COMMISSIONING RESULTS OF MICROTCA.4 STRIPLINE BPM SYSTEM*

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Abstract

SLAC National Accelerator Laboratory is a premier photon science laboratory. SLAC has a Free Electron Laser (FEL) facility that will produce 0.5 to 77 Angstroms X-rays and a synchrotron light source facility. In order to achieve this high level of performance, the beam position measurement system needs to be accurate so the electron beam bunch can be stable. We have designed a general-purpose stripline Beam Position Monitor (BPM) system that has a dynamic range of 10pC to 1nC bunch charge. The BPM system uses the MicroTCA (Micro Telecommunication Computing Architecture) for physics platform that consists of a 14bit 250MSPS ADC module (SIS8300 from Struck) that uses the Zone 3 A1.0 classification for the Rear Transition Module (RTM). This paper will discuss the commissioning result at SLAC LINAC Coherent Light Source (LCLS), SLAC Sanford Synchrotron Radiation Lightsource (SSRL), and Pohang Accelerator Laboratory (PAL) Injector Test Facility (IFT). The RTM architecture includes a band-pass filter at 300MHz with 30 MHz bandwidth, and an automated BPM calibration process. The RTM communicates with the AMC FPGA using a QSPI interface over the zone 3 connection.

NEW ELECTRONICS AND TEST SUITE

The test result presented at IBIC 2013 was conducted using a 16bit 125MSPS SIS8300 ADC module. After the conference, more tests were done using the 14bit 250MSPS ADC module on LCLS-I. In addition, more tests were moved to automate testing to decrease testing time and increase accuracy by eliminating operator error.

250MSPS ADC Module

With a 250MSPS ADC, the BPM electronic was able to capture two times the waveform data. With the faster ADC, a 30MHZ band-pass filter replaced the 15MHz band-pass filter used for the original electronic.

A narrower band-pass filter will produce a ringing signal with less amplitude comparing to a wider band-pass filter. By using a wider band-pass filter, it will increase the dynamic range of the BPM electronics by the square-root of the bandwidth factor (i.e., in our case $\sqrt{2}$). Figure 1 shows the comparison between 125MSPS system and 250MSPS resolution difference.

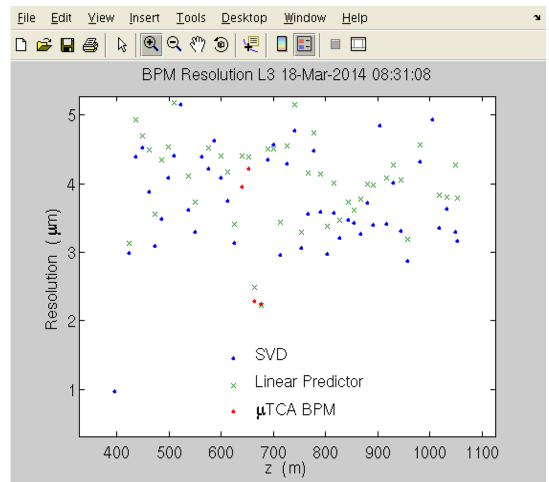

Figure 1: Resolution measurement with both 125Msa/s and 250Msa/s ADCs shown in red.

Automated Test Suite

To decrease the testing time for the eight BPM systems, an automated test suite was created using MATLAB and Python script. Each module was tested for signal to noise ratio (SNR), effective number of bits (ENOB), linearity test (IP3), attenuator linearity test, and simulated beam resolution. Two Agilent vector generators were controlled via SLAC intranet. The operator has the ability to choose between the full test and individual tests. Each test records the board serial number of the date the test is performed. Comparing to the original test duration, the test suite reduced the testing time by 75%. In addition, test results can be accessed later if needed.

POHANG ACCELERATOR LABORATORY – INJECTOR TEST FACILITY

In preparation for the new PAL FEL, PAL has constructed an injector test facility (ITF) to test instruments like TCAVs, modulators, BPMs, and other accelerator components. PAL asked SLAC to build seven BPM systems for the PAL ITF. The ITF is composed of two Kystrons and one TCAV for beam

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profile monitoring. The operating conditions were the Klystrons voltages set between 35kV to 40kV with L0a set to 116 degrees and L0b set to 90 degrees. The beam energy was between 45MeV to 70Mev. [2] Figure 2 shows the Klystron layout of the ITF.

Figure 2: PAL ITF gallery layout.

Deployment

The work for the PAL BPM system was developed under a Work For Others (WFO) agreement [1]. SLAC was responsible for developing the BPM electronics for PAL. PAL was responsible for developing the stripline BPMs and providing a test facility to measure the performance. There are seven BPM instruments in the entire ITF. Figure 4 illustrates the first four BPMs are mounted rotated 45 degree, the last four BPMs are non-rotated and each BPM is mounted on a motor mover system. Three member of SLAC's BPM team traveled to PAL in June and deployed seven BPM systems. Figure 3 illustrates the mTCA BPM electronics and the BPMs at the end of the ITF.

Figure 3: microTCA BPM system installed at PAL ITF.

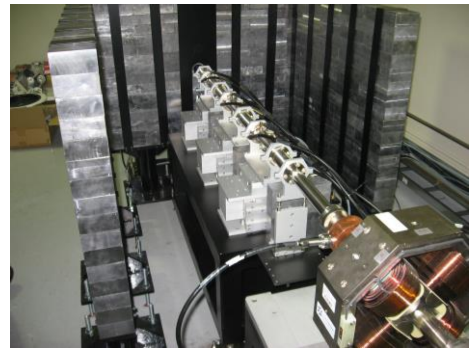

Figure 4: Stripline BPMs inside PAL ITF.

Verification

Both SLAC's BPM and PAL's ITF team verified the performance of the SLAC BPM electronic. Several tests were performed at PAL's ITF. Each board's resolution was tested using a single BPM. Figure 5 shows at 200pC beam energy, the BPM electronic produced approximately 1.7micron resolution.

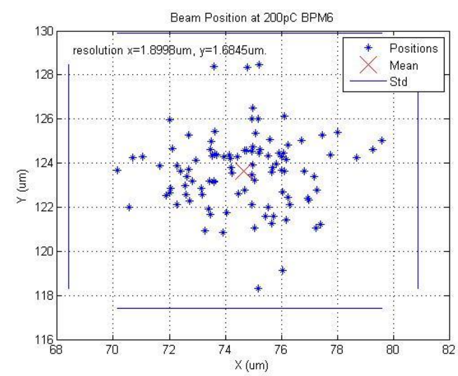

Figure 5: Example of single board resolution.

Beside the single board resolution, resolution was also tested using all seven BPMs. By using the data from all the BPMs, the beam position jitter could be removed by using both the linear predictor method and single value decomposition method. Figure 6 illustrates at 10pC beam energy the BPM electronic yielded 10micron resolution. Figure 7 shows at 200pC, the BPM electronic yielded ~3micron resolution.

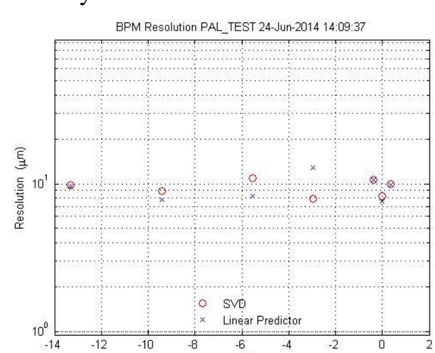

Figure 6: Multi-BPM resolution test at 10pC.

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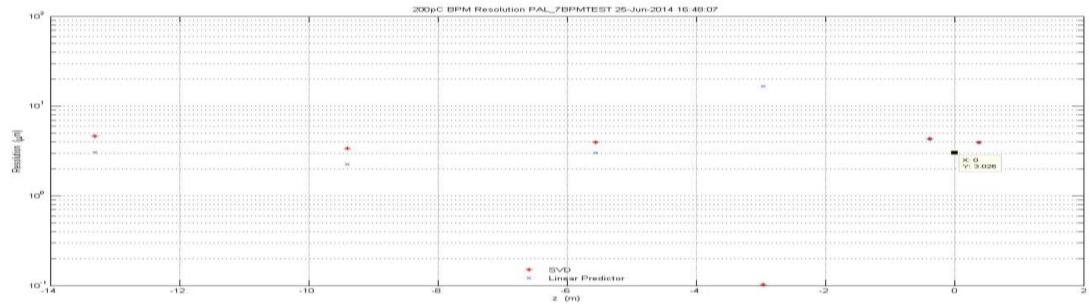

Figure 7: Multi-BPM resolution test at 200pC.

In addition to resolution tests, a series of linearity tests were performed. The BPMs that were mounted on movers have both X-axis and Y-axis mover. To verify the linearity of the electronic, the beam position was recorded while the mover swept both X-axis and Y-axis in 5mm steps. (See Figure 8 & 9) The data shows good linearity correlation over +/-1mm range.

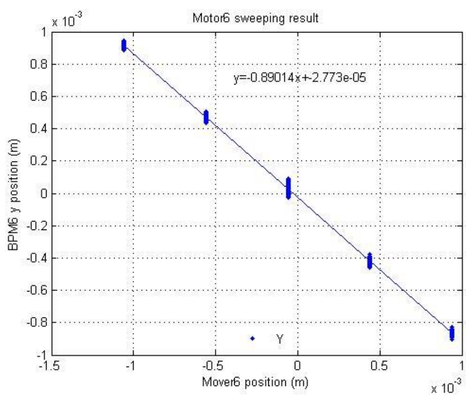

Figure 8: Y-axis BPM sweep.

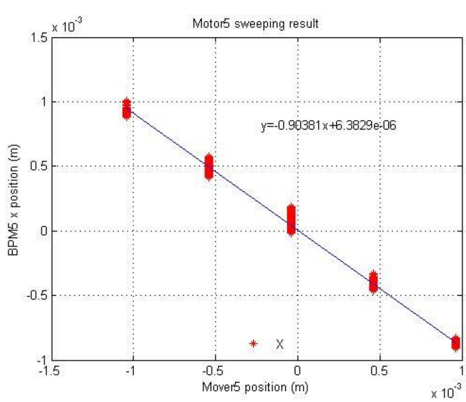

Figure 9: X-axis BPM sweep.

Summary of Test Results

Ordinarily, the BPM system is used to qualify the beam quality. When the BPM system needs to be qualified, the beam needs to be stable and predictable. After several days of testing, data shown the ITF beam has a large beam jitter due to low beam energy and the beam had a significant energy spread. The figure 10 illustrates this condition.

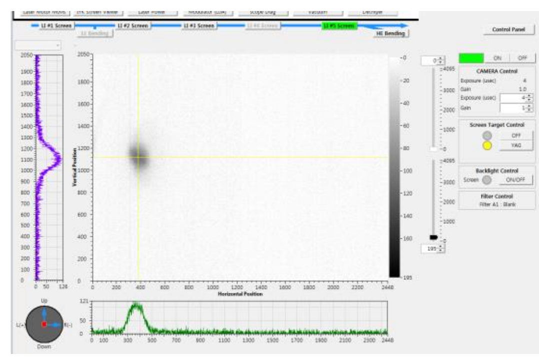

Figure 10: PAL ITF 200pC beam profile [1].

This made the resolution test difficult. Despite having difficulty qualifying the beam resolution, both PAL and SLAC's team were satisfied with the results of 10um at 10pC and between 3 and 5um resolution at 200pC.

STANFORD SYNCHROTRON RADIATION LIGHTSOURCE

After reviewing the initial test result of the 125MSPS BPM electronic, SSRL decided to upgrade two of the BPMs. The two mTCA BPMs are in the BTS (booster-to-SPEAR) transport line that is part of the injector. BTS is between the booster ring that boosts the energy of the beam from the LINAC to 3GeV and the SPEAR ring. Specifically, the BPMs are at the end of BTS where it is critical to know the exact location of the beam in order to have the best injection into SPEAR. The system has been deployed at SSRL during the summer downtime. It is now waiting for beam testing when the facility restarts during October 2014, (See Figure 11).

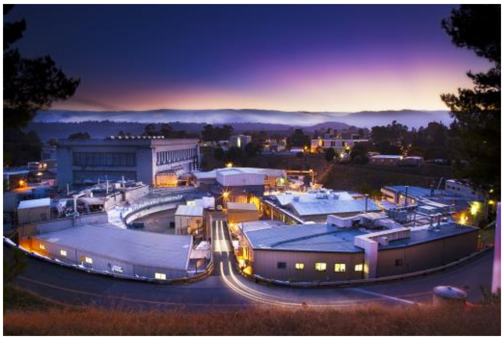

Figure 11: SSRL SPEAR.

CONCLUSION

SLAC's MicroTCA.4 based BPM system has been deployed at SLAC's LCLS, SSRL facility and PAL's ITF during 2014. Test results show the system is robust and meets the performance requirement of various facilities. To improve the analysis of the BPM resolution the code needs the linear predictor MATLAB subroutine to include or exclude the complex values. SLAC and PAL will collaborate in building 144 more stripline BPM electronics for their LINAC for their XFEL. We anticipate the system will be deployed in March of 2015.

ACKNOWLEDGEMENTS

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REFERENCES

[1] DOE/ SLAC WFO 13-197.a2 agreement.
[2] Private communication with So-Jeung Lee.

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