High Resolution Photon Beam Position Monitor

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Abstract

The resolution of the photon beam position plays a major role to the ultra stable requirement of the photon beam for a low emittance synchrotron light source. The local feedback system is considered to stabilize the photon beam fluctuation with a gain bandwidth of 200 Hz for the VUV and soft X-ray beam line at SRRC. The power line interference and 1/f noise in the low current measurement cause a strong reduction of S/N ratio in this wide band application. This paper reports the resolution improvement of the photon beam position about 100 times utilizing the technique of modulation and demodulation on the photo current.

1. INTRODUCTION

SRRC is a facility of the third generation light source characterized by its high brilliance photon flux radiated from the ultra small beam size of the electrons[1]. Therefore, the working condition and the supporting structure of the magnet ought to be very stable. The variation of the magnet current and position will no longer keep the electrons circulating on the golden orbit with constant beam size.

The local feedback system is planned to stabilize the photon beam. Since the electron is guided in the aluminum vacuum chamber which has a shielding effect of the AC magnetic field, the current change with the frequency higher than the cut-off frequency (20 Hz and 40 Hz) is damped. The second pole (200 Hz) of the steering magnet response restricts the bandwidth of the feedback. The delay time between the detecting of the photon position and the setting of the local bump should be within a couple of millisecond to avoid the unstable feedback.

When we started to design the local feedback system at SRRC, we had following requirements which should be solved in a convenient way:

- Measure the low photo current with high S/N ratio in the desired bandwidth,
- Control the gain of the current measurement for the single bunch and the multi-bunch operation,
- Send the information over 100 meters to the computer within the desired time delay,
- High speed communication with the local controller of the steering magnets.

The digital lock-in technique in this paper provides two advantages which are measuring low current with high resolution and distance communication without time delay. The gain control is manipulated by the digital processor which communicates with intelligent local controller (ILC) through the reflective memory.

2. MODULATION

First, we considered a signal demodulation scheme to increase the S/N ratio on the conventional photon beam position monitor (PBPM). The photo current has the time structure decided by the RF bunching (2 ns) and the revolution time (400 ns) of the stored electrons. The demodulation scheme on each time structures has its own disadvantages. The electronics for the high frequency application (500 MHz) is quite expensive. The phase of the 2.5 MHz component depends on the filling pattern.

Therefore, we applied a lock-in technique utilizing the photo-electric effect with a exciting voltage. The frequency is chosen at 10 kHz which is high enough to give us a reasonable detecting speed but not too high for the electronics. The modulated signal can be sent through the twist pair cable over 100 meters without interference. A single digital signal processing (DSP) card is able to do the jobs of the modulation, demodulation, gain control orbit calculation and the parameters learning.

Figure 1 shows the circuitry of the PBPM. Since the photo current is very low, the photo plates and the transformers are arranged in the bridge configuration to cancel the leakage current rising from the cable capacitance. The transformers contain the amorphous metal core with the characters of high leakage inductance, low cross inductance and low cross capacitance. The adjustable capacitors provide the possibility of the bridge nulling both for the summing and the differential output. The residual of the bridge nulling is achieved under 10 nA with 1 V voltage excitation.

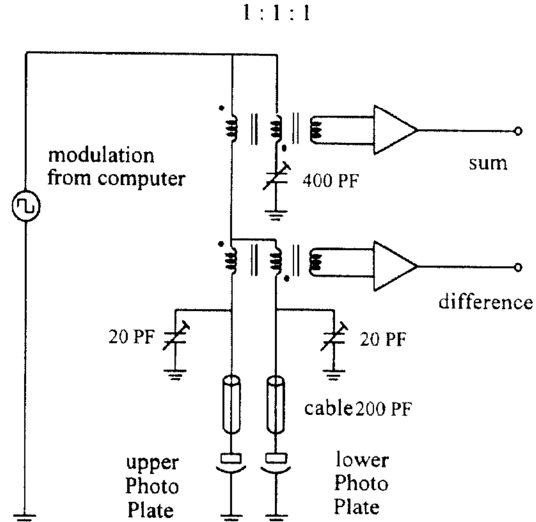

Figure 1: The circuitry of the PBPM.

3. DEMODULATION

The DSP card has one TMS320C31 floating point processor and two AM/D16SA daughter I/O modules. Each I/O module provides 2 input channels with 16 bit resolution and 200 kHz sampling rate. For the test run, we select the PC version of the DSP module. Figure 2 shows the configuration with a PC add-on module for the feedback system. The setting signal of the correction magnet is sent directly to the power supply, since there are only three operating beam lines at present. For more operating beam lines in the future, this PC modules will be replaced by the VME modules which communicate with the ILC through the reflective memory.

The DSP card converts the modulated analog signal from the PBPM to 16 bit digital data with a sampling rate of 100 kHz. The processor demodulates and averages the sum and the difference of the position from 100 kHz to 1 kHz. The operations of demodulation and filtering increase the digital resolution. To cancel the effect of the beam size variation, the difference value is normalized by the sum.

The setting value of the local bump will be calculated with the compensated PI regulation. The adaptive learning algorithm matches the four bump parameters such that there is no bump leakage[2].

4. PRELIMINARY RESULT

Before the new PBPM is available, the circuitry was tested on the beam profile monitor at the white beam line. Figure 3 shows the spectrum of the photo current without the lock-in circuit. The 60 Hz component is not included, since the amplitude is an unreasonable value of 200 μm. Applying the lock-in circuit, the 60 Hz component came to a reasonable value of 24 μm. Figure 3 shows the spectrum with lock-in circuit. We observed the noise reduction, especially in the low frequency region.

These results were measured without the long distance drive and the normalization. The broad band signal at 12 Hz and 22 Hz comes from the magnet vibration. The peak at 25.5 Hz and 29.5 Hz are driven by the ventilator and vacuum pump, respectively. The broad band structure around 35 Hz comes from the cooling water running in vacuum chamber. It is not surprising that vacuum chamber has contribution on the electron jitters, since the eddy current will be induced from the movement of chamber in magnetic field.

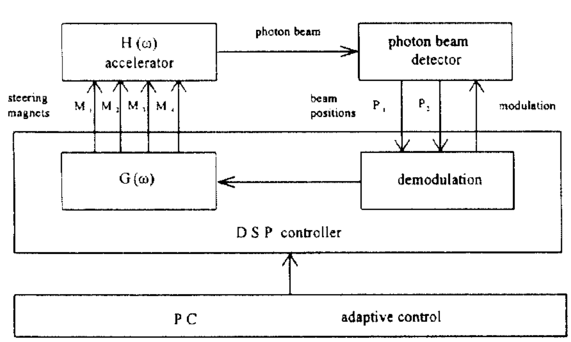

Figure 2: The configuration of the feedback system.

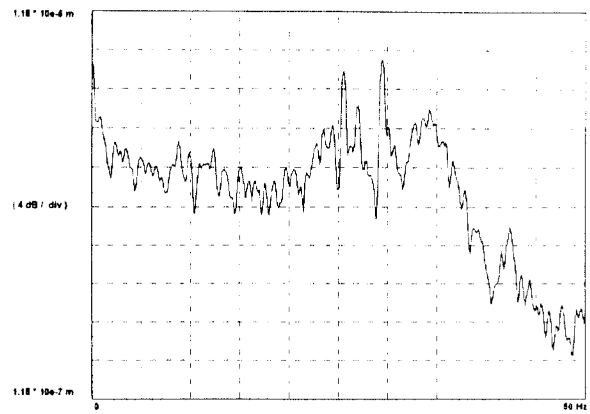

Figure 3: The spectrum of the photo current without lock-in.

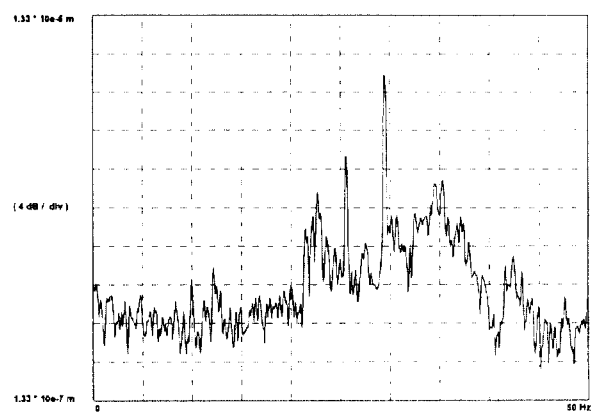

Figure 4: The spectrum of the photo current with lock-in.

5. CONCLUSION

The lock-in technique by means of the photo-electric effect provides the excellent method of the photon beam detection. The interference from the power line is reduced by 10 times, and the 1/f noise is also suppressed around 10 times. The communication with modulated analog signal has the advantages of low cost and negligible delay time.

6. REFERENCES

[1] *SRRC Design Handbook*, Synchrotron Radiation Research Center, Taiwan, 1990.

[2] Cheng, Y. and Hsue C.-S. "Adaptive Closed Orbit Correction". p. 1704, Proceedings of the 1991 IEEE Particle Accelerator Conference.