MEASUREMENT OF THE BEAM PROFILES WITH THE IMPROVED FRESNEL ZONE PLATE MONITOR

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Abstract

We present the recent progress of the FZP (Fresnel Zone Plate) beam profile monitor constructed at KEK-ATF damping ring. This monitor is based on an X-ray imaging optics with two FZPs [1]. In this monitor, the transverse electron beam image at bending magnet is twenty-times magnified by the two FZPs and detected on an X-ray CCD camera. The expected spatial resolution is less than 1μm in R.M.S. Recently, we install the new mechanical shutter to improve time resolution of the monitor and avoid the effects of the short-term movement of beam or the monitor itself. By applying this shutter, the shutter opening time is reduced less than 1ms and the beam profile could be measured more accurately. In this paper, we report the measurement results of beam profile by the improved FZP beam profile monitor.

INTRODUCTION

The Accelerator Test Facility(ATF) was built at High Energy Accelerator Reseach Organization (KEK) in order to develop the key techniques of ultra-low emittance beam generation and manupulation. The ATF consists of 1.28GeV S-band electron linac, a damping ring and extraction line. A low emittance beam is generated in the ATF damping ring where the natural horizontal emittance is designed to 1.1×10^{-9}m·rad. The target value of the vertical emittance is 1.1×10^{-11}m·rad. The typical beam sizes are less than 50μm horizontally and less than 10μm vertically. Our monitor (called as FZP monitor) is aimed to develop for measuring such small beam sizes and beam profiles

Fig.1 shows the setup of the FZP monitor. This monitor is based on an X-ray imaging optics with two Fresnel Zone Plates (FZPs) by using the synchrotron radiation (SR) from the bending magnet. To avoid the large diffraction limit from the visible light, X-ray SR (3.235keV) is selected by

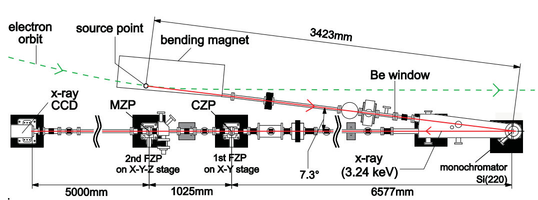

Figure 1: Setup of FZP monitor

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Si monochromator. The transverse electron beam image at bending magnet is 20-times magnified by the two FZPs (shown in Fig.1 as 'CZP' and 'MZP'). and detected on X-ray CCD camera. Thanks to the small diffraction limit of SR in the X-ray regime and the large magnification (M=20) of two FZPs, the expected spatial resolution is less than 1μm in R.M.S. [2].

We briefly summarize the history of FZP monitor before describing the recent progress of FZP monitor. The FZP monitor was installed in 2002 and could measure the clear beam profile with less than 10μm vertical beam size [1]. After installing the new monochromator which was made in order to suppress the angle drift of the Si cristal, the vertical position drift of the beam image on CCD was much reduced by a factor of about 100 and was stabilized with a few μm level for a long time [3]. We improved the two FZP folders so that the FZPs could be removed up from the optical path in the vacuum. This improvement allowed us to perform more precise beam-based alignment by detecting the X-ray SR light on X-ray CCD camera directly. As a result, the aberration effects of FZPs became negligible small for the beam profile measurement[3]. Furthermore, an X-ray pinhole mask was installed to reduce the background component of the transmitted X-rays. Finally the beam profile with 50μm horizontal beam size and 7μm vertical beam size was stably obtained in 2004 [4].

Receltly, we found the unknown 100Hz oscillation of beam positon. This amplitude is as large as 5-6μm in R.M.S. and is not negligible small compared with the vertical beam size. Unfortunately the previous shutter opening time of X-CCD camera is at least 20ms, then the measured vertical beam size on X-CCD camera was enlarged by the superposition of this oscillation effect. We emphasize that this 100Hz oscillation is not concerned with the mechanical vibration of FZP monitor beam line itself[4]. But we now do not find the source of 100Hz vibration. To neglect this 100Hz vibration, we newly install the mechanical shutter which has the shutter opening time with less than 1ms. In this paper, we present the result of the beam profile measurement with this newly installed shutter.

MEASUREMENT OF THE BEAM PROFILE

We install the new mechanical shutter in ATF damping ring and measure the beam profile. Fig.2 shows the block diaglam of FZP monitor. In order to shorten the shutter opening time of the mechanical shutter, the small aperture of the mechanical shutter is needed. Then we apply the

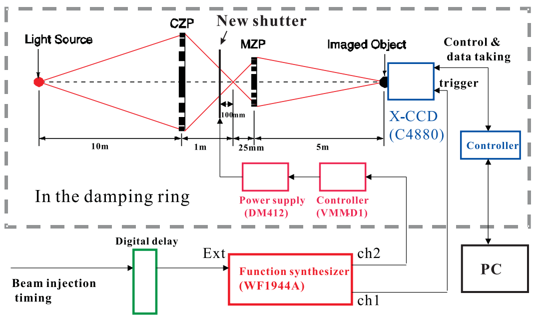

Figure 2: The block diagram of FZP monitor

mechanical shutter with 1mm diameter aperture which is smaller than the previous shutter aperture (5mmϕ) set in front of the X-ray CCD camera. Furthermore the mechanical shutter is installed near the first focal point of X-ray SR not to scrape off the transverse beam profile. The trigger timing is synchronized with the beam injection timing of damping ring and is divided with shutter trigger and CCD trigger timing. The shutter opening time is controlled by changing the trigger TTL pulse width. The measured minimum shutter opening time of this new shutter on the test bench is 1ms on the "NORMAL" mode and 0.3ms on the "HIGH" mode, which are small enough to neglect the 100Hz oscillation.

Figure 3: The measured beam profile by using newly installed mechanical shutter

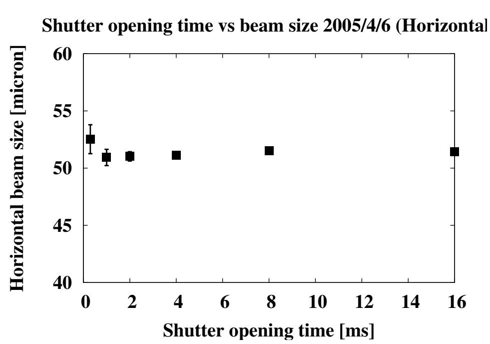

Figure 4: The shutter opening time vs horizontal beam sizes

Fig.3 shows the measured beam profile by using newly installed mechanical shutter. The shutter opening time is 1ms. The clear beam profile is obtained. We also measure the beam profile by chainging the shutter opening time of the new mechanical shutter. Fig.4 and Fig.5 show the change of the horizontal and vertical beam sizes corresponding to the shutter opening time, respectively. The horizontal beam size does not depend on the shutter opeining

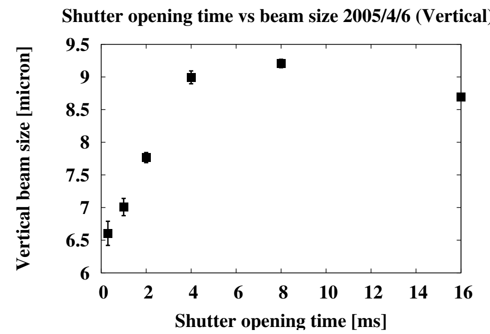

Figure 5: The shutter opening time vs vertical beam sizes

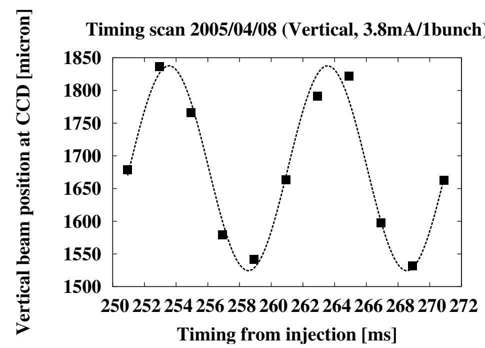

Figure 6: trigger timing vs the vertical beam profile center

time. On the other hand, we find the enhancement of the vertical beam size as the TTL pulse width of trigger timing is enlarged. To confirm that this enhancement will depend on the 100Hz oscillation, we measure the center position of the obtained beam profile by chainging the shutter trigger timing with fixed 1ms shutter opening time. Fig.6 shows the results of the vertical center position changes corresponding to the beam tirigger timing. The 100Hz oscillation of the center position is observed as shown in Fig.6 by applying the sinusoidal fitting with 100Hz frequency. This amplitude corresponds to the 5.5μm vertical amplitude of the beam oscillation. The beam size enhancement as shown in Fig.5 is explained by this 100Hz oscillation. We note that the 100Hz center position oscillation was also found horizontally, whose amplitude corresponds to 10μm horizontal beam oscillation. But this amplitude dose not affect the beam size enhancement horizontally.

In order to validate these measured beam size with 1ms shutter opening time, we compare with the calculation by using the optics of the ATF damping ring with including the intra beam scattering effect[5]. Fig.7 and Fig.8 show the comparisons of the measured horizontal and vertical beam size (boxs) and the calculation (lines), respectively. The horizontal axis shows the beam current of damping ring and vertical axis is the measured and calculated beam sizes. These measurements are agree well with the calculation assuming the betatron coupling is 0.3$\sim$0.6% including the intra beam scattering effect. We note that the measured energy spread at extraction line as shown in Fig.9 also agree well with the calculation with same assumption.

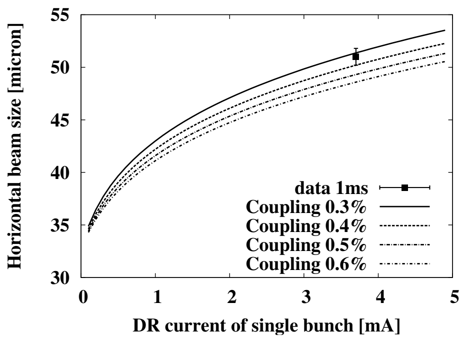

Figure 7: The comparison between the measured horizontal beam size and calculation

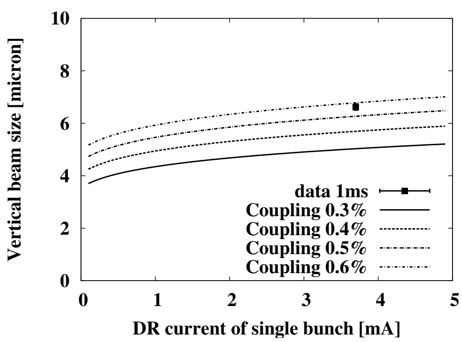

Figure 8: The comparison between the measured vertical beam size and calculation

MEASUREMENT OF THE DAMPING TIME

FZP monitor is suitable to measure the damping time because of the large dynamic range of this monitor. Futhremore the impoved time resolution by newly installed mechanical shutter allows us to measure the damping time presicely. In 2005, the beam operation with wiggler was started. It is important to measure the effect of the wiggler magnet. Then we measure the damping time with/without wiggler magnet precisely[6]. Fig.10 is the measurement of the vertical damping time with/without wiggler magnet.

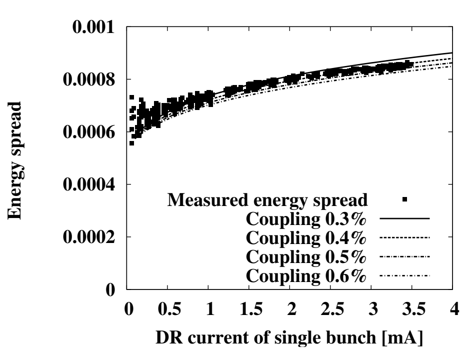

Figure 9: The comparison between the measured momentum spread and calculation

The horizontal axis shows the elasped time from the beam injection into damping ring. The vertical axis is the measure beam size by FZP monitor. The open circles (black boxes) in Fig.10 show the measured vertical beam sizes without(with) wiggler. By fitting the damping effect to Fig.10, We obtained that the vertical damping time without wiggler magnet is (30.9 ± 0.6)ms and with wiggler magnet is (20.7 ± 0.8)ms. The effect of wiggler magnet to the damping time was measured. The design values of the damping time with/without wiggler magnet is 21.1ms, 28.5ms, respectively. These values agree well with the damping time measurments.

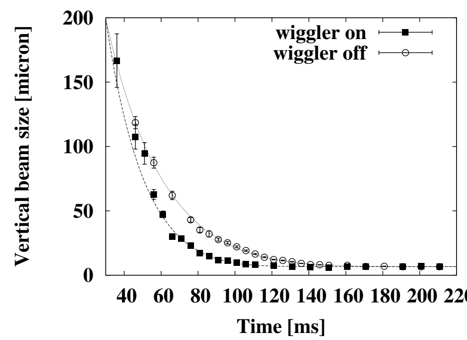

Figure 10: The results of the measured vertical damping time.

SUMMARY

We install the new mechanical shutter and measure the beam profile by using this shutter. The unexpected 100Hz beam oscillation can be removed by this mechanial shutter with 1ms shutter opening time. After that we can perform the precise measurment of the beam profile. The three measured values, which are horizontal and vertical beam size meaured by FZP monitor and the momentum spread, agree well with the calculation by the optics of ATF damping ring by assuming that the betatron-coupling is 0.3$\sim$0.6%. The damping time with/without wiggler magnet in the ATF damping ring are also measured by this monitor. The measured damping time are agree well with the calculation of the beam dynamics by usnig ATF damping ring optics.

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