PROGRESS OF CAVITY BEAM POSITION MONITOR AT SXFEL

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Abstract

Shanghai Soft X-ray FEL Test Facility (SXFEL) has started the infrastructure construction in 2015. All beam diagnostic systems are under processing and measurement, including C-band Low-Q cavity BPMs. This paper presents the progress of the cavity BPM system, including design and the measurements on a lab platform. Measurements shown that the cavity BPM frequency is 4.7GHz ± 8MHz, and the complete test platform verify that the cavity BPM system, which including signal processing electronics can work as expected.

INTRODUCTION

The SXFEL project at the Shanghai Synchrotron Radiation Facility (SSRF) campus serves as a test facility of China's future hard X-ray FEL user facility, while it can be easily upgraded to a FEL user facility at "water-window" spectral region for scientific investigations with high brilliance X-ray pulses of ultra-fast and ultra-high resolution processes in material science and physical biosciences.

The construction of the SXFEL has started since April 2015, and the first X-ray FEL light is planned to be delivered to the beam line in 2017.

The SXFEL consists of following parts:

1. A photo-injector generating a bright electron beam and accelerating it to ~ 130 MeV.
2. The main linear accelerator, where the electron beam is longitudinally compressed and accelerated to ~ 840 MeV.
3. The FEL undulator complex where X-ray radiation is generated.
4. The photon beam transport & diagnostic line.

To achieve the physical design of SXFEL, the diagnostic system need to achieve requirements listed in Table 1, and the dynamic is 0.1nC~0.5nC.

CAVITY BPM SYSTEM

The cavity BPMs have been chosen for the real time measurements of the electron beams positions along the undulator of the SXFEL. The layout is shown in Fig. 1.

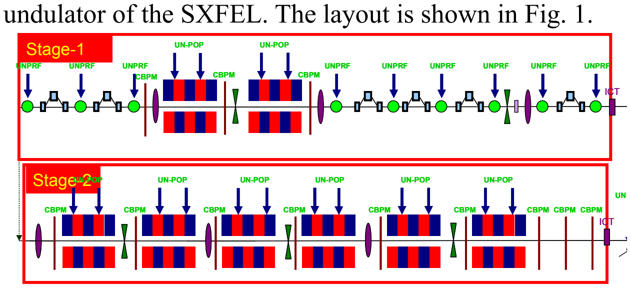

Figure 1: Layout of cavity BPM along undulator.

Table 1: Beam Diagnostics System Specification

Parameter	Main technical specifications
Position	Stripline BPM, Resolution: 10μm@0.5nC
	Cavity BPM, Resolution: 1μm@0.5nC
Size	YAG/OTR, Resolution:30μm@1nC, Repeatablity:50μm
Charge	ICT, Resolution:1%
Length	CSR, Resolution:100fs
Arrive time	Phase cavity, Resolution:200 fs

Cavity BPM Pickups

The cavity BPM system consists of the cavity BPM probes, the RF front-end and data acquisition (DAQ) electronics is shown in Table 2. The working frequency of the position mode and the reference cavity of the CBPM are designed to be 4.7GHz preliminary to avoid the interference of the dark current caused by the frequency multiplication of the RF. The signals will be lead out through the 50Ω load and the system quality factor will be mainly determined by the external quality factor.

Table 2: The Cavity BPM Design Parameter

Parameter	TM110	TM010
Frequency	4.7GHz	4.7GHz
Q	~60	~60
Ports number	4	2
Signal amplitude@50Ω	12mV/μm/nC (peak)	100V/nC (peak)

CBPM responses with a series of simulated electron beams passing the CBPM at different positions have been modeled with MAFIA. The output signal and the corresponding spectrum at the electrode of the CBPM are shown here in Fig. 2.

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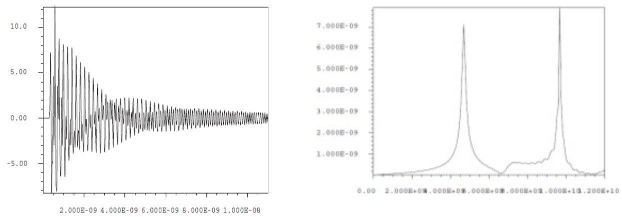

Figure 2: Simulation of output signal and spectrum at the electrode of the CBPM.

The suppression of the fundamental mode in the design of the CBPM is about 106dB and the sensitivity of the electrode at peak voltage is about 12mV/μm/nC. The estimated resolution is about 0.07μm@1nC by comparing the data with those from Spring-8. The radius of the reference cavity is 20.25mm. The inner and the outer radius of the ring structure are 15mm and 20.25mm, respectively. The length of the pipe is 10mm. The working frequency is optimized to be 4.7GHz.

The cavity BPM is shown in Fig. 3.

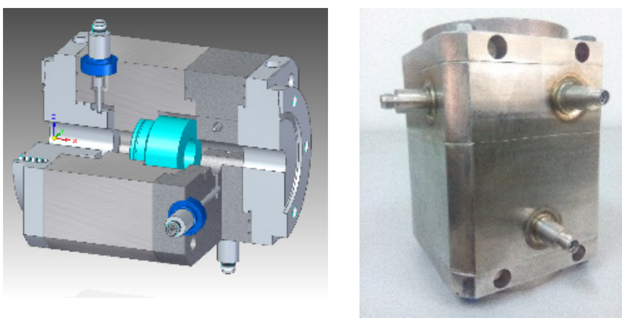

Figure 3: The cavity BPM.

Signal Processing

The cavity BPM signal processing consists of RF front-end electronics and DAQ electronics. The RF front-end converts the RF signals down to IF signals before DAQ. The diagram of RF front-end shows in Fig. 4[1].

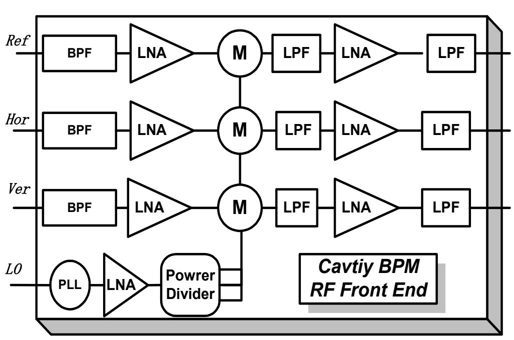

Figure 4: RF front-end diagram.

DAQ electronics will sample signals output from the RF front-end. Then the FPGA on the DAQ electronics will process the sampled digital signal to get position data.

CAVITY BPM TESTS

Network Analyser Measurement

The BPM has been measured with Agilent N5230A PNA-L network analyser. Figure 5 is the screen shot of the analyser measurement, it shows that the pickup central frequency is 4.7GHz±8MHz.

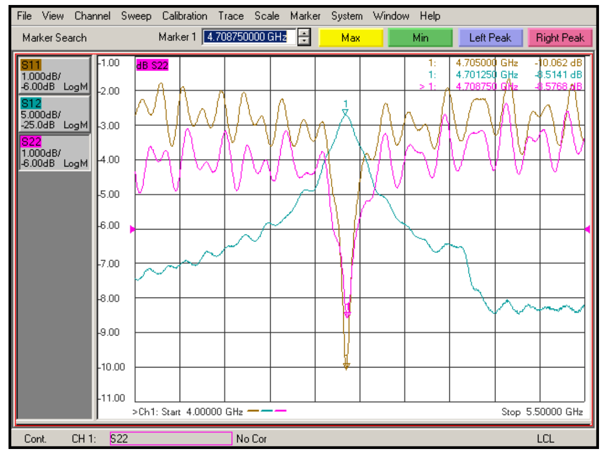

Figure 5: Screen shot of analyser measurement.

Lab Test

A lab test platform has been constructed to simulate beam environment, Fig. 6 is the platform diagram and Fig. 7 is the scene photo.

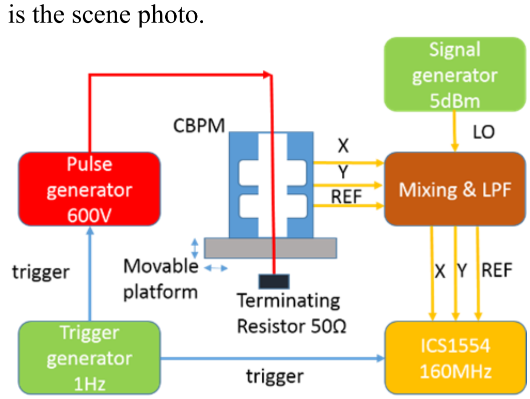

Figure 6: Lab test platform diagram.

Figure 7: Lab test photo.

The BPM was located on a movable platform, and a 600V pulse signal was fed into the cavity through a cable across the BPM to simulate beam passing. A trigger generator drives the pulse generator with 1Hz signal, which signal was also used to trigger DAQ electronics—ICS1554[2]. The reference and position signals were down converted to about 20MHz IF signal with a 4.72GHz local oscillator and RF front-end. The commercial DAQ board ICS1554, which consists of four 16bits 160MHz ADCs and FPGA, was used to sample the IF signal.

The raw RF signal was sampled with a 6GHz oscilloscope at 25G samples/s. Figure 8 and 9 are the sampled RF position signal and reference signal respectively, the signal decay time is about 20ns.

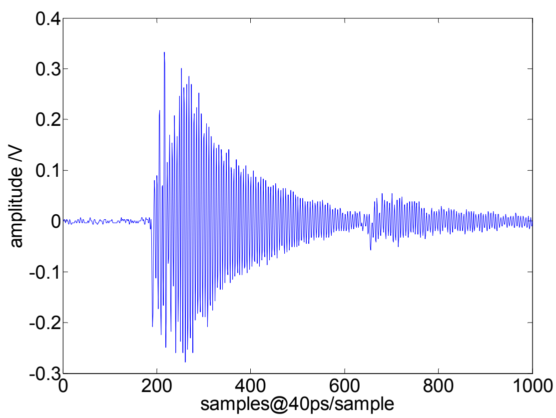

Figure 8: Raw RF position signal.

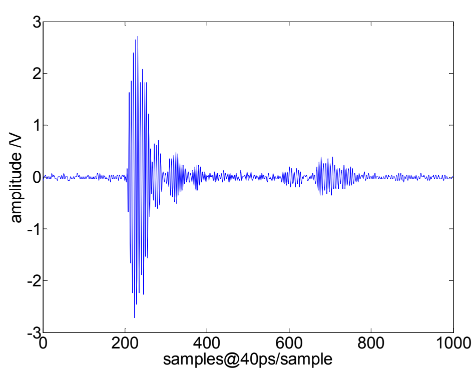

Figure 9: Raw RF reference signal.

The IF signal is sampled with ICS1554 at 160M samples/s. Figure 10 shows sampled ADC data of both position cavity and reference cavity.

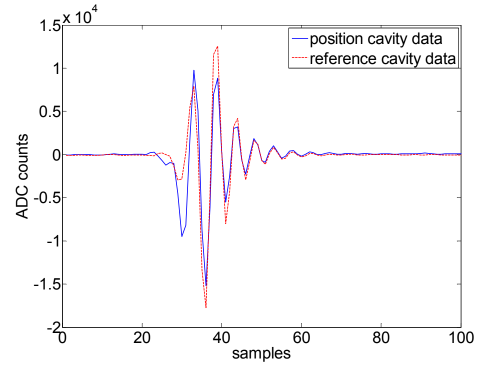

Figure 10: IF data sampled with ICS1554.

To get the amplitude of position cavity and reference cavity from the sampled IF signal, several algorithms have been studied, including square root of the IF signal's absolute integration and curve fitting to the IF signal. The algorithm will be implemented later in FPGA. And beam tests will be carried out later on SDUV FEL.

SUMMARY AND OUTLOOK

The measurement of the SXFEL cavity BPM showed that the frequency deviation value is about 8MHz from the designed 4.7GHz, and deviation within ±5MHz can be achieved with fine-tuning in future volume production. A complete lab test platform used to simulate beam environment has been constructed, which verified that the BPM pickup, the RF front-end electronics and DAQ electronics can work as expected. Recently, beam test will be carry out on SDUV FEL, results will be given in future paper.

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[1] B.P. Wang, Y.B. Leng, et al., "Development of cavity beam position monitor system", IPAC'13, Shanghai, China, 2013.

[2] Hardware Reference Manual: ICS1554 Operating Manual, GE Fanuc Intelligent Platforms Ltd, 2008:3~4(2008); http://defense.ge-ip.com/products/2234.

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