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ELECTROMAGNETIC BENCH TESTING OF ALS UPGRADE BEAM POSITION MONITOR BUTTONS AND ASSEMBLIES

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Abstract

The ALS Upgrade Project (ALS-U) consists in the replacement of the existing ALS storage ring and the addition of a new accumulator ring in order to decrease the horizontal beam emittance to about 70 pm rad, resulting in an increase of two orders of magnitude in the soft X-Ray brightness. The vacuum chambers of two new rings, and of the transfer lines connecting them, will include 327 new beam position monitors (BPM). The design of these BPM is now completed and relies on the procurement of about 1,500 BPM buttons (including spares and prototypes) from commercial suppliers and their installation on the BPM chamber enclosures. Our design includes more than a dozen different BPM designs and almost as many different buttons. All the buttons, as well as the assembled BPM, have to undergo vacuum and RF testing to characterize them and detect defective units before their installation. In this paper, we describe our electromagnetic testing plan and report on the results covering the entire button production for the accumulator ring and the prototypes for the storage ring, as well as the electromagnetic (EM) measurement for the assembled ALS-U Accumulator Ring (AR) BPMs.

INTRODUCTION

The ALS Upgrade Project (ALS-U) [1] consists in the replacement of the existing ALS storage ring and the addition of a new accumulator ring in order to decrease the horizontal beam emittance to about 70 pm rad, resulting in an increase of two orders of magnitude in the soft X-Ray brightness. The vacuum chambers of two new rings, and of the transfer lines connecting them, will include 327 new beam position monitors (BPM). About 1500 BPM buttons (including spares and prototypes) are produced from the commercial vendors. The assembly of the BPM blocks are carried out at both LBL machine shop and the commercial vendors. Comprehensive mechanical, vacuum, electromagnetic and beamline testings have been carried out to validate the design, characterize the product and detect defective units before their installation. In this paper, we mainly focus on the electromagnetic (EM) bench testing and one beam testing at ALS.

OVERVIEW OF ALS-U BPM SYSTEMS

The beam position monitor system is an essential diagnostic instrumentation for ALS-U. There are 72 BPMs in Accumulator Ring (AR), 235 BPMs in Storage Ring, and dozens in the transfer lines. The 69 out of the 72 BPMs in AR are regular round BPM with a ID of 30 mm. Four capacitive buttons with a diameter of 8mm are assembled on the BPM housing at 45, 135, 225 and 315 degree respectively. The remaining 3 BPMs are of elliptical housing, with two buttons on the top and two on the bottom. The 235 BPMs in SR are more diversified with two button sizes (ID of 4 mm and 6 mm) and various chamber geometries, as shown in Fig. 1. For all types of BPMs, we have calculated their transfer impedance and horizontal/vertical sensitivities. For many SR BPMs with "keyholes", we have also calculated their inherent horizontal electrical center offset due to the asymmetric chamber.

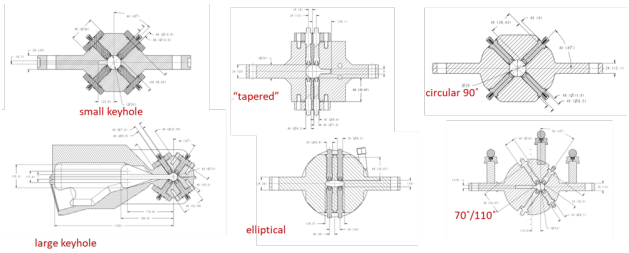

Figure 1: Some of the SR BPMs, showing the variety of the SR BPM structures.

BPM ELECTROMAGNETIC BENCH TESTING PLAN

The BPM EM bench testing is carried out for both the individual buttons and the BPM assembly blocks. The EM testing is highly integrated with mechanical/vacuum testing, vendor manufacturing and ALS-U beamline pre-staging.

Button Testing

In the button testing, the parameters to be checked include the capacitance, the characteristic impedance and the ground isolation. The capacitance is measured by S11 from the Vector Network Analyzer (NWA) with an appropriate electric delay [2]. The characteristic impedance is measured by the Time Domain Reflectometer (TDR). The ground isolation is checked by a voltmeter.

For the prototype buttons, the above three parameters are measured for every button, to thoroughly validate the design and evaluate the production quality.

For the production buttons, capacitance measurement is carried out on every button. Then the buttons are grouped into 4 based on their capacitance, to make sure the 4 buttons installed on the same BPM assembly block have close capacitance. Characteristic impedance and ground isolation

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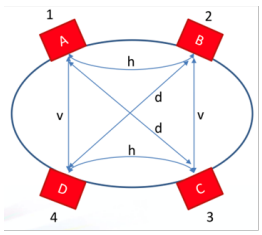
are checked for one button out of ten to monitor the overall quality of the batch.

BPM Assembly Block Testing

For the BPM assembly block, any mechanical imperfection in the buttons or chamber can cause an artificial offset of the electrical center, thus the beam position errors. For ALS-U, the electrical center offset is required to be within 100-200 um. After the buttons are installed on the BPM chamber, the RF testing is carried out to check the electrical center offset. If the offset is out of the spec but not by much, fine tuning of the button insertion will be carried out to bring the offset back to the acceptable range.

The center offset is measured by the Lambertson method [3]. With a 4-port NWA, we measured the transmission coefficients between each port at 500 MHz and calculated the center offset from the S parameters, as illustrated in Fig. 2, whereS_x and S_y are the horizontal and vertical sensitivity. Notice that the magnitudes of A, B, C and D correspond to the induced signal strength at each port, thus can indicate which button to be adjusted if the initial offset is out of the spec.



Unknown gains A, B, C, D can be determined via S parameters:

$$A = cost.\sqrt{\frac{S_{21}S_{14}}{S_{42}}}$$

$$\Delta x = \frac{1}{S_x}\frac{A+B-C-D}{A+B+C+D}$$

$$\Delta y = \frac{1}{S_y}\frac{A+D-B-C}{A+B+C+D}$$

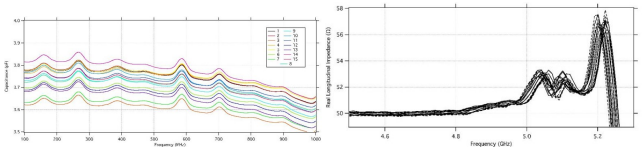
Figure 2: Lambertson method for measuring the electrical center offset.

The center offset's response to the environment impact is also examined, including the thermal cycle, the mechanical shock, the vacuum, the chamber baking, etc.

AR BPM TESTING

Button Testing

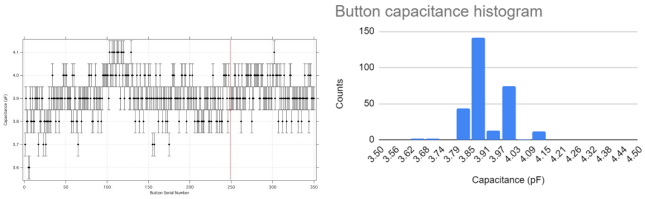
Before committed to the full production, we first tested a batch of prototype buttons from the vendor. The capacitance and impedance measurements of 15 AR BPM prototype buttons are shown in Fig. 3. These tests verify both the targeted EM parameters and the production consistency.



(a) Capacitance (b) Characteristic impedance

Figure 3: EM bench testing of 15 AR BPM button prototypes.

For the 350 AR production buttons to be installed on the beamline, the capacitance is measured for every button, as shown in Fig. 4. Only one button was found to be faulty with a shorted capacitive gap and was removed. Characteristic impedance and ground isolation were measured on randomly selected 44 buttons.

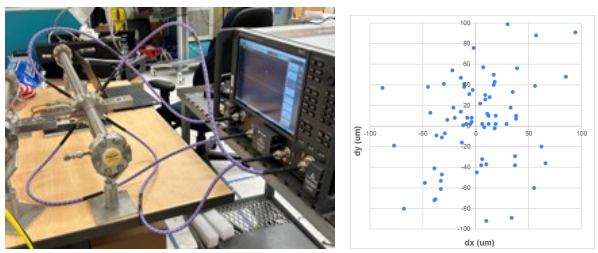


(a) Capacitance values (b) Capacitance histogram

Figure 4: Capacitance of 350 AR BPM production buttons.

BPM Block Assembly Testing

The assembly of the AR BPM is carried out at LBL machine shop. Once the vacuum group finishes assembling one BPM block, the diagnostic group is called upon to carry out the EM testing to check the electrical center offsets. The measurement setup based on the Lambertson method is shown on the left of Fig. 5.



(a) Measurement Setup (b) Center offsets results

Figure 5: AR BPM assembly block electrical center measurement by Lambertson method.

Out of the 72 assemblies we measured, 4 assemblies have an initial electrical center offset larger than 100 um which is the specified threshold for AR. From the A, B, C, D value in the Lambertson method, we can decide which button should be inserted more. The bolts on the flange are slightly tightened to push down the button more into the chamber housing, and the center offset is re-measured. It can be iterated a few times until the offset is reduced to below 100 um. Eventually, all the BPM centers are within the spec, as shown on the right of Fig. 5. With all the 72 blocks measured and tuned, the EM bench testing on the AR BPMs has concluded.

To better understand the relation between the torque on the button flange bolts and the electrical center offset, we carried out a test with a prototype block. Starting from a fresh gasket and putting on a button "just-touching", we gradually tightened the flange bolts with an increasing torque, and measured the electrical offset at each increment of the torque, as shown in Fig. 6. This test gives us a quantitative

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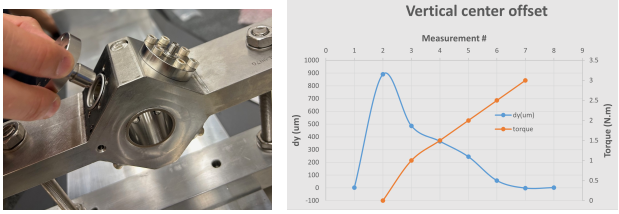
understanding of how much offset we can adjust by this bolt-tightening method without undermining the vacuum.



(a) Button and fresh gasket (b) Offset and torque variation

Figure 6: Study on the relation between the torque on the flange bolts and the center offset on AR BPM block prototype.

SR BPM TESTING

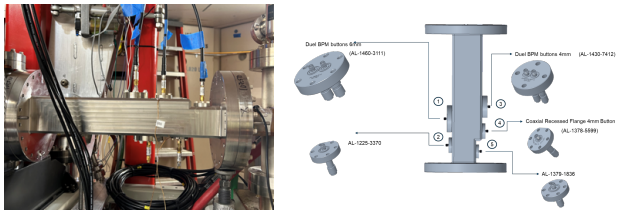
The SR BPM system is more complex than the AR in terms of BPM numbers and geometry variations. Also due to the smaller chamber size, the same amount of structure error will induce larger position error in SR than AR. The experience learnt from AR will considerably benefit the development of the SR BPM system.

Prototype Button Bench Testing

Due to the large number of the buttons in SR, we have engaged three vendors for potential button production. After receiving the prototypes of each type of button, we carried out the EM bench test similar to AR. Based on the measurement results, some buttons have been re-designed and re-fabricated by the vendor to improve their performance. The testing validates the buttons' design and provides information for vendor selection.

Beam Testing at ALS

A testing chamber was made to accommodate five different types of SR buttons for the beam testing at ALS, as shown in Fig. 7. With a 500 mA full current, no heating was observed with multiple thermal couplers attached to the chamber body. The power spectrum of the BPM output signal shows no resonance except the expected ALS beam spectrum. These results validate the good RF seal between the button stem and the vacuum housing, retiring a major concern on the potential trapped modes in the BPM buttons.



(a) Testing chamber on ALS (b) Model of the buttons and chamber

Figure 7: AR BPM assembly electrical center measurement by Lambertson method.

CONCLUSION

In this paper, we present the EM bench testing for the ALS-U BPMs. Detailed and thorough testing plan has been made for both the buttons and the assembly blocks. For buttons, we check their key EM parameters and prepare them for the assembly. For the assembly block, the focus is to measure the electrical center offset and make fine tuning if necessary. The EM bench testing is a key step to achieve the required beam position accuracy for ALS-U.

ACKNOWLEDGEMENTS

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REFERENCES

[1] C. Steier *et al.*, "Design Progress of ALS-U, the Soft X-ray Diffraction Limited Upgrade of the Advanced Light Source", in *Proc. IPAC'19*, Melbourne, Australia, May 2019, pp. 1639–1642. doi:10.18429/JACoW-IPAC2019-TUPGW097

[2] A. Blednykh *et al.*, "NSLS-II Storage Ring BPM Button Development", in *Proc. IPAC'15*, Richmond, VA, USA, May 2015, pp. 748–750. doi:10.18429/JACoW-IPAC2015-MOPMN021

[3] G. R. Lambertson, "Calibration of position electrodes using external measurements", LSAP Note-5, Lawrence Berkeley Laboratory, 1987.