Performance of the SLAC-PAL-Vitzrotech X-band Cavity BPMs in the LCLS-II Undulator Beam Lines*

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LCLS-II

ABSTRACT

The hard X-ray and soft X-ray undulator beamlines of the LCLS-II X-ray FEL incorporate dozens of X-band RF beam position monitors for accurate tracking of the electron beam trajectories and Beam-Based Alignment. For this crucial function, a design was jointly developed between PAL and SLAC, consisting of a monopole reference cavity and a dipole position cavity, with signals coupled out through coaxial vacuum feed-throughs. For the relatively large quantity needed, the production of completed units was contracted to the Korean company Vitzrotech, who developed the manufacturing process to successfully fabricate the needed quantity. Herein, an overview is given of the production experience, tuning, installation and performance of these devices.

INTRODUCTION

The LCLS-II free electron laser at SLAC requires monitoring of the beam position with sub-micron level resolution in both x and y. The device chosen by the project to achieve this is an X-band cavity beam position monitor, or RFBPM, of a unique configuration whose design was developed over the last couple of decades [1], [2], [3]. It consists of two independent resonant cavities, dipole and reference, with signals coupled out through coaxial vacuum feed-throughs. A distinguishing feature benefiting sensitivity is the magnetic coupling of the dipole cavity fields into side waveguide stubs in a way that shields the pickups from the monopole mode [4]. The design adopted had been recently deployed in the PAL-XFEL in Pohang, Korea. For production of the 65 units required in the soft X-ray and hard X-ray undulator beamlines of LCLS-II, the technology was transferred to the Korean industrial firm Vitzrotech in Gyeonggi-do. The full complement of RFBPMs was completed, installed and recently commissioned at SLAC.

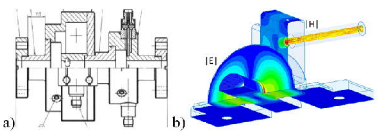


Figure 1: a) cutaway and external view of RFBPM geometry and b) field simulation of dipole cavity coupling.

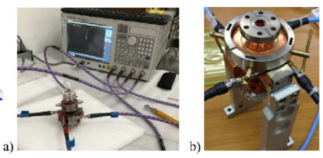


Figure 2: a) RF testing on 4-port network analyzer and b) fine tuning of cavity with tuning collar and tools.

PRODUCTION EXPERIENCE

Roughly a hundred units in total were fabricated over a 2–3 year production span. Problems were encountered and overcome by Vitzrotech, with consultation from SLAC and PAL. These included issues with the multi-stage brazing integrity, coupling β variation, *x-y* dipole mode frequency spread, and, most frequently, vacuum leaks through one or more of the 6 coaxial feed-throughs per unit. By the final batch of 18 units delivered not a single failure was encountered.

TABLE 1: Cavity Specifications and Statistics

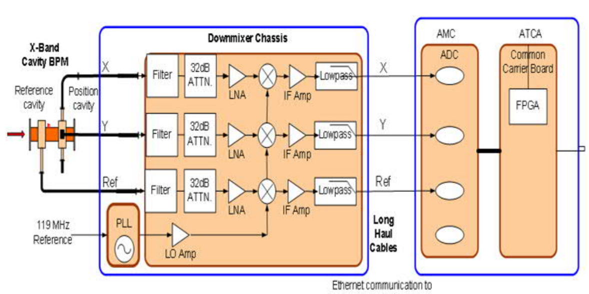
Cavity	Param.	Specification	Average	SD
ref.	f_r (GHz)	11.424±0.01	11.4234	.0012
	Q_L	1,700–2,800	2,511	180
	β_{tot}	1.25–2.1	1.486	0.219
	Q_0	5,200–6,700	6,227	542
dipole	f_r (GHz)	11.424±0.01	11.4234	.0017
	Q_L	1,900–3,000	2,425	204
	β_{tot}	1.25–2.1	1.729	0.174
	Q_0	5,800–7,300	6,619	592

Figure 3: Dressed and mounted for beamline integration on undulator girder.

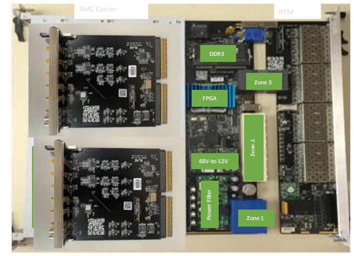
Electronics Design

In order to achieve the required performance, the SLAC Technical Innovation Directorate has developed a common hardware and firmware platform for beam instrumentation based on the Advanced Telecommunication Computing Architecture (ATCA) platform with a SLAC built advanced mezzanine card (AMC) along with a common carrier FPGA board.

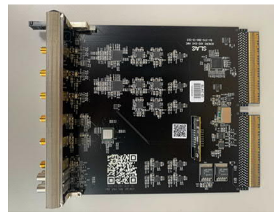
The cavity BPM signals are downmixed from 11.424 GHz to 40 MHz using a super heterodyne receiver as shown in the block diagram shown below. This technique has been used on LCLS-I, LCLS-II and PAL X-FEL. To meet the dynamic range requirement and maintain good linear response, there are digitally controlled attenuators that provide 30 dB of dynamic range



Carrier Card



AMC Card

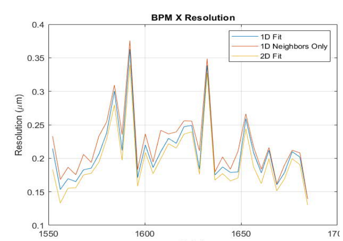


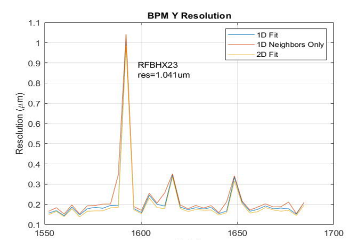
The Carrier Card illustrated above contains a FPGA (Xilinx Kintex Ultrascale XCKU040 or XCKU060). It has serial connections to the backplane Ethernet, and to the RTM and AMC cards. JESD204b is used to the AMC cards The carrier card also contains DC-DC power supplies from the -48V to a variety of voltages used by the AMC cards. Each carrier card supports two AMC cards and one RTM card.

The AMC card plugs into the carrier card as illustrated above. The AMC module contains a shaping filter, two gain stages, two dual 370MSa/s JESD204b ADCs, JESD clock distribution, a DAC that allows testing of the ADC inputs and external trigger input/outputs.

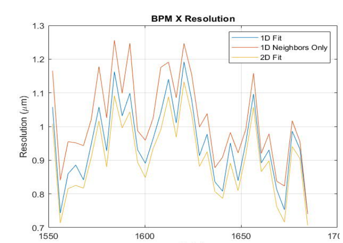
Performance Results

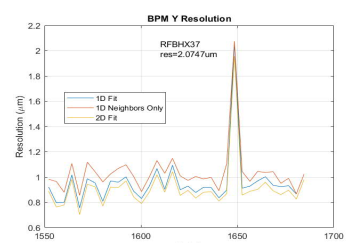
Cavity BPM Test were done at SLAC on LCLS-II. The linearity was measured to be greater than +/-1mm. The beam single shot resolution was measured at 165pC in both the hard x-ray lines to be between 200nm and 350nm. The resolution was also measured at SLAC at 26pC to be between 1-1.2um.





165pC tests with one BPM had a Y-plane resolution that was drastically worse. It was discovered this was due to an oscillation on the Monopole cavity electronics and has since been repaired. The next figures are of 26pC charge. At 26 pC the resolution for most BPMs is 1 mm. The data was taken with the electronics calibrated and optimized at 180 pC. Thus, some improvements can still be made to increase the resolution at low bunch charge





CONCLUSIONS

The CRADA and industrial partnership with Pohang and Viztrotech has been very successful. We have in-stalled 65 BPMs in LCLS-II HXR and SXR. LCLS-II cavity BPMs work as specified and are recording shot to shot data at 120 Hz. Future operational operations will include running at 1 MHz repetition rates.

REFERENCES

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ACKNOWLEDGEMENTS

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