THE OBSERVATION OF ELECTRON BEAM SIZE VARIATION BY UTILIZING THE NONLINEARITY OF A FAST PHOTODIODE

Ian C. Hsu, C. I. Chen, Chuan-Ing Yu, Cha-Ching Chu
Department of Nuclear Science, National Tsing Hua University
and
Synchrotron Radiation Research Center
Hsinchu, Taiwan. 30043

ABSTRACT

In the experiment study of accelerator physics, a turn by turn monitoring of the beam profile can provide very unique information. We proposed a method which may measure a turn by turn electron beam profile through its synchrotron radiation by using a fast photodiode. Here, we utilized the nonlinearity of the response of the photodiode detector. In this paper, we will present the experimental results. We had examined this idea by using a modulated He-Ne laser to simulate the synchrotron radiation light. The results agree with our computer simulation results. The results of measuring the beam size variation of the electron beam in the storage ring of Taiwan Light Source (TLS) will be presented and discussed.

1. INTRODUCTION

In many accelerator physics experiments, e.g., the coherent damping time measurement and the dynamic aperture study experiments, we like to know the turn by turn variations of the beam positions. Usually, it is accomplished by the button type or the strip line type electrode beam position monitors (BPM). However, the measurements done by these types of BPM only gave us the information of the position of the beam centroid. If the beam centroid motion combined with the decoherence mechanism, the BPM would not be able to distinguish them. This means that by using the BPM, we can not distinguish the coherence damping or the decoherence. In order to distinguish them, we need to monitor the beam profile simultaneously. For lepton machines, the synchrotron radiation provides a very useful beam profile information. However, to perform a turn by turn beam profile monitor, we need a very fast detecting system. For the speed requirement we need, the commercial photodiode array and the following up electronic system is not available neither a cost reasonable approach. In this paper, we proposed a method to monitor the beam profile by using a fast single photo diode. We had examined this idea by using a modulated He-Ne laser to simulate the synchrotron radiation light. The results agree with our computer simulation results. By changing the optics of the synchrotron radiation monitor system, we can change the synchrotron radiation beam size. Using the fast photodiode, we can detector the beam size variation which agree with the results from the CCD measurement. Because changing the optics is a slow beam size variation, therefore, the photodiode measurement results can be checked by the CCD measurement. For the fast beam size variation test, we turned off the transverse feedback system and reduced the sextupole magnet strength to drive beam into unstable. In the preliminary result, we may detect the beam size variation signal.

2. THEORY

Most P-N silicon photodiodes are linear (better than *1%*) over a wide range of magnitude of the incident power. In linear region, the total photocurrent is independent of the incident photon beam size as long as the total power is the same. At high photon intensity, however, nonlinearity is introduced due to the device saturation. Total photocurrent in nonlinearity region now is not only dependent on the incident total photon power but also dependent upon the photon beam size. This means that in the nonlinearity region, we can get the photon beam profile information by means of measuring the total photocurrent. More detailed discussions and computer simulations can be found in a previous paper.[1]

3. THE EXPERIMENTS AND DISCUSSIONS

In the first case, we examined the nonlinear phenomenon of the photodiode in the laboratory by using a modulated He-Ne laser to simulate the synchrotron radiation as the measured beam. In the second case, we used synchrotron radiation as the measured beam. In the experiments of the second case, for electron beam current around *200mA*, the synchrotron radiation itself is too weak to saturate the photodiode. Thus for all of the synchrotron radiation measurement, i.e. the second case in this study, we always used a *5.0mA* He-Ne laser with beam size $\sigma \cong 0.4mm$,at the location of the photodiode, to saturate the photodiode.

Figure 1 shows the system setup for the first case. In this figure, the saturation beam is used to saturate the photodiode such that the photodiode can be operated in the non-linear region, even for the very low power measured beam.

The factors those would affect the photodiode′s output photocurrent are the measured beam′s photon power, the bias voltage applied to the photodiode, and the saturation beam′s photon power. Figs. 2 and 3 demonstrate how the three factors affect the output photocurrent. In the experiments, we measured the output voltage which was induced by the output photocurrent. In Fig. 2, three curves shown the output voltage for the cases of no saturation beam and two different saturation beam′s photon power. We can see that with a 1.8 mW saturation beam, the measurement dynamic range increased by a factor of 6 in diameter and a factor of 36 in the beam size.

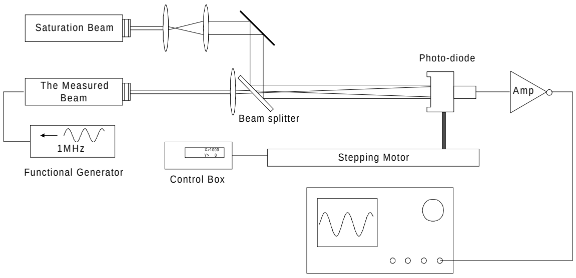

Fig.1 Schematic drawing of the experimental setup for the case of using laser to simulated synchrotron radiation as the measured beam.

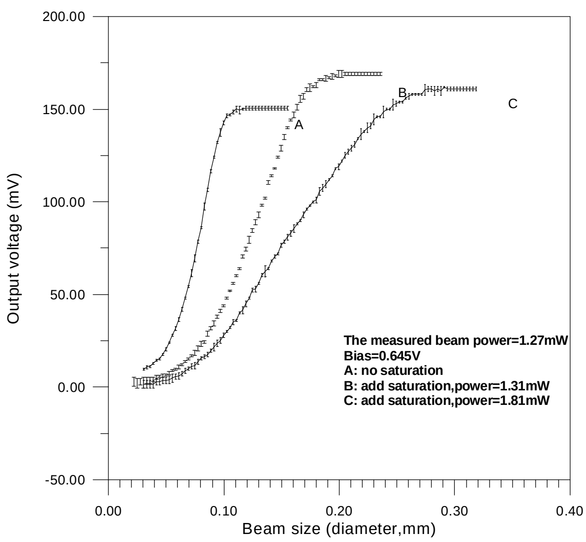

Fig.2 Three curves shown the output voltage for the cases of no saturation beam and two different saturation beam′s photon power.

In Fig. 3, a weaker measured laser beam was use. The power of the measured beam is about the same as that of the synchrotron radiation emitted from a 150 mA electron beam. The two curves shown the effect of different bias voltage. The results agree with what we excepted that with a lower bias voltage the diode become easier to be saturated.

Figure 4 shows the system setup for the second case. In this figure, the measured beam is the synchrotron radiation ; the saturation beam is used to saturate the photodiode, such that the photodiode can be

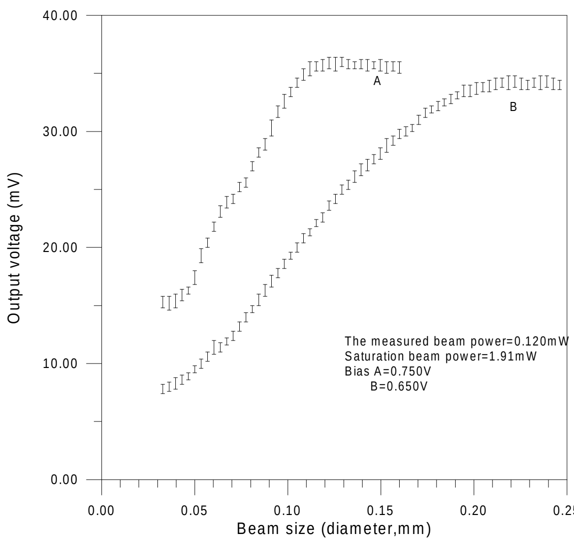

Fig.3 A weaker measured laser beam was use. The two curves shown the effect of different bias voltage.

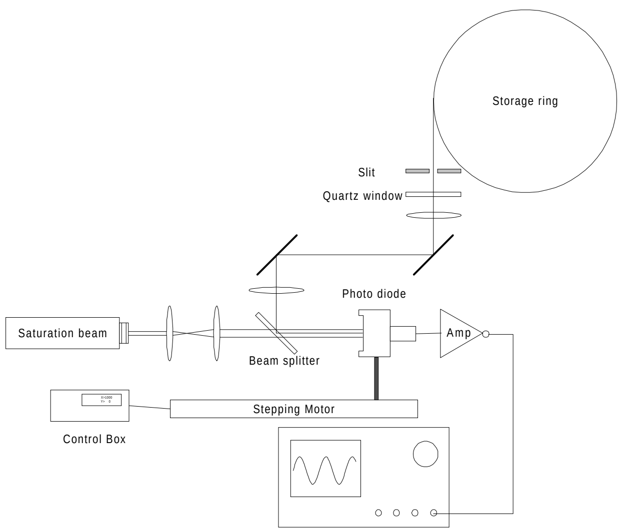

Fig.4 Schematic drawing of the experimental setup for the case of using synchrotron radiation as the measured beam.

operated in the non-linear region, even for the low power synchrotron radiation. By changing the optics of the synchrotron radiation monitor system, we can change the synchrotron radiation beam size. Because changing the optics is a slow beam size variation, therefore, the photodiode measurement results can be checked by theCCD measurement. Fig. 5 shows the synchrotron radiation measurement results. The beam size value in the horizontal axis was measured by the CCD. The two curves are for two different electron beam current with the same bias voltage and the same saturation beam. For the fast beam size variation test, we turned off the transverse feedback system and reduced the sextupole magnet strength to drive beam into unstable. In the preliminary result, we may detect the beam size variation signal. Figure 6 shows the FFT of the time domain signal which was taken by the phodiode at the situation described above. The revolution frequency is 2.5 MHz. The vertical tune corresponds to the frequency of 2.80 MHz and the horizontal tune corresponds to the frequency of 2.95 MHz. The spikes of frequencies 3.15MHz and 3.375 MHz seem corresponding to the quadrupole mode of the both transverse directions' motion. We need more data to clarify this point. Because the saturation beam is not a Flat-Top (uniform) beam but a Gaussian beam, therefore the beam's dipole motion will be also detected by the photodiode. This could be a by product of the saturation beam. However, if we need a clear beam size variation signal, we will need a Flat-Top beam. This is what we are developing now.

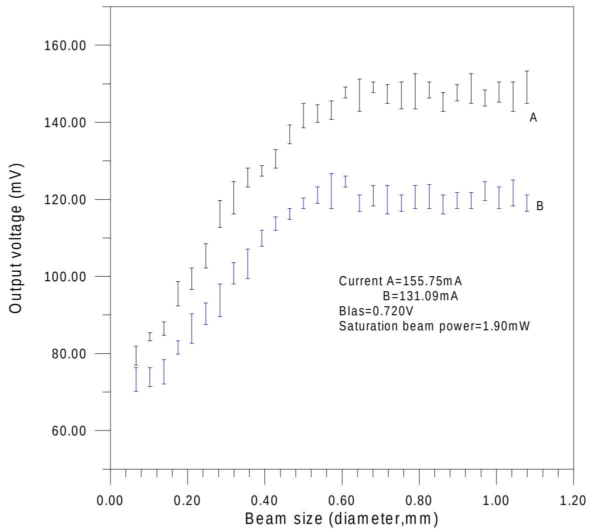

Fig.5 The synchrotron radiation measurement results. The two curves are for two different electron beam current with the same bias voltage and the same saturation beam

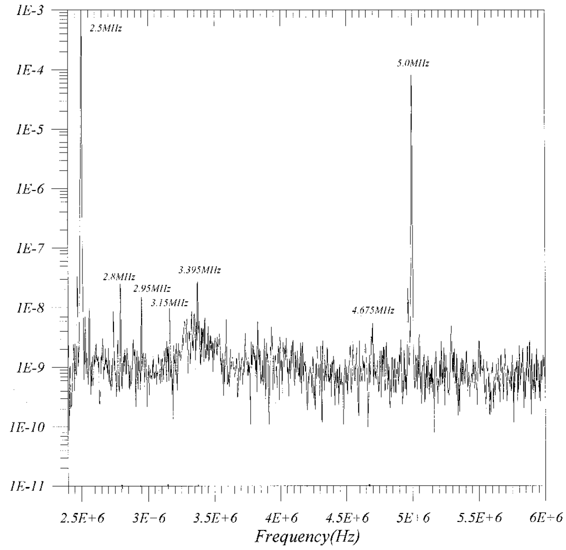

Fig. 6 The FFT of the time domain signal which was taken by the phodiode for an unstable beam. The revolution frequency is 2.5 MHz. The vertical tune corresponds to the frequency of 2.80 MHz and the horizontal tune corresponds to the frequency of 2.95 MHz.

4. ACKNOWLEDGMENT

We would like to thank Dr. K.-T. Hsu of SRRC, Taiwan, for his help in providing the BPM signal and the optics system of the synchrotron radiation monitor. This work was supported by the NSC of Taiwan, under contract NSC 85-2112-M-007-019.

REFERENCE

[1] Ian C. Hsu et al., in *Proceeding of the 1995 Particle Accelerator Conference* (Dallas, Texas, USA, 1995), pp. 2515-2517.