and the parts for a prototype kicker are in the procurement process. The feedthrough design has been finalized with the vendor and will be manufactured and delivered in the coming month. Two FID pulsers with differential output have been delivered and are undergoing high voltage and reliability tests [8].

CONCLUSION

We have completed the simulation of a fast stripline kicker for the MBA upgrade. The main challenges are the fast rise and fall time, and high voltage required to deflect the 6 GeV beam. Manufacturing of the feedthroughs and kicker part are under way and we have plans for both bench and beam test of the kicker.

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REFERENCES

[1] T. Naito et al., “Multibunch beam extraction using the strip-line kicker at the KEK accelerator test facility,” Phys. Rev. ST Accel. Beams, 14:051002, 2011.
[2] D. Alesini et al., “Design, test, and operation of new tapered stripline injection kickers for the e+e- collider DAΦNE,”. Phys. Rev. ST Accel. Beams, 13:1111002, 2010.
[3] L. Emery et al., “User's Guide for SDDS-compliant EPICS Toolkit Version 1.5,” http://www.aps.anl.gov/
[4] M. Borland, private communications.
[5] “CST Microwave Studio,” https://www.cst.com /Products/CSTMWS.
[6] Cosmotec, Inc., private communications.
[7] A. Blednykh, private communications.
[8] F. Lenkszus, et al., “Fast Injection System R&D for the APS Upgrade,” These proceedings, TUPJE069.