Study of Fast Energy Electron Beam Profile Monitor System

Ian Hsu, C. I. Yu and C. C. Chu
Institute of Nuclear Science,
National Tsing-Hua University and
Synchrotron Radiation Research Center,
Hsinchu, Taiwan 30043, R. O. C.

ABSTRACT

In the experimental study of accelerator physics, a turn by turn monitoring of the beam profile CAN provide very unique information. In this paper, we proposed a method which may measure a turn by turn electron beam profile through its synchrotron radiation by using a fast photo-diode. Here, we utilized the non-linearity of the response of the photo-diode detector. At high photon intensity, non-linearity occurred due to the saturation of the device. In this paper, we will present the theory and the test 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[1]. But the photon power intensity of synchrotron radiation in the storage ring of TLS(Taiwan Light Source) is not sufficient to saturate the photo-diode as what we expected. In order to utilize the idea on the synchrotron radiation, we used an external light source to saturate the photo-diode and the synchrotron radiation be the probe beam. In this paper, the theory and the experiment of the above idea will be 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 to 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. That 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 photo diode 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.

2. THEORY

Most P-N silicon photo-diodes are linear (better than *1%*) over a wide range of magnitude of the incident power [2]. 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, non-linearity is introduced due to the device saturation. Total photocurrent in non-linear 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 non-linear region, we can get the photon beam profile information by means of measuring the total photocurrent. A detail discussion has been presented in a previous paper [1].

3. EXPERIMENTS and RESULTS

We used a He-Ne laser to simulate the synchrotron light. The setup of the simulation experiment is shown in figure 1. The power of the He-Ne laser is *1.33mW*, which is sufficient to saturate the photo-diode. We use a functional generator to modulate the He-Ne laser intensity at frequency of *1MHz*. The movable convex lens is used to change the incident photon beam size. The photo-diode (PIN10DI manufactured by UDT) is negatively biased. The output of the photo-diode is then magnified by an amplifier of gain *147V/V* with output resistance *50ohm*. The CCD camera is used to measure the laser beam size. The results are shown in figure 2. In this figure, we compared the results of two different bias voltage, i.g. *0.3V* and *0.828V*. We can find that the smaller bias voltage made the saturation easier. We also find that the minimum power intensity to saturate the photo-diode is about $0.3325 mW/mm^2$.

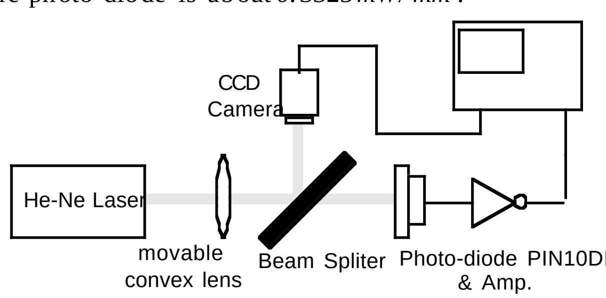

Fig. 1 Experiment Setup

The total photon power of the synchrotron radiation in the storage ring of SRRC is about an order of 10^{-2} (mW) at single bunch mode, with $1mA$ beam current . The photon beam size is approximately the same order as the He-Ne laser we used in this study($\sim 0.28\text{-}4mm^2$). Thus the power intensity is not sufficient to saturate the photo-diode as what we predicted in figure 2.

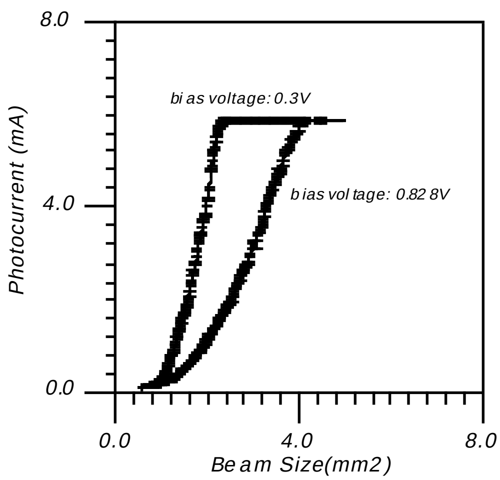

Fig. 2 Plot of the photocurret vs. incident photon beam size for two bias voltage, $0.3V$ and $0.828V$.

Figure 3 shows the signals of the photo-diode as synchrotron radiation incident on it. From the figure we see that the photo-diode can detect the revolution frequency of the electron beam but fail to sense the beam profile changes. This is due to the low power intensity of the SR as mentioned above.

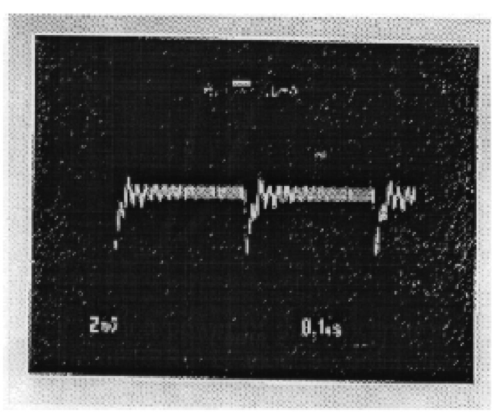

Fig. 3 The response of the photo-diode as the SR of the storage ring in SRRC impinging upon it

To solve this problem, we used an external light source to saturate the photo-diode to sense the beam profile variation of the SR; This variation information indicates the dynamics of the electron beam in the storage ring. The setup of the saturation experiment is shown in figure 4. The power of the saturation beam is $1.09mW$ and that of the probe beam is the same as before.

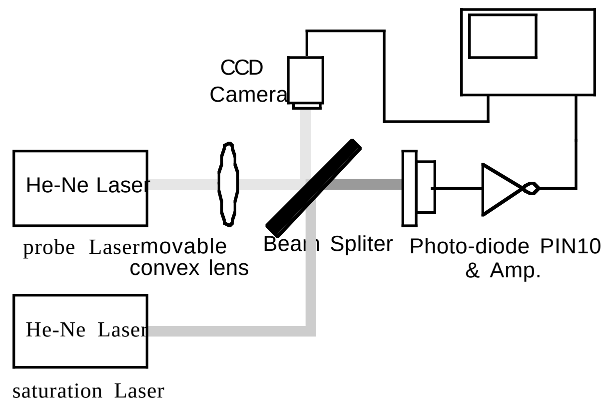

Fig. 4 External light saturation experiment setup

The corresponding beam size vs. the distance between the photo-diode and the convex lens is shown in figure 5. In this experiment we used an anti-reflection coated convex lens with focal lens $17cm$. The results of the photocurrent we measured are shown in figure 6. We found an obvious variation of the photocurrent when the beam size was changed. Further, we used filters to change the power intensity of the probe beam. The results is shown in figure 7. The minimum photon power can saturate the photo-diode is about $0.06mW$ at the beam size of $0.28mm$ that is about the same as the power intensity of the SR which we are going to use.

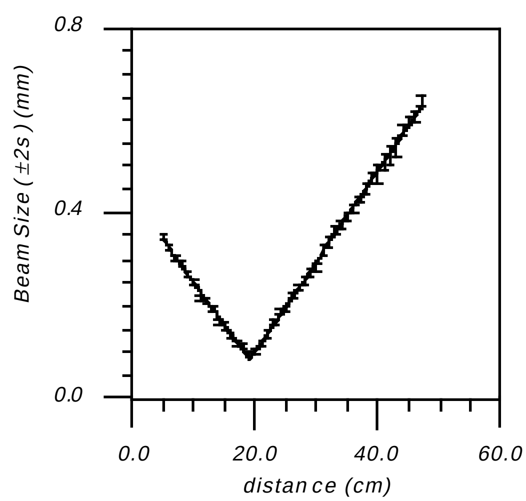

Fig. 5 The corresponding beam size vs. the distance between the photo-diode detector and the movable convex lens.

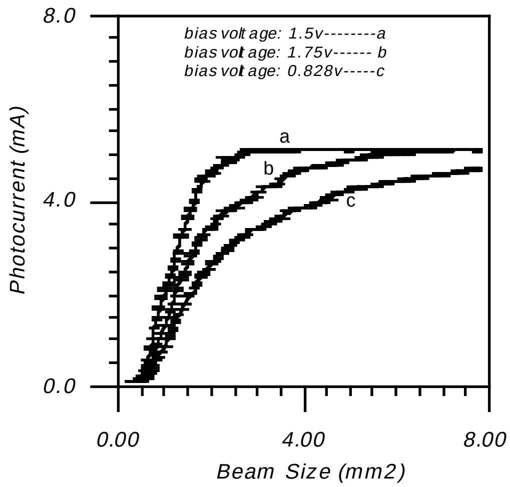

Fig. 6 Plot of the photocurrent vs. photon beam size, three kinds of bias voltage were presented (The power of the saturation beam is *1.09mW*, without modulation, that of the probe beam is *1.33mW*, *1M Hz* modulated by a functional generator)

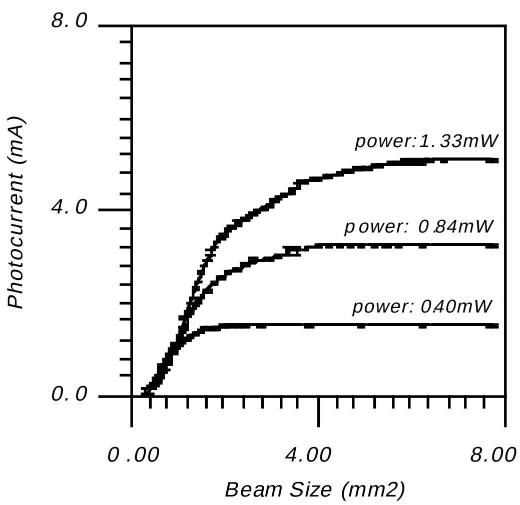

Fig. 7 Plot of the photocurrent vs. photon beam size, for three probe beam power. (The bias voltage was *1.175V*. The power of the saturation beam is *1.09mW*, without modulation. The probe beam was *1M Hz* modulated by a functional generator)

4. DISCUSSIONS

The results from the laser beam experiment prove the feasibility of the idea we first mentioned. That is, we can use the non-linearity of the photo-diode to sense the beam profile variation information as long as the total power of the incident photon is the same.

In the single bunch case, the SR power intensity is, however, too small to saturate the photo-diode as applying the method for sensing the electron beam profile changes in the storage ring. To solve the problem, we used an external light source to saturate the photo-diode first. In this case the changes of electron beam profile may be detected although the SR intensity is small.

Further, we will search an absorber which can be easily saturated by the SR from the electron beam. The more the absorber is saturated, the larger the transmitted SR is. The differences between the transmitted SR of different power intensity can then be measured by the photo-diode operated at the linear region.

5. ACKNOWLEDGMENTS

We would like to thank Drs. Y. Cheng and K. T. Hsu of SRRC for their help by prviding the video amplifier.

6. REFERENCE

[1] I. Hsu, C. C. Chu and C.I. Yu, "Turn by Turn Beam Profile Monitor by Utilizing the Non-linearity of the Photo-detector", in EPAC'94 Conference Proceedings, London, June 1994, p1649.

[2] Melles Griot, Optics guides 5, Ch.22.