PLS Beam Position Monitoring System*

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Abstract

The Pohang Light Source(PLS) beam position monitor(BPM) has been designed and a prototype BPM is being tested. There are 9 BPM's in each of 12 achromat sections totaling 108 BPM's along the 280 m storage ring. Each BPM consists of four pick-up electrodes, ~ 30 m long coaxial cables and a narrow band signal processing board. One BPM per superperiod is a wide band detector. Along with the beam dynamical requirements, two points are emphasized in the design of the BPM. The button electrode unit is modular for easy and accurate calibration before being installed on a 10 m long single-piece vacuum chamber. The detector electronics are based on the VME-bus interface for fast data communication.

1 Introduction

The Pohang Light Source is a 2 GeV, 3rd generation synchrotron light source under construction.[1] Accurate and fast measurement of beam position is important for stabilization of the beam orbit. Machine parameters relevant to the beam diagnostics are listed in Table I. Each BPM consists of four button pickup electrodes and signal detector electronics. One of the 9 BPMs per achromat will be a wide band detector for fast, turn-by-turn, beam position measurement. The other BPMs are narrow band processors tuned to 500 MHz for accurate measurement and correction of the closed orbit. All BPM detector boards are VME-bus interfaced and are housed in 12 VXI crates. The 12 crates will be controlled by a VME-bus Orbit Subsystem Control Computer. A fully digital orbit feedback system has been proposed.[2]

Table I. Relevant parameters for beam diagnostics.

nominal energy	2 GeV
rf frequency	500.082 MHz
harmonic number	468
revolution frequency	1.06855 MHz
maximum current	100 mA
single bunch current	7 mA
natural bunch length	10.08 mm(34 ps)
beam size at symmetry point	
horizontal	348 μm
vertical	66.3 μm
beam life-time	6 hrs

The PLS BPM system should satisfy the following requirements for closed orbit measurement: measurement repeatability within 30 μm, 20 μm position resolution over the entire range of beam current, 150 μm absolute accuracy including mechanical, thermal and survey errors, and the capability of 15 Hz real-time closed orbit feedback. Wide band detector electronics should have a 2 MHz sampling rate to measure the turn-by-turn beam position. This system should also meet the same operational requirement as the narrow band detector for closed orbit measurement. Design parameters of the BPM are tabulated in Table II.

Table II. BPM design parameters.

resolution at nominal current	$\leq$ 20 μm rms
beam life-time stability	$\leq$ 30 μm rms
absolute accuracy	$\leq$ 150 μm rms
closed orbit measurement mode	$\geq$ 1 orbit/sec
real time orbit feedback mode	$\geq$ 120 orbits/sec
single turn mode	$\geq$ 2 M positions/sec
dynamic range	
closed orbit mode	1~100 mA(40 dB)
single turn mode	0.2~2 mA(20 dB)

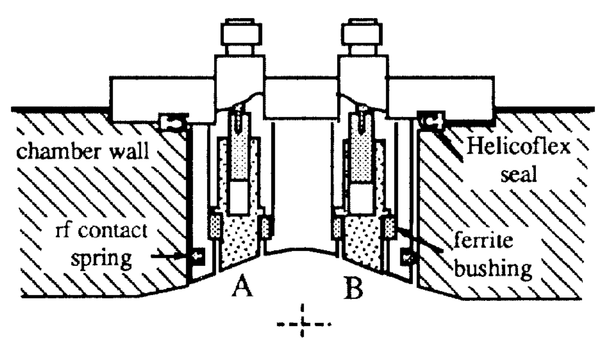

Figure 1: Schematic diagram of a BPM plug. Two electrodes are assembled in one BPM plug

*Work supported by MOST and POSCO

2 Electrode Assembly

The storage ring beam position is sensed by four capacitive pick-up electrodes symmetrically positioned on the vacuum chamber. One sector of the PLS vacuum chamber consists of three long pieces: a 10 m curved chamber, a 7 m curved chamber and a 7 m straight section chamber. Each chamber is formed by top and bottom pieces machined from large aluminum plates which are welded together. Precise calibration of BPMs which are mounted on such a long chamber is difficult. Thus a BPM electrode unit is modularized, with two button electrodes assembled in a single BPM plug as shown in Figure 1.

A BPM consists of two BPM plugs mounted on the top and bottom chamber pieces. This modular electrode unit has advantages in precision machining(± 10 μm) and accurate testing and calibration of BPM modules before installation on the chamber. In each prototype BPM plug, two electrodes are accurately positioned with ferrite bushings in precisely machined holes. These ferrite bushings also damp out various rf resonances. Vacuum SMA feedthrus are welded to the BPM flange and connected to the electrodes by means of rf contact bands. In this way, the position of the electrodes will not be affected by the position offset of the feedthroughs. Both the feedthru and the electrode assembly show poor impedance characteristics because of the thick electrode and intricate coaxial line structure. This non-constant impedance of the electrode assembly, however, may not degrade the BPM performance, since the detector electronics are tuned to a narrow band signal.

The vacuum property of the BPM plug is another point to be inspected carefully because of its intricate structure. Much care has been taken to design venting grooves to avoid air traps. For better impedance characteristics and vacuum properties, a pair of prototype BPM plugs will be custom-manufactured with the electrode assemblies vacuum-brazed directly into the plugs.

The diameter of an electrode is 9.5 mm, which is comparable to the bunch length. The short bunch signals are picked up by four electrodes and delivered to the detector electronics via conductor-tube shielded coaxial cables. The beam spectrum extends to very high frequencies. It has the upper 3 dB corner at 9 GHz and the high-pass shoulder at 160 MHz, well below the 500 MHz working frequency. Beam-electrode coupling is about 0.19 Ω and the multi-bunch signal voltage at 500 MHz is about 22 mV rms.[4] A beam simulation antenna method has been used to determine the BPM sensitivity and the electrical position. An antenna wire is supported and stretched tightly by a hacksaw-like frame and terminated at one end. A stepper motor x-y translation stage is used for movement of the antenna. The accuracy and the repeatibility of the driving system has been measured to be less than 1.5 μm rms.

The center of the chamber is found by touching the wire antenna on a pair of reference plugs. The averaged position of touch points is then the center of the chamber. We used a 4-channel, 1 GHz digitizing oscilloscope for the measurement. The sensitivities S_x and S_y at the center of the chamber are 6.15 %/mm and 6.13 %/mm respectively. A contour plot of the BPM sensitivity is shown in the Figure 2. The linear approximation with less than 1 % error of the position reading is good within a circle of 6 mm diameter.

After installation of the BPMs on the chamber, we will use a network analyzer to find electrical offsets including coaxial cables.[3]

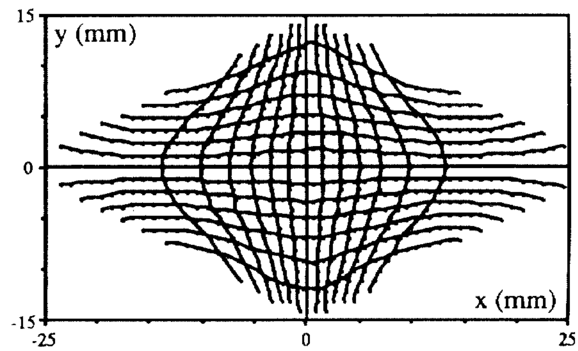

Figure 2: Contour plot of the sensitivity of a BPM. Each line is seperated by $S_x \cdot x = 0.1$, and $S_y \cdot y = 0.1$.

3 Detector Electronics

The PLS BPM electronics consists of a four channel rf switch, a single channel signal detector and a VME-bus interface. Four pickup signals are scanned via a fast four channel switch and detected by a common signal processor. After scanning four switches, the fifth clock is used for the detection of the system offset, which is then subtracted from the electrode signals. To avoid the transient periods at both the rising and falling edges of the switching signal, a sample/hold gate will be set well within the rf switch-on period. We need to scan the switch within 1 msec for the 15 Hz real time closed orbit correction. A fast GaAs rf switch(SW-254) has low insertion loss, good linearity up to 33 dBm and good thermal stability; less than 3 % absolute and less than 0.4 % relative drift in the temperature range of 10 to 50 °C. The button signal is tuned at 500 MHz through a band pass filter and down converted to 10.7 MHz in a mixer. The heterodyned signal is detected and amplified by a well known TV video detector circuit. The beam signal is then digitized by a 12bit ADC and passed to the VME-bus.

As of now, dynamic range of the prototype detector is $\sim$ 30 dB. To improve the detector performance, we do various modifications. To assure 40 dB channel to channel isolation of the switch, 3 SPDT switches will be used instead of a single SP4T switch. A 1 % band pass filter is domestically produced which is smaller in size than commercial products but shows better characteristics; 1.6 % 3 dB band width, 10 % 60 dB band width, -25.6 dB return loss, and VSWR of 1.11. A diplexer circuit is used to provide good terminations to spurious harmonics of local oscillator and rf signal. To reduce connection length and to increase isolations, all these rf-components and IF-circuits will be integrated in a machined aluminum case having shielded rooms for different components.

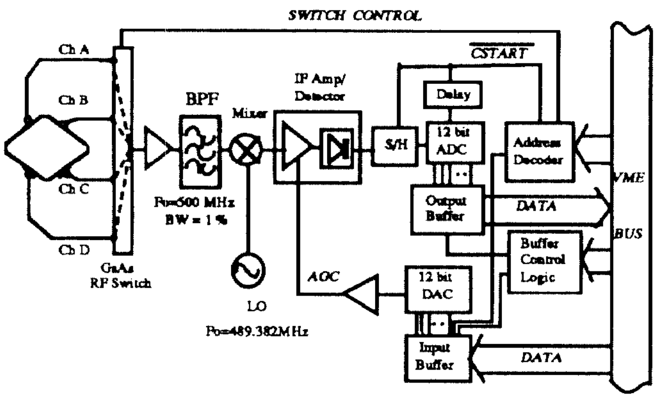

Figure 3: Block diagram of the detector electronics

A block diagram of the narrow band BPM detector electronics is shown in Figure 3. They will be used mainly for closed orbit measurement. However, this BPM can also be used as a beam-finding tool during commissioning. By watching whether the beam signal is induced or not on a certain pickup electrode, we can conclude whether the beam has passed or not. This can also be used as a first-turn beam position measurement system. By detecting four button signals alternatively induced by four sequentially injected beams, we can measure the first-turn beam orbit. It is possible to select these measurement modes with the fully programmable logic of the beam position measurement system. There are several narrow band detector systems recently developed which we studied including the NSLS[5], ALS[6] and ELETTRA[7] BPM systems.

A wide band detector will be installed in each sector of the lattice. These detectors will be used for both single turn measurement and closed orbit measurement. Most of the fluorescent screens installed on ID chambers will be removed when insertion devices are installed. Wide band detectors are then particularly useful for trouble-shooting and recommissioning. The four signals will each have a seperate detector circuit which is a replicas of the narrow band detector circuit. A video digitizer and a 1024-byte FIFO memory is used to store each button electrode signal.

4 Summary

There will be 96 narrow band BPM's for closed orbit measurement and 12 wide band BPM's for fast measurement of the turn-by-turn single bunch beam position in the PLS storage ring. A prototype BPM has been fabricated and tested. The sensitivities along the x- and y- axes are almost symmetric at the center of the chamber, 6.15 %/mm and 6.13 %/mm respectively. The contour map of the sensitivity curves also shows good linearity of less than 1 % inside a 6 mm circle, and shows good symmetry up to $\pm$ 10 mm.

By housing the rf components inside a machined aluminum case which has partitioned rooms for different components isolation is improved. A well-proven TV video detector circuit is applied to the BPM. With the VME-bus based design of BPM detector boards we have great flexibility in the beam position measurement and feedback operations. One feature is the capability of broadening the dynamic range of the detector by using a switchable gain or attenuator for the IF amplifier.

Now we continue to improve the performance of the BPM: simplification of the BPM plug by brazing the electrodes instead of assembling many parts, avoiding air traps and improving rf characteristics, set-up of the BPM test chamber and x-y stage on an optical table to avoid errors from vibrations, widening of the detector dynamic range up to 50 dB, and use of a 65 psec impulse generator to simulate the beam signal.

References

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