DIGITAL BEAM POSITION MONITOR FOR SSRF

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Abstract

The newly developed Digital Beam Position Monitor (DBPM) prototype system is introduced. The DBPM system differs with the conventional beam position monitor system in the use of DSP chips and the digital signal processing technology , it can be used in the accelerator complex by selecting different operation modes. Performance of this DBPM system has been measured in the lab and it's fulfilling the requirement of third generation synchrotron radiation facility. Also the on-line test result at BEPC storage ring will be introduced.

INTRODUCTION

Third generation synchrotron radiation source provides a wide range of photon energy from vacuum ultraviolet to soft X-rays and supplies high brilliance, it also provides flexibility to accommodate a variety of operation modes. Therefore, the beam position monitor system has to ensure the adequate beam quality. The DBPM system introduced here can work in different modes, it can be used throughout the accelerator complex.

The proposed SSRF facility is a third generation complex. This project has been discussed for several years and it's on the final stage to decided by the government. SSRF project has a 100MeV LINAC, inject to the booster where the electron ramped to 3.5 GeV then stored the electron beam in a 3.5GeV storage ring. The storage ring has a beam life time of more than 15 hours, which can produce VUV to X-ray synchrotron radiation. The machine's main parameter is listed in table 1.

Table 1: SSRF main parameter related to beam diagnostic[1].

Electron energy:	3.5 Gev
Circumference of storage ring	432 m
Beam current: Multi-bunch mode Single bunch mode	 200-300 mA 5 mA
RF frequency	499.654MHz
Harmonic number (storage ring)	720
Revolution frequency (storage ring)	0.694MHz
Harmonic number (booster)	300
Revolution frequency (booster)	1.666 MHz
Injection period	2 Hz

Third generation light source has rigid requirement of beam position monitor system, beam position should be measured at a resolution of sub-micron, which have to be provided at a few kHz bandwidth, in order to successfully operate a fast (global) orbit feedback. It's also very important to measure the beam orbit in turn-by-turn (TBT) mode so that many machine studies can be done. Therefore, the BPM electronics has to deliver position data with more than 0.5MHz bandwidth. It's easy to change among different operation modes while DSP technology is used, the DBPM system introduce here can support high speed/medium precision and low to medium speed/high precision measurements.

DBPM ELECTRONICS [2,3]

The DBPM electronics is a four channel system, it mainly consists of three modules: a RF front end module, a digital receiver module and a digital signal processor (DSP) module. As illustrated in Figure 1.

Four button BPM signals send into RF Front End module, which is tuned to 499.654MHz (first harmonic of machine RF frequency). The four RF signals get mixed to an intermediate frequency. The band limited IF signals from the RF module send into QDR (Quad-Digital Receiver), where get sampled and down-converted to baseband signal, the under-sampling technique and digital filters are used to define the system bandwidth, which in turn affects measurement resolution. The baseband signal send into DSP board for beam position calculation and other processing.

The DBPM system is fully integrated in the EPICS (Experiment Physics and Industrial Control System [4]) control system, so IOC (Input-Output Controller) is used to communicate with the upper layer GUI (Graphic User Interface) and DSP driver. Real time database is running on IOC which communicate with required channels, these channel can be displayed and controlled in the console. Including the selection of operation modes, display of beam position and tune measurement in the control room, archived orbit data can be stored with ChannelArchiver[4] for further analysis.

SYSTEM SPECIFICATION

The system is working well and measurements have been done in the laboratory and BEPC[5] to check the system specification. Some of them are introduced here.

Gain linearity

For the RF Front End module, four 16 bit DACs are used to set the four channel gains individually, this can make the real gains for all channels are exactly the same after gain calibration. To determine the bandwidth for the system, IF signal amplitude vs. RF amplitude relationship curves are measured for some DAC settings. As show in Figure 2, which tell the system has a wide linear range from -70dBm to about -5dBm.

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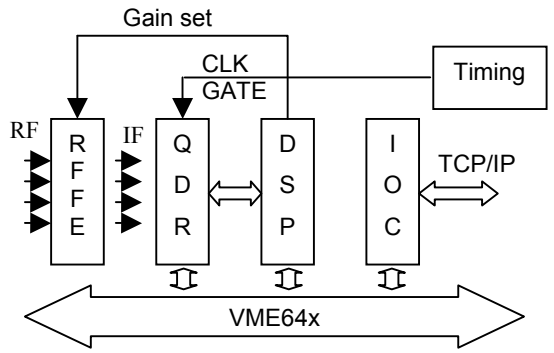

Figure 1: Block diagram of DBPM system.

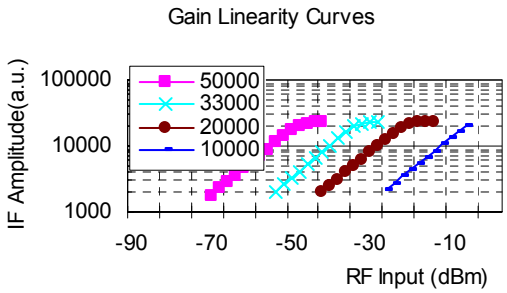

Figure 2: IF amplitude vs. RF amplitude relationship for different gain setting.

Long term stability

Measurement of long term stability of DBPM electronics has been performed with constant input power level and a constant DBPM gain setting at the frequency of 499.654MHz. The long term stability and air temperature variation have been analyzed, the result is showed in figure 3. When the air temperature goes down, the calculated beam position variation get bigger, but the average intensity for these four channels is smaller. While air temperature change is less than 2ºC long term stability (>12 hours) can be less than 2 microns.

BEPC experiment

In January 2003, Rok Ursic and Borut Repic from I-TECH company visit Beijing, they solved some problems why debugging the system, on-line test also have been done in a real machine. BEPC(Beijing Electron-Positron Collider) is the first generation storage ring which mainly used in high energy physics, it can also running in synchrotron radiation mode.

At BEPC storage ring experiment, several steps are taken to verify the electronics specification and do some machine study using the new DBPM system. The first one is electronics resolution for beam position measurement, the measurement resolution should have some relationship with different storage beam current; the second step the damping time of storage ring for different stored beam has been analyzed; also, from the turn-by-turn position data, storage ring tune can also get from it by FFT.

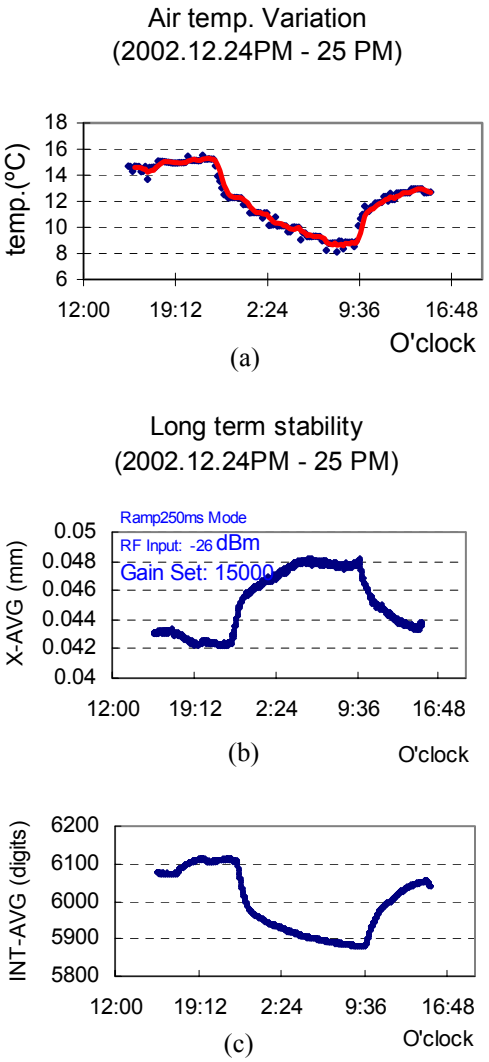

Figure 3: Long term stability compared with the air temperature variation. (a) Air temperature variation curve for more than 24 hours, (b) (c) recorded horizontal position and average intensity for all channels at the same time.

DBPM electronics resolution has been measured in different storage beam current, as show in figure 4. As stored beam current increasing, the DBPM resolution goes down, the resolution can reach 2 microns @10mA beam (in closed-orbit mode).

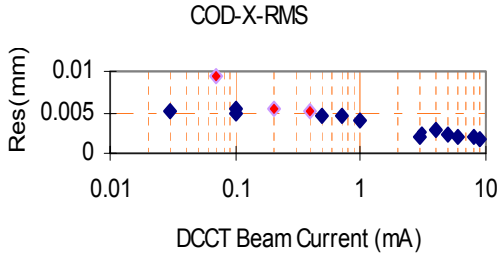

Figure 4: DBPM resolution vs. beam current.

The damping time of storage ring at different stored beam current has also been analyzed as show in table 2. As show in the table, damping time are longer while the stored beam current goes down, this is compatible to the theoretical calculation. Figure 5 gives a typical damping waveform.

Table 2: Damping time for different storage beam current.

DCCT reading (mA)	Damping Time (ms)
8	~ 6.34
6	~ 6.89
5	~ 7.05
4	~ 7.04
3	~ 12.27

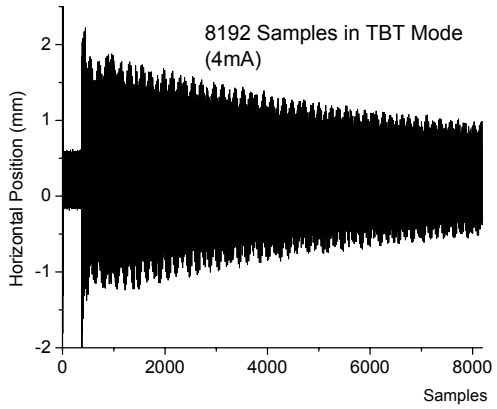

Figure 5: A typical damping waveform in TBT mode

From the turn-by-turn data get from the DBPM electronics, it's easy to do get the fractional tune of storage ring by doing off-line FFT (Fast Fourier Transform), actually, this FFT function can be integrated in the software in the future. Figure 6 gives a FFT spectrum, horizontal, vertical and longitudinal sideband are clearly appeared while there have strong enough kicker.

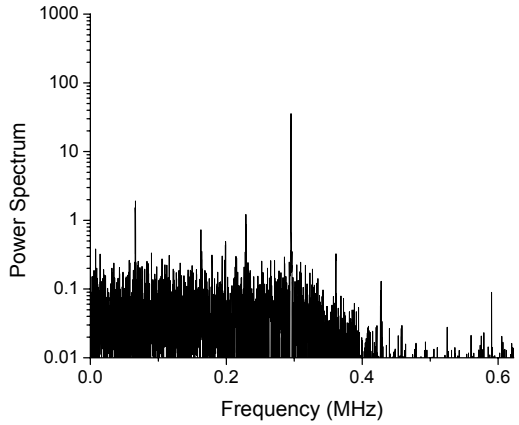

Figure 6: FFT spectrum of turn-by-turn position data

CONCLUSION

The DBPM has reached requirement of the third generation light source in all available operation modes. One set of such DBPM system can be used everywhere of accelerator complex. This system can not only be used in position monitor, but also the beam current measurement system, tune measurement and position feedback system etc. Its complete integration into the EPICS based control system allows online re-programmability by the operators in the control room through BPM control panel.

This DBPM system is a commercial product of I-TECH company and it has been fully used in SLS, ELETTRA, great thanks to SLS and I-TECH experts, while debugging and test this system, they have give us many good ideas and technical instruction. Also, BEPC colleagues have do us a great favor while doing on-line test in Beijing.

REFERENCE

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