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Tests of Digital BPM Signal Processors for SHINE

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·Abstract

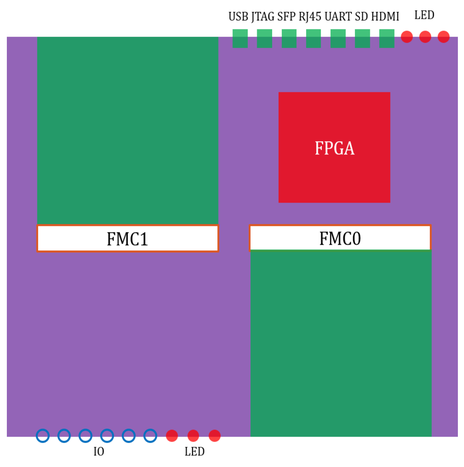
Digital signal processors that can handle 1MHz bunch rate BPM signal processing is under development for SHINE. At the same time, two general purpose processor prototypes for all BPM signal sampling and processing have been developed. One uses 14bits ADC, the other uses 16bits ADC. Both processors have been completed. This paper will introduce the tests of the processors and the related performance evaluations.

·Introduction

Shanghai HIgh repetitioN rate XFEL and Extreme light facility (SHINE) is a 3 km long hard X-ray FEL facility built underground in Shanghai. The designed beam repetition rate is 1MHz. The project was initiated at the end of 2018. Now the research of key technologies has entered the final stage. There will be three types of BPMs located in different parts of the machine, including stripline BPM, cold button BPM, and cavity BPM.

BPM electronics will use independent RF front-end modules and digital signal processors. All three types of BPM will use unified digital signal processor hardware. The processor will be used for signal processing of different BPMs through the development of corresponding FPGA firmware and software. Considering the beam dynamic range, the relative resolution of the processor should be better than 0.1%.

In order to cultivate qualified vendors for SHINE, two kinds of processor prototypes were developed at the same time. One processor uses 14 bits ADCs, the other use 16 bits ADCs.

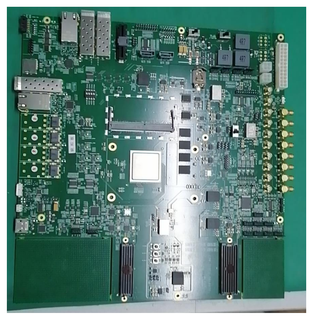


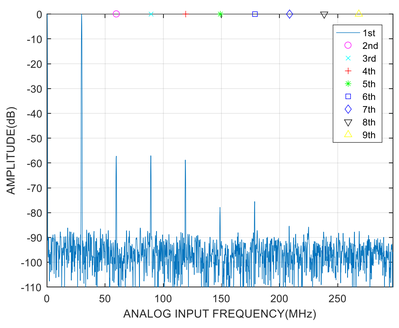
Processor structure

Table 1: Processor specification

Parameter	Value
Channels	4
Bandwidth	≥1GHz
ADC bits	≥14
Max ADC rate	≥ 500MSPS
FPGA	Xilinx Zynq Ultra+MPSoC
Clock	External
Trigger	Ext./Self/Period
SFP	≥2
Interlock	Lemo
DDR	≥512MB
Software	Arm-Linux/EPICS
Relative resolution	≤0.10%

·Tests of processor A





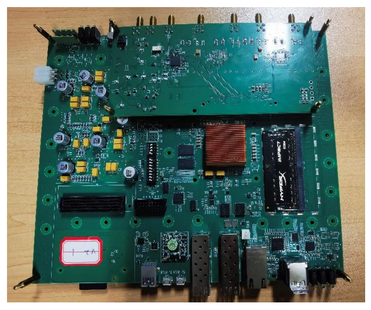
Spectrum of sampled signal.

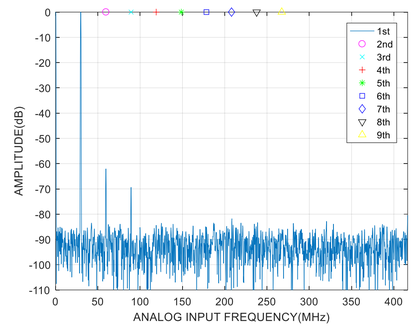
Processor A uses 14 bits ADCs. In lab test, the 29.75MHz input RF source signal was divided into 4 channels and fed into the processor. The sampling rate was set to 595MHz.

The relative position was calculate with Δ/Σ algorithm like orthogonal stripline BPM. The relative position resolution is 3.47e-5.

Beam tests have not yet been done.

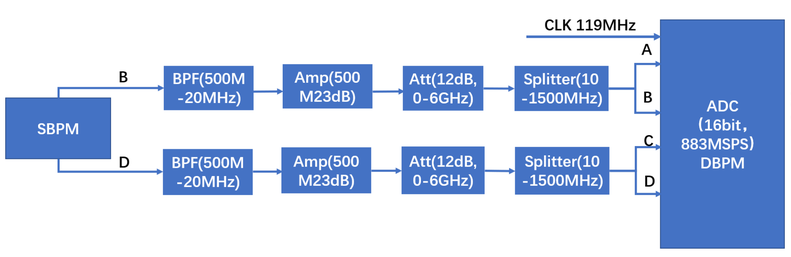
·Tests of processor B

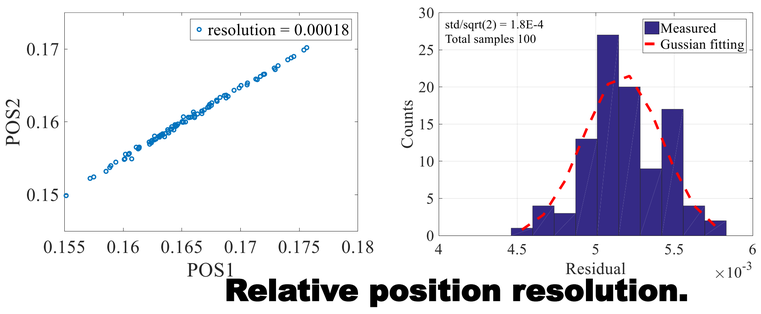




Spectrum of sampled signal.

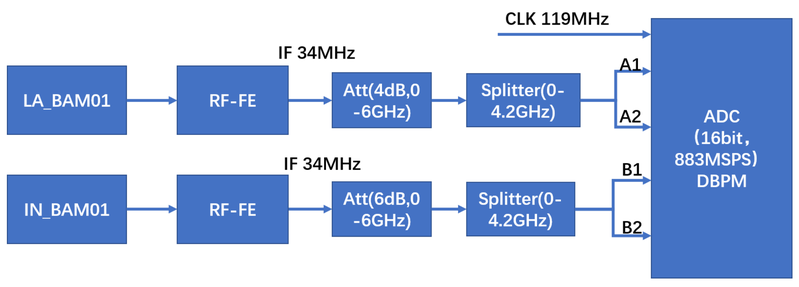
Processor B uses 16 bits ADCs. In lab test, the 29.75MHz input RF source signal was divided into 4 channels and feed into processor. The sampling rate was set to 833MHz. The relative position resolution is 1.74e-5.

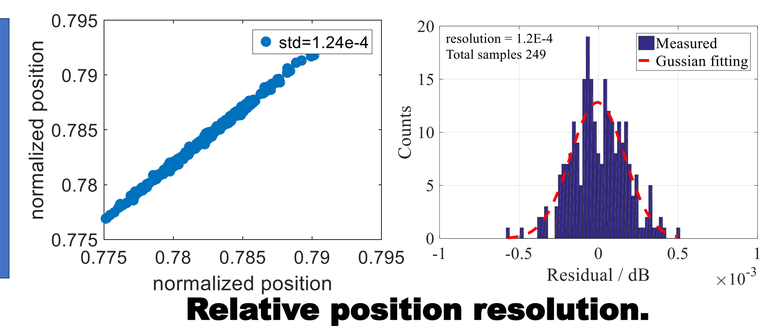




Relative position resolution.

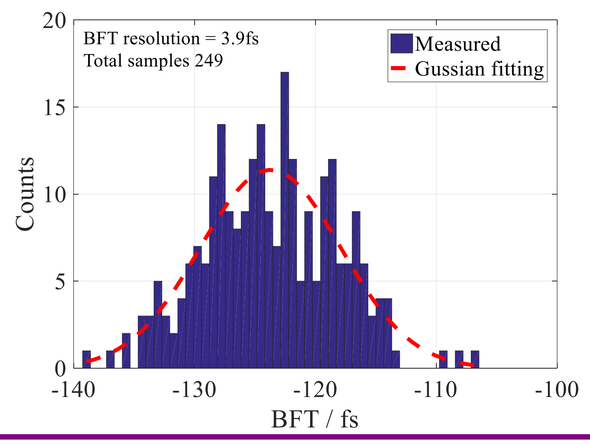
The prototype processor B has been tested on SXFEL. The relative position resolution of stripline BPM is 1.80e-4.





Relative position resolution.

The output signals of two beam arrival time(BAM) pickups were treated as the signals from an cavity BPM. The relative position resolution of cavity BPM is 1.24e-4.



The beam flight time(BFT) between IN_BAM01 and LA_BAM01 can be obtained from the same data. The relative BFT resolution is 3.9fs.

·Conclusion

Tests of two prototype processors show that the performance of both processors meets SHINE's requirements. Next we will focus on developing firmware and software.