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THE RF BPM PICKUP ELECTRODES DESIGN FOR THE APS-MBA UPGRADE*

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Abstract

The Advanced Photon Source (APS) is currently in the preliminary design phase for a multi-bend achromat (MBA) lattice upgrade. Beam stability is critical for the MBA and will require roughly 570 rf beam position monitors (BPMs) to provide the primary measurement of the electron beam trajectory through the insertion device (ID) straight sections and in the storage ring arcs. The BPM assembly features 8 mm diameter pickup electrodes that are welded to a stainless steel chamber and integrated shielded bellows both upstream and downstream of the chamber to decouple the BPM electrodes from mechanical motion of adjacent chambers. The design, simulations, and prototype test results will be presented.

INTRODUCTION

The APS Upgrade project (APS-U) requires rf BPMs at roughly 570 locations in the APS storage ring to achieve the beam stability requirements outlined in Table 1 [1]. For the preliminary design, the horizontal AC rms beam stability requirement is based on 10% the rms beam size at the ID source points from 0.01 to 1000 Hz, while the vertical requirement in microns will remain at the conceptual design values, with 10% of beam size being an operational goal. In addition, long-term drift over a 7 day period may be no more than 1 µm.

Table 1: MBA Beam Stability Requirements

Plane	AC rms Motion (0.01 – 1000 Hz)	Long-term Drift (100 s – 7 days)
Horizontal	1.3 µm 0.25 µrad	1.0 µm 0.6 µrad
Vertical	0.4 µm 0.17 µrad	1.0 µm 0.5 µrad

THE RF BPM PICKUP ELECTRODES R&D OVERVIEW

The four pickup electrodes used in each BPM are evenly distributed circumferentially around the circular MBA beam pipe and provide the primary measurement of the electron beam trajectory in the storage ring. Their sensitivities, charge induced voltages and wake impedance are all critical for the beam stability.

"As-built" 10.8 mm diameter APS button pickup electrodes and the elliptical APS standard chamber were modelled as shown in Fig. 1. The simulation was made using CST Microwave Studio (MWS) [2] for 24-siglet fill pattern 102 mA (15 nC per bunch, rms bunch length 10 mm). Measurements on as-built BPM electrodes installed in the existing APS storage ring were also made to validate the simulation model. Simulation results agreed well with the measured data, as shown in Fig. 2.

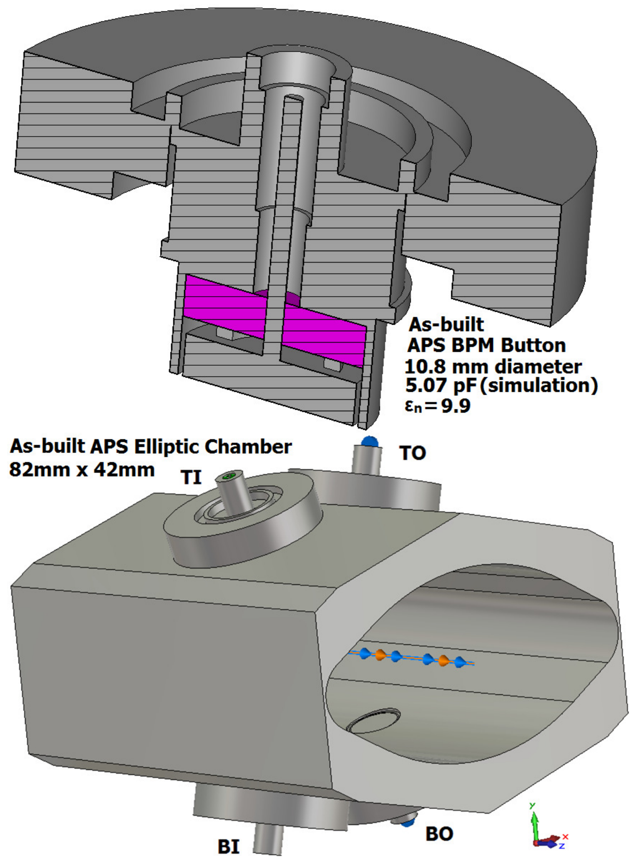

Figure 1: As-built APS BPM button and elliptic chamber.

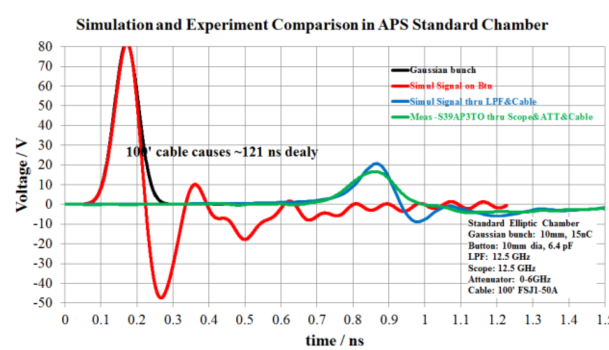

Figure 2: Simulation and experiment in APS elliptic chamber with BPM.

An MBA pickup electrode design has been developed which is essentially a scaled version of that for existing APS BPMs to match the planned MBA beam pipe aperture.

To help validate the new design, two sets of four prototype button pickup electrodes were purchased from two independent suppliers (vendors A and B) and then bench

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tested. One of the sets, from vendor B, was delivered fully assembled into a vacuum chamber assembly with two rf-shielded bellows, as planned for APS-U, shown in Fig. 3.

Figure 3: MBA integrated BPM / rf-lined bellows from vendor B.

Experience with the prototype pickup electrode assembly and integrated shielded bellows informed design improvements to both. The outer shell of the pickup electrode was thinned to reduce the heat required to weld the part to the chamber and reduce the amount of heat conducted to brazed joints. A decision was also made to use an alternative bellows rf liner scheme, which uses leaf springs to maintain contact between the flexible and rigid portions of the bellows liner.

MBA PICKUP ELECTRODE DESIGN

Design goals for button pickup electrodes are exceptional sensitivity, high charge induced voltage on the button to maximize signal-to-noise ratio, and low wakefield impedance. The pickup electrode design parameters are shown in Table 2.

Table 2: MBA BPM Pickup Electrode Design Parameters

Fill Pattern	Mode	Current (mA)	Single Bunch Current (mA)	Bunch Charge (nC)	Bunch Length (ps/mm)
48	User	200	4.2	15.34	75.8/22.7
324	User	200	0.6	2.27	56.1/16.8
Single	Studies	1	1	3.68	57/17.1

The baseline model was designed, simulated, and optimized based on a trade-off analysis of critical parameters. The cross section of the final design is shown in Fig. 4.

INTEGRATED BPM / RF-LINED BELLOWS DESIGN

The MBA button pickup electrodes are welded to a stainless steel chamber, which is integrated within a pair of rf-lined welded bellows to minimize mechanical motion due to thermal growth and vibration on adjacent vacuum chambers [3, 4]. The "outside fingers" design, shown in Fig. 4, will reduce or eliminate error in the electrode signal due to displacement of the rf fingers as is expected with heating of the BPM assembly and neighboring chambers by synchrotron radiation and induced surface currents.

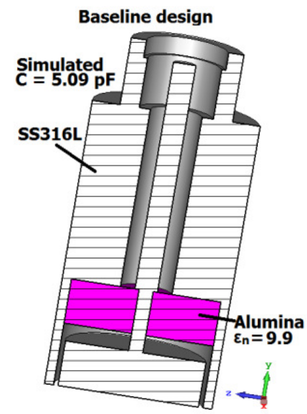

Figure 4: 8 mm diameter MBA button pickup electrode baseline design.

The beam power loss and the power dissipation on the metals and loads for full BPM assembly indicated by simulations using CST MWS and assuming a 48-siglet fill pattern at 200 mA (15 nC per bunch, rms bunch length 21 mm) is shown in Fig. 5 and summarized in Table 3.

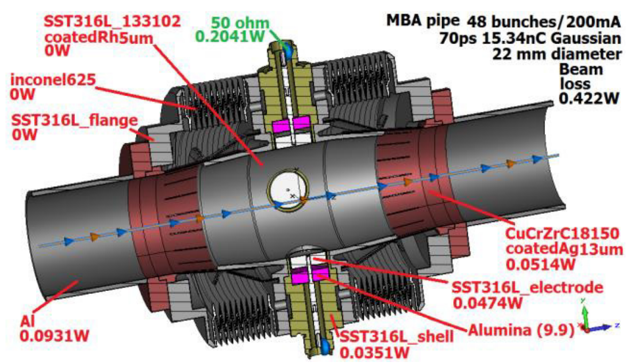

Figure 5: The simulated beam power loss and the power dissipation in MBA integrated BPM / rf-lined bellows with "outside fingers' and chamber.

Table 3: Simulated Beam Power Loss and Power Dissipation in MBA Integrated BPM/rf-lined Bellows with "Outside Fingers" and Chamber

200 mA/48 Fill Pattern, Bunch Length 21 mm	Metals	Four Loads (50 Ω)	Beam Power Loss
Subtotal (W)	0.227	0.204	
Total (W)	0.43		0.42

The charge induced voltages on the pickup electrodes for different beam offsets were also found using simulations, (Fig. 6). The computed sensitivity is found to be 0.117 mm^{-1} which compares favorable with existing APS button sensitivities of 0.058 mm^{-1} (horizontal) and 0.055 mm^{-1} (vertical plane).

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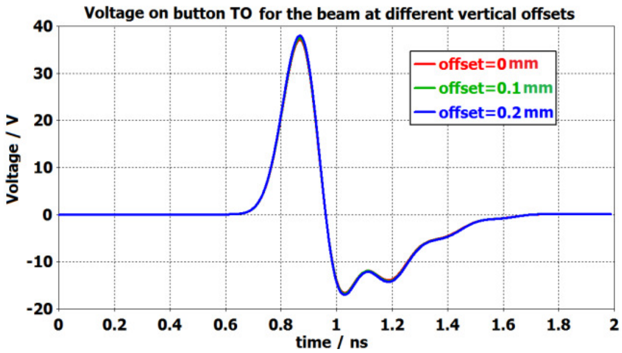

Figure 6: Simulated charge induced voltages on the MBA pickup electrodes for the beam at different vertical offsets.

THE PICKUP ELECTRODE PROTOTYPES TESTING

Each of the vendors that supplied the prototype button electrodes suggested modifications to the design to better accommodate their fabrication processes. None of these modifications were found to have a significant impact on performance.

Dimensional checks of the prototypes received from both vendors were generally good. Vacuum leaks and distortion of the center conductor were found in the electrodes provided by vendor B, however it is believed that these occurred as a consequence of overheating during welding of these to the chamber.

Electromagnetic measurements were made and compared with simulation results. The set of four button pickup electrode prototypes from Vendor A was measured by time-domain reflectometry (TDR). The results of TDR test and TDR simulation are shown in Fig. 7 and they agreed well.

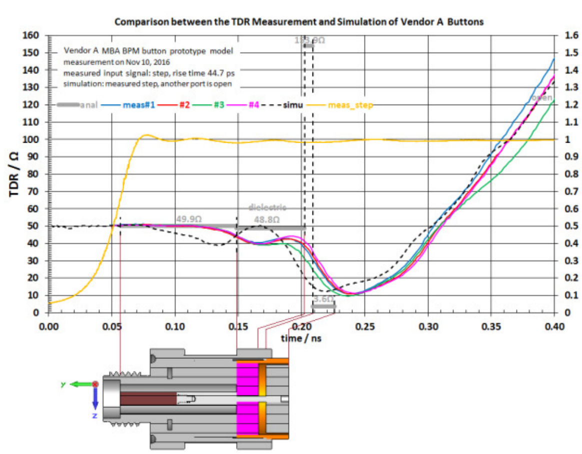

Figure 7: Vendor A BPM button TDR measurement, analysis and simulation.

The capacitances of the buttons provided by Vendor A were measured and calculated using different methods. The results are summarized in Table 4.

Table 4: Vendor A Button Pickup Electrode Capacitance

Analytic	**Simulated**		**Lab Measured**	
formula	**Static**	**Smith Chart at 352 MHz#**	**Capacitance Meter**	**Network Smith Chart at 352 MHz#**
4.12	4.70	5.02	4.1	3.85
			4.2	4.00
			4.4	4.19
			4.2	3.95

simulated or measured from the SMA end.

A transmission (S_{21}) measurement on a pair of pickup electrodes was made using the setup shown as Fig. 8. A G10 (a high-pressure fiberglass laminate) tube supports the two electrodes with buttons facing each other. The support also allows the gap between the two buttons to be adjusted.

The transmission between two prototype buttons from Vendor A was measured back-to-back with 5 mm gap and the results are shown in Fig. 9. The measurements of different buttons were consistent and agreed well with the simulation.

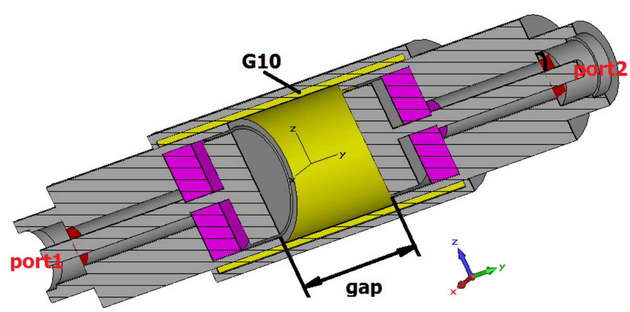

Figure 8: Transmission (S_{21}) of buttons back-to-back measurement setup.

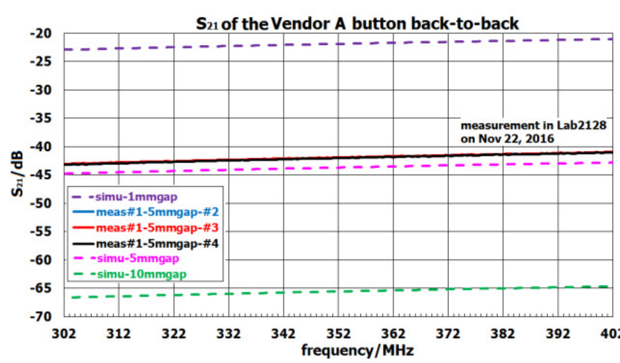

Figure 9: S_{21} comparison of the measurement and simulation between two buttons from Vendor A in back-to-back setup with 5 mm gap.

CONCLUSION

The APS "as-built" 10.8 mm diameter button pickup electrode and elliptic standard chamber were modelled and simulated. The model and simulation was validated by beam measurements.

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The MBA button pickup electrode baseline model has been analysed and designed. Prototypes have been manufactured and measured. The results of analysis, simulation and measurement were consistent. The dimensional and electric checks of the button pickup electrode prototypes from Vendor A were good.

The MBA BPM assembly integrated inside pair of rf-lined welded bellows has been designed and optimized. Its electromagnetic performance was simulated. It will be bench tested in the lab and beam tested in APS storage ring.

ACKNOWLEDGMENT

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