Commissioning Result of MicroTCA.4 Stripline BPM System

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SLAC NATIONAL ACCELERATOR LABORATORY

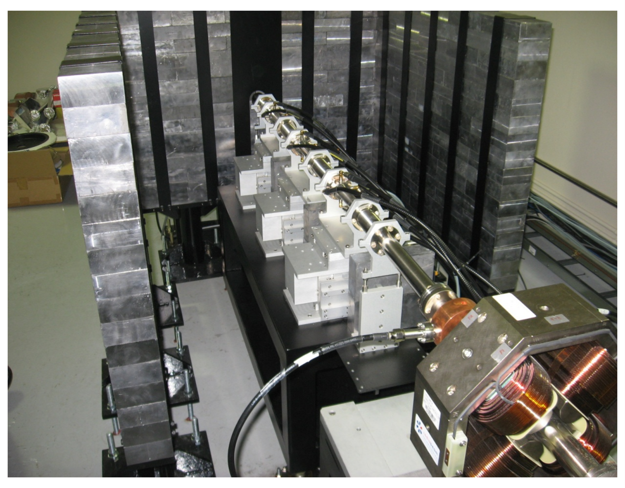
Abstract

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.

Pohang Accelerator Lab ITF and SLAC National Accelerator Lab SSRL

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 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. The beam energy was between 45MeV to 70Mev.

‣PAL ITF gallery layout



‣Stripline BPMs inside PAL ITF

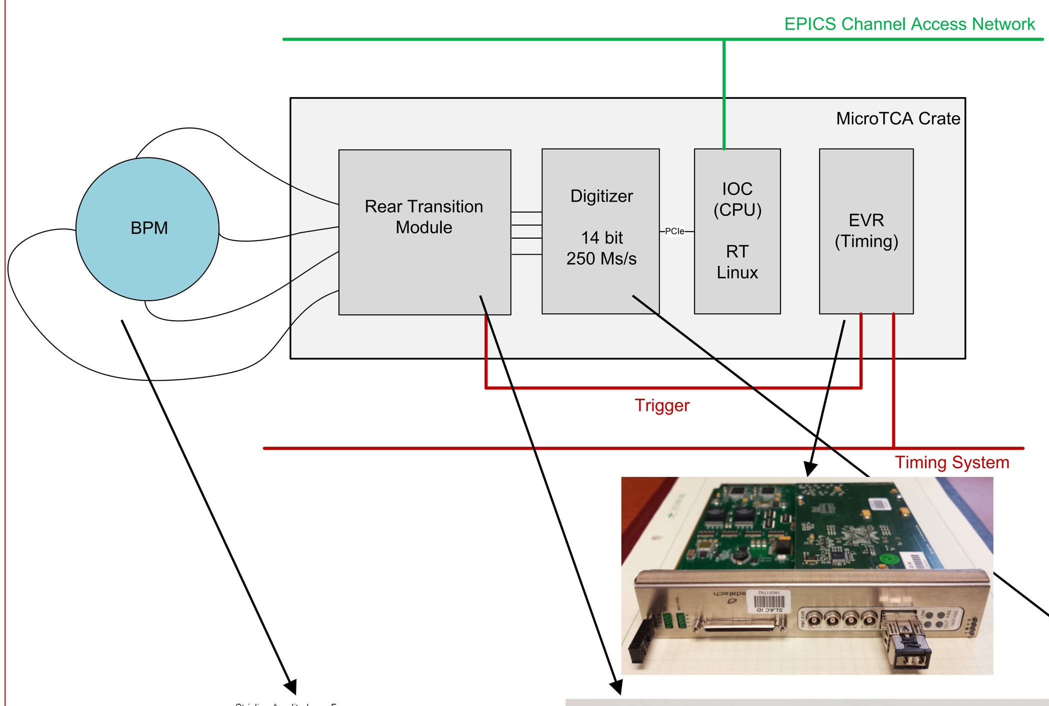
After reviewing the initial test result of the 125 MSPS BPM electronic, SSRL decided to upgrade two of the BPMs. The 2 mTCA BPMs are in the BTS (booster-to-SPEAR) transport line which is part of the injector. BTS is between the booster ring that boosts the energy of the beam from the LINAC to 3GeV and 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.

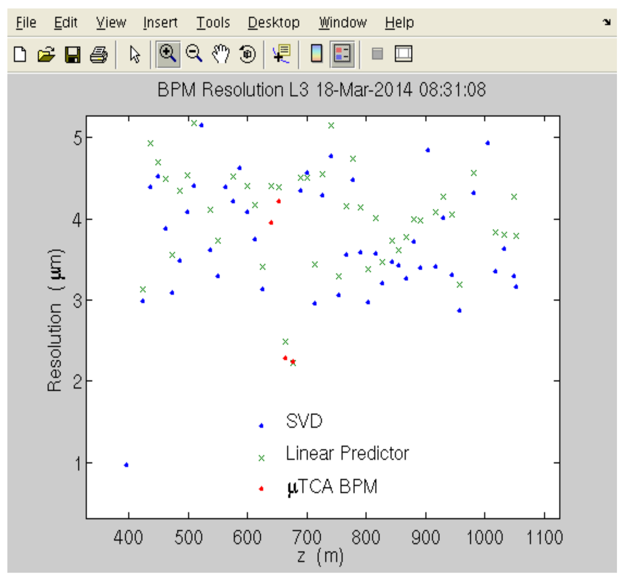
‣SLAC SSRL SPEAR

$$\left[\frac{(S_{41}-S_{21})+(S_{43}-S_{23})}{S_{21}+S_{41}+S_{23}+S_{43}}\right]\times PCMM = offset(mm) \quad (1)$$

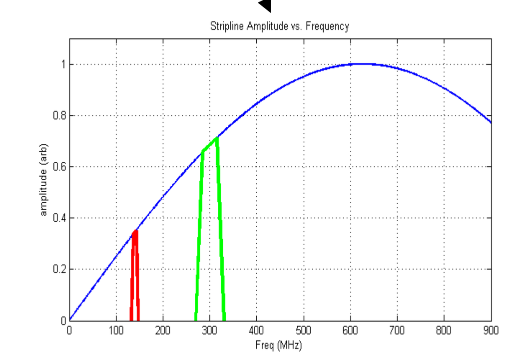
Each SLAC BPM has a diameter of 0.87in with a 7% azimuthal coverage. There are four striplines inside the structure, spaced by 90 degrees. The striplines are 4.75in long. To verify each BPM structure does not exceed the maximum acceptable offset, each BPM is tested using a network analyzer. The network analyser measures the strip to strip coupling coefficient. To increase efficiency a Python script was created to automate the testing process. Equation 1 shows the formula used to calculate the horizontal (X) and vertical (Y) axis offset. PCMM is the measured radius of the BPM structure and S represents the coupling coefficients between electrodes.

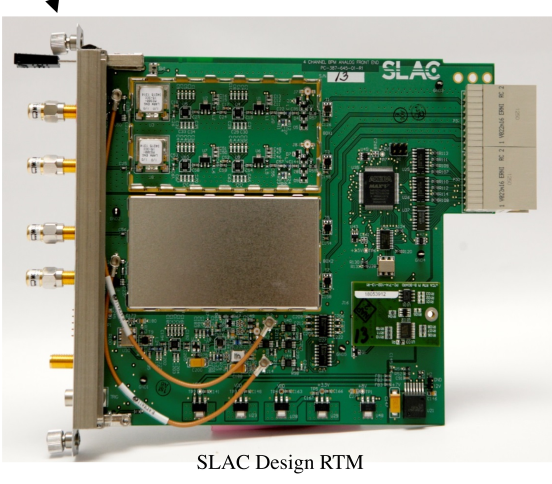
New Electronics and Automated Test Suite



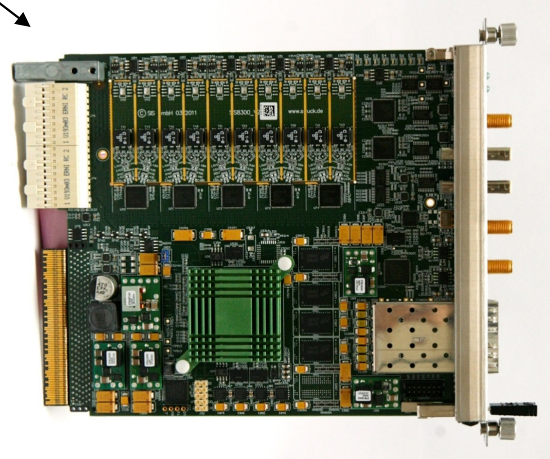


Resolution measurement with both 125Msa/s and 250Msa/s ADCs shown in red





SLAC Design RTM



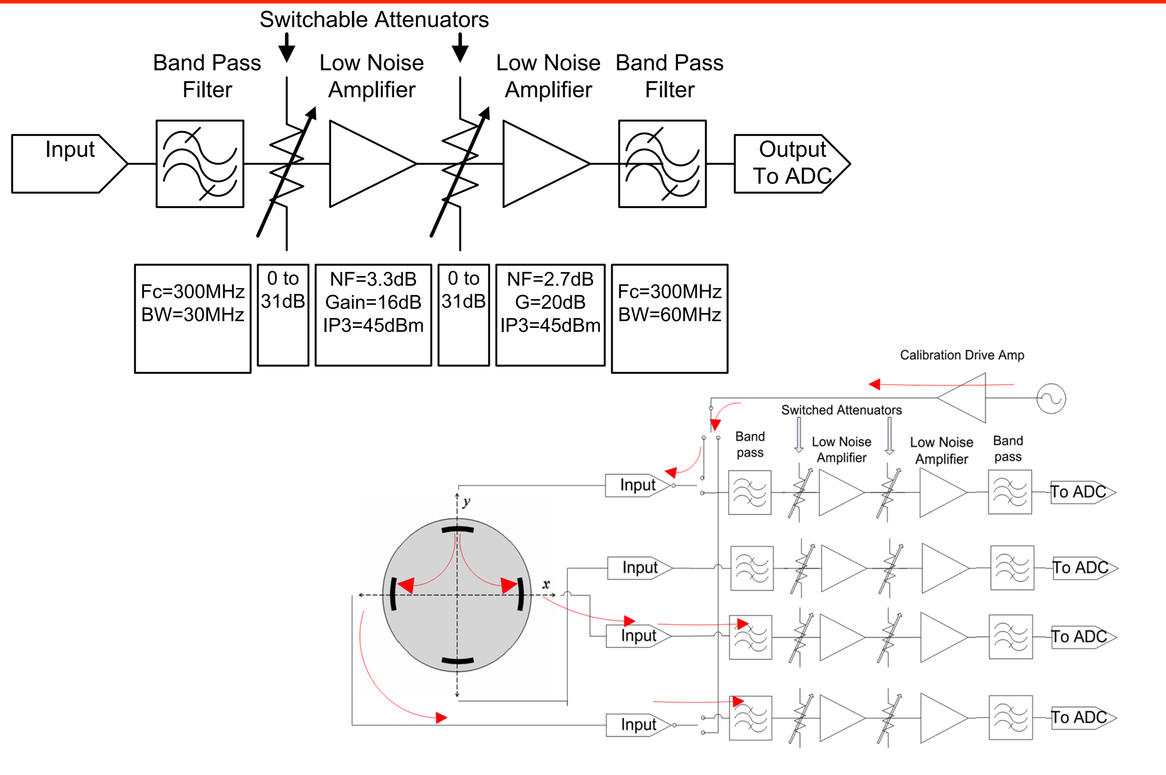
Struck SIS8300 250MSPS 14bits ADC

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.

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.

Digitizer and Rear Transition Module



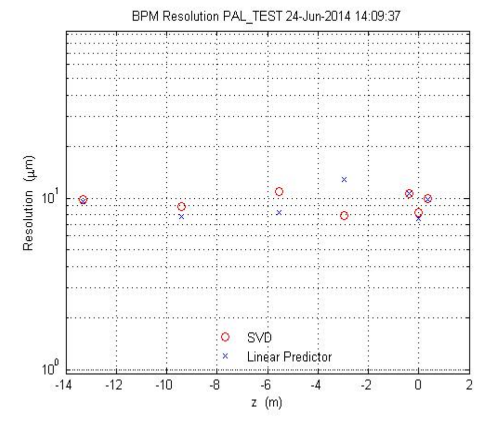
Rear Transition Module:

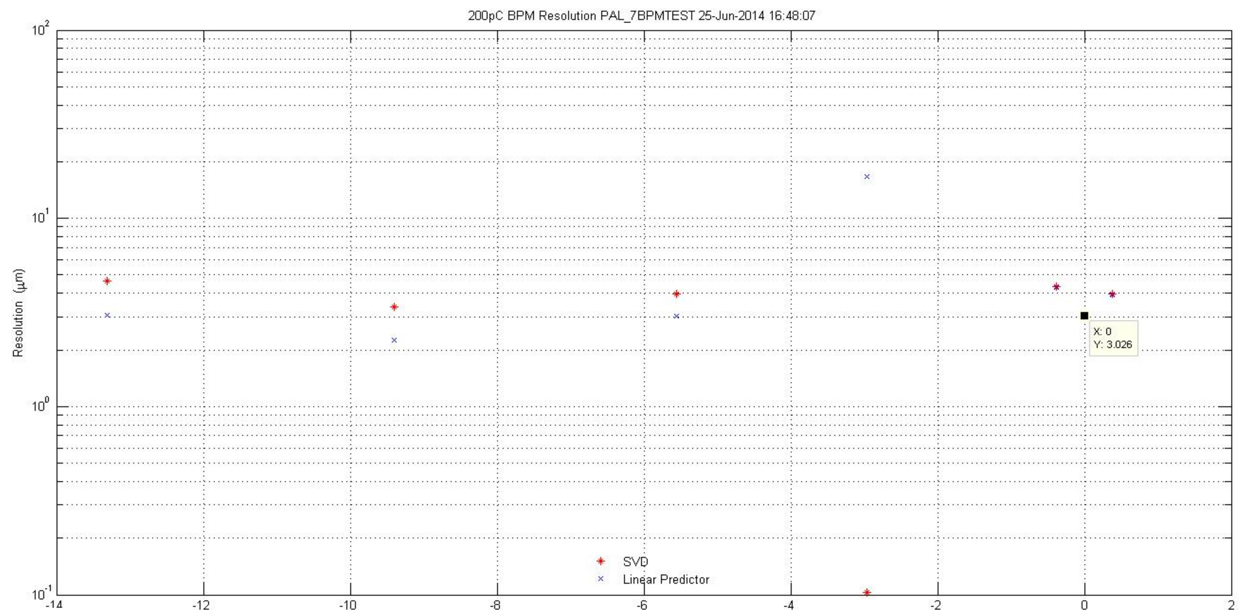
- Four processing channels, one calibration network.
- Two variable attenuators and RF amplifiers to meet the 10pC to 1nC dynamic range requirement.
- Altera MAX-V CPLD controlling the self-calibration state machine and attenuator settings.

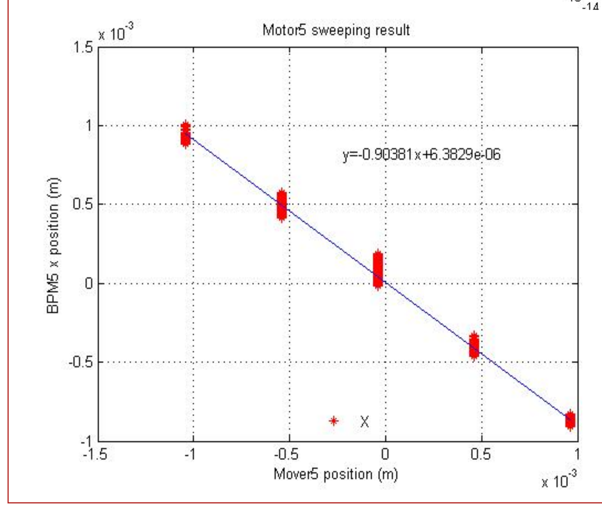
Digitizer

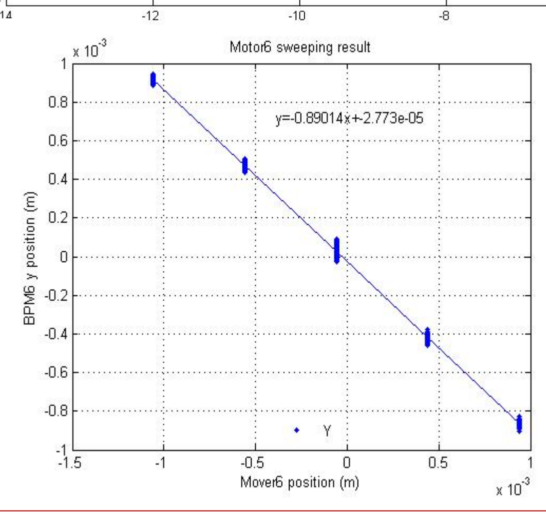
- Struck SIS8300 14bit 8 channel ADC module.
- Uses a band-pass sampling technique
- 250MHz sampling clock to under-sampling 300MHz BPM signal.
- 250MHz sampling clock will place the BPM signal in the middle of the Nyquist zone, thus maximize the signal captured.
- First stage bandpass filter has 30dB attenuation at 362.5MHz and 40dB attenuation at 237.5MHz.
- High attenuation at the Nyquist zone edge to prevent signals from leaking into the next Nyquist zone.

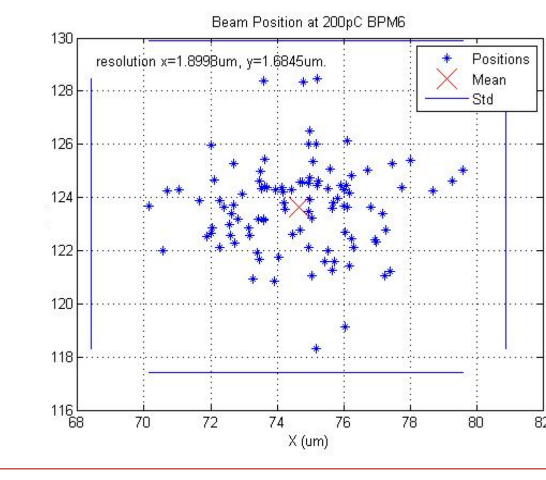
Test Results at PAL ITF

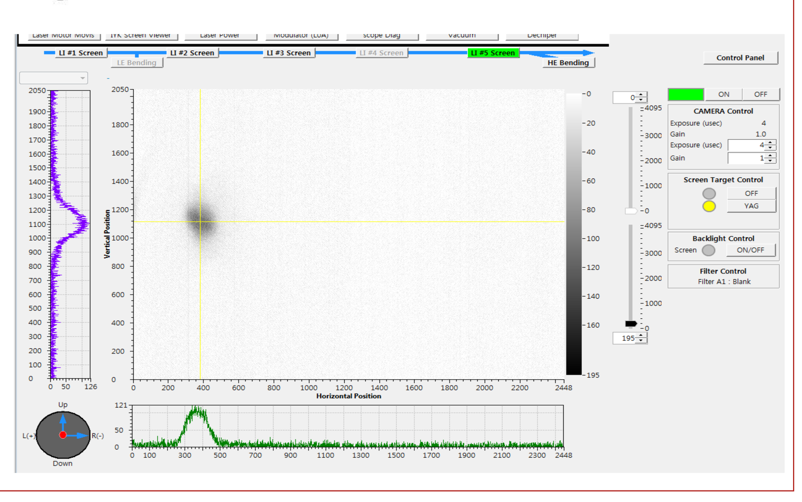






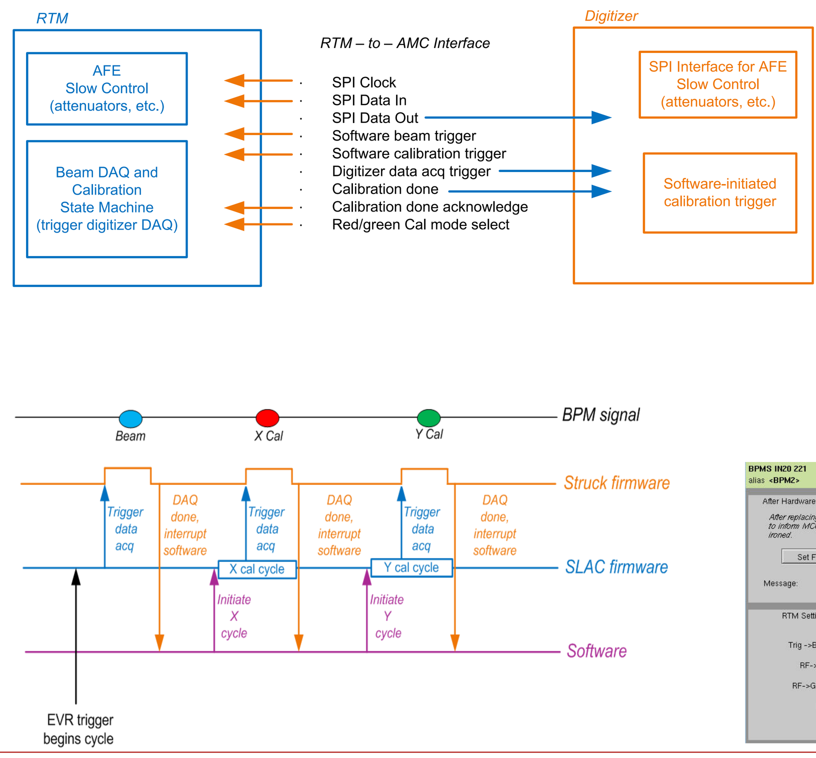


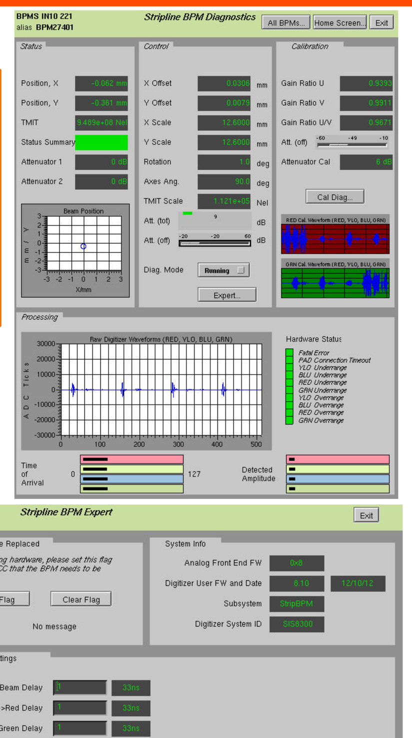




- Single board resolution test is 1.7μm to 1.8μm at 200pC beam energy.
- Multi-board resolution test shows 10 μm resolution at 10pC beam energy.
- At 200pC, the BPM electronic yielded ~3μm resolution.
- Motor sweep over +/- 1mm in x-axis and y -axis shows linear correlation between BPM mechanical position and detected beam position.
- Data shown the ITF beam has a large beam jitter due to low beam energy and the beam had a significant energy spread.

Software and Firmware





MicroTCA System

The BPM system is currently using; ELMA 12-slot crate, NAT mTCA.4 MCH, Wiener 1000W Power supply, Struck SIS8300 ADC, MRF PMV EVR, and Vadatech AMC100 PMC carrier. This configuration has allowed the BPM system to have eight RTM and eight SIS8300 in a single crate. (Figure 11) Each pair of modules consumes ~70W of power. The Wiener power supply is the only power module that has the power handling capability and has the fewest IPMI communication issues with the MCH.

Summary and Future Directions

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.

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