PRELIMINARY TEST RESULTS OF A PROTOTYPE FAST KICKER FOR APS MBA UPGRADE*

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Abstract

The APS multi-bend achromatic (MBA) upgrade storage ring plans to support two bunch fill patterns: a 48-bunch and a 324-bunch. A "swap out" injection scheme is required. In order to provide the required kick to injected beam, to minimize the beam loss and residual oscillation of injected beam, and to minimize the perturbation to stored beam during injection, the rise, fall, and flat-top parts of the kicker pulse must be within a 16.9-ns interval. Stripline-type kickers are chosen for both injection and extraction. We developed a prototype kicker that supports a ±15kV differential pulse voltage. We performed high voltage discharge, TDR measurement, high voltage pulse test and beam test of the kicker. We report the final design of the fast kicker and the test results.

INTRODUCTION

A prototype stripline kicker was developed for the APS MBA upgrade storage ring. Its design was reported in IPAC15 [1]. Further optimization of the kicker model was performed. Fabrication of the kicker and feedthroughs started February of 2016. The kicker was delivered recently. We performed a series of tests of the kicker. We report the final design of the kicker and the test results.

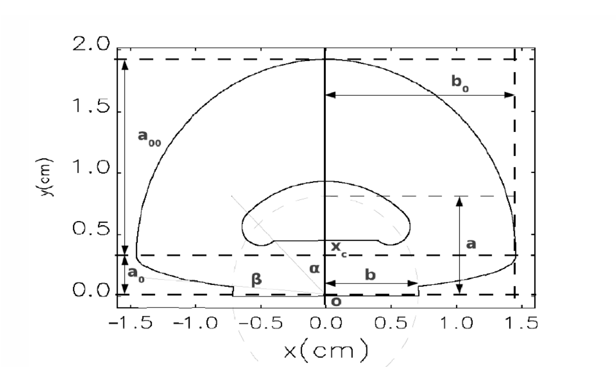

Figure 1: Geometry of the stripline kicker 2-D model. With these parameters: a=7.8 mm, b=7.14 mm, α = 43.83°, a0= 2.87mm, a00=15.91 mm, b0=14.54 mm, blade thickness=3.0 mm.

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FINAL KICKER GEOMETRY

CST Microwave Studio [2] was employed in the optimization simulation of the kicker and feedthrough. We used its frequency domain solver to perform 3D impedance and field simulation, and optimization of the matching of the interface between the feedthroughs and the kicker blades. We also use its time-domain tool to evaluate the impedance of a Gaussian beam bunch. CST MW studio has TDR simulation. We compared its results with TDR measurement of the kicker [3]. A final geometry was selected. Figure 1 shows the main cross-section of the final geometry and its parameters. Figure 2 shows a 3D model of the kicker.

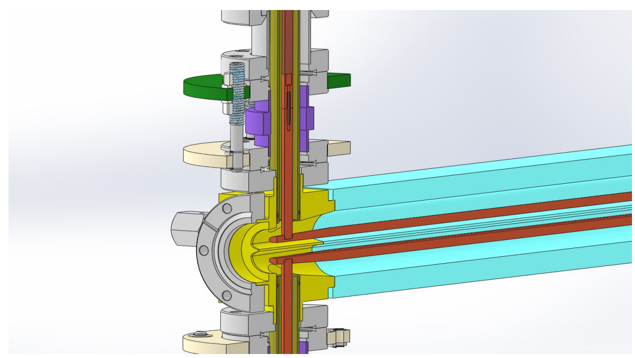

Figure 2: A plot of the kicker design model.

FEEDTHROUGH DESIGN

The feedthroughs are critical components. They serve as insulator, vacuum seal and blades support. Their impedance must match to 50 Ω. Because of the location of the kickers, they must be able to sustain bake-out at 150 C° and high radiation. The air-side breakdown voltage is of particular concern. We decided to collaborate with COSMOTEC to develope the feedthroughs. Figure 3 shows a plot of the final feedthrough model. Figure 4 shows a photo of a feedthrough.

KICKER FABRICATION AND ASSEMBLY

The kicker was designed with collaboration of APS and Argonne Physics Department. Argonne Physics Department assembled the kicker. The kicker assembly was delivered on August 18. Testing of the kicker started right after that. Figure 5 shows a photo of the installed kicker assembly.

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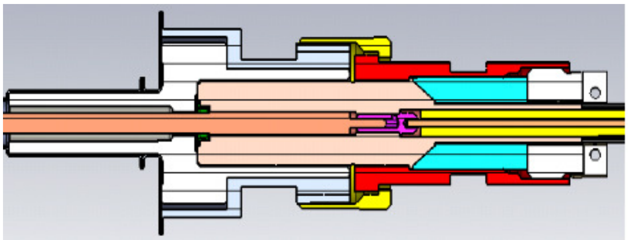

Figure 3: Cross-section view of the feedthrough and air-side connector model.

Figure 4: Feedthrough picture.

Figure 5: The kicker installed in the BTX beamline.

HIGH VOLTAGE PARTIAL-DISCHARGE TEST

Partial-discharge tests were conducted on the feedthroughs and kicker assembly. A Phenix Partial Discharge Detector was used for the test and we applied up to 9 kV. Measured inception voltages were 8.5 kV and 9 kV for the top and bottom blades, respectively. Since the maximum rating of the cable is only 5.6kV(rms) these results show the inception voltage is above 9kV.

TDR TEST

TDR (time domain reflectometry) tests were conducted on the feedthroughs and kicker assembly. Figure 6 shows the differential results for the kicker assembly. The measured results are in good agreement with the results of CST MW simulation[2]. Main mismatches are in three places: (1) a 67 Ω mismatch at the cable connectors; (2) a 37 Ω mismatch at the ceramic seal of the feedthroughs.

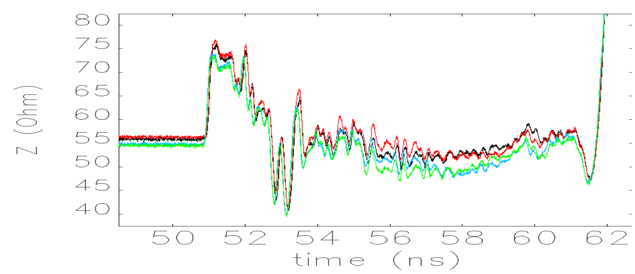

Figure 6: Differential TDR measurement results of the fast kicker. Each colour represents data from one port.

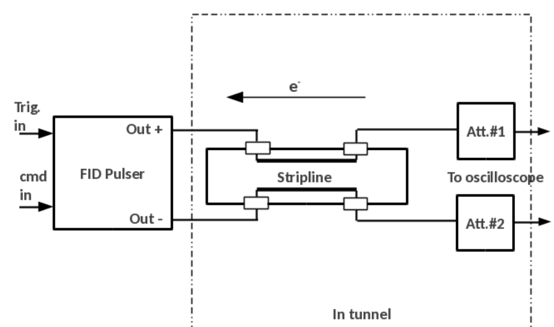

Figure 7: Connection diagram for pulse and beam test of the fast kicker.

HIGH VOLTAGE PULSE TEST

An FID dual-channel high voltage pulser is employed for this test. Figure 7 shows a connection diagram for the test. Figure 8 shows scope waveforms of the positive and negative return signal with 15kV pulse amplitude. Measured amplitude reduction through the kicker is about 2%, excluding cable losses. Stability of the waveform amplitude is around 0.5%. The kicker was tested with 20kV pulse amplitude for more than 48 hours and showed no discharge or vacuum activity.

KICKER BEAM TEST

The kicker has been installed in the Booster to Beam Dump (BTX) beamline. Figure 9 shows the location and its surrounding area. A 7GeV Booster beam was used for the test. A Yttrium aluminium garnet (YAG) screen is installed downstream for kick angle measurement.

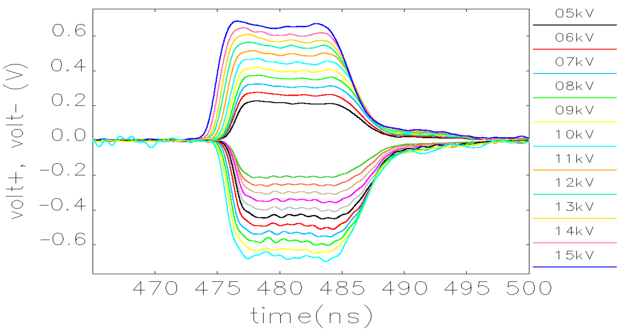

Figure 8: Return scope waveforms of the positive and negative channels.

Figure 10 shows the beam spot movement when the kicker amplitude is increased from 0 to 15kV. And Figure 11 shows the processed beam y-centroid data. The processed slope is: 199.0 µm/kV and a kick angle of 0.64 mRad at 15kV kicker amplitude.

CONCLUSION

We have successfully developed a stripline fast kicker prototype for the APS MBA upgrade. Test results of the kicker assembly showed that it produced a deflecting angle of 0.64 mRad for a 7GeV, or 0.75 mRad scaled to 6GeV beam energy, which exceeds the requirement of 0.72 mRad. We did not experience any issues with HV breakdown at 20kV pulse amplitude. A 6% amplitude reflection was observed. This needs to be addressed in future pulser and kicker improvement. Further tests of beam impedance and rf heating are necessary in order to fully characterize the kicker performance in storage ring environment.

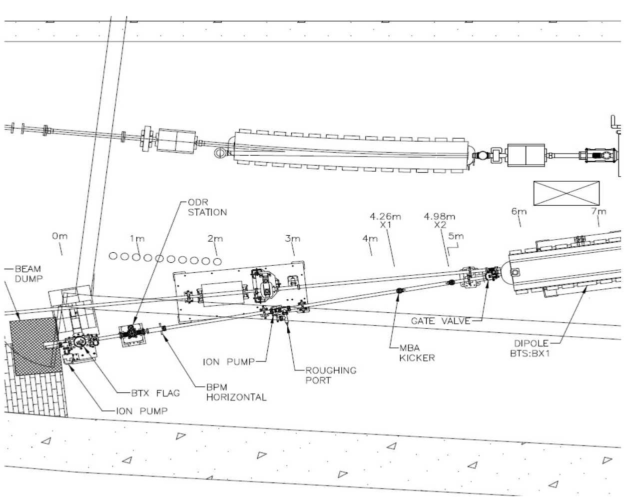

Figure 9: Kicker installation location. A YAG screen is located 4.64 m downstream of the kicker for kick angle measurement.

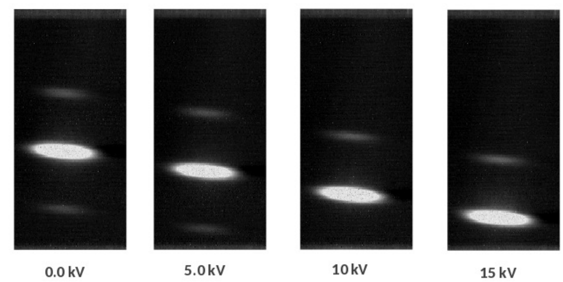

Figure 10: Beam spot movement when kicker amplitude varies from 0 to 15kV.

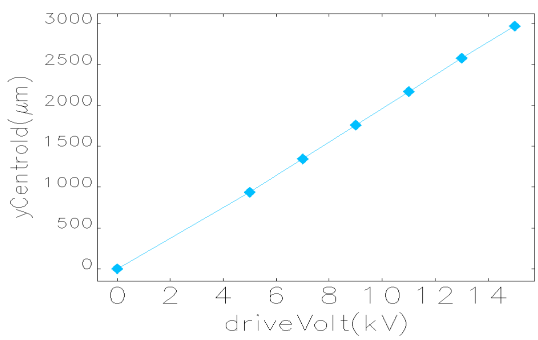

Figure 11: Measured y-centroid position vs kicker amplitude.

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REFERENCES

[1] C. Yao et al., "Development of Fast Kickers for the APS MBA Upgrade," in *Proc. IPAC15*, pp. 3286-3288.

[2] "CST Microwave Studio," https://www.cst.com /Products/CSTMWS.

[3] X. Sun *et al.,* "simulation studies of a prototype stripline kicker for the aps-mba upgrade," presented at NAPAC2016, Chicago, IL, USA, October 2016, paper WEPOB16, this conference.