Development of a Fast Light Shutter for Beam Diagnostics

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1. Introduction

A fast light shutter [1] which extract the light pulse from a particular bunch in a bunch train is useful for the beam diagnostics of electron (or positron) storage rings. It enables us to measure the beam parameters, such as the transverse beam profile, bunch length, beam oscillation and so on, bunch by bunch. We developed a fast light shutter system with a fast Pockels cell which opens/closes in the bunch spacing at the revolution frequency of the SPring-8 storage ring, and applied it to a photon counting system for measurement of the single bunch impurity installed at the machine diagnostic beamline BL38B2 [2].

A brief explanation of the principle of the light shutter and the characteristics of the light shutter are given in section 2. In section 3, we present the results of the measurement of the single bunch impurity with the light shutter.

2. Fast Light Shutter

A schematic of the fast light shutter system is shown in Fig. 1. The shutter system consists of a fast Pockels cell (Fastpulse Technology, N1072FW), two polarizers whose polarization angles are perpendicular to each other and a high voltage pulser (Kentech, HMP1 Pulse Generator). This shutter operates in the visible light range.

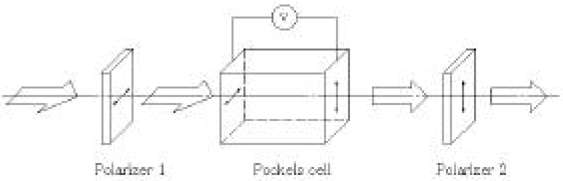


Fig. 1. A schematic of the fast light shutter system. With the high voltage applied to the Pockels cell, the polarization plane of the incident light is rotated, and the light can pass through the second polarizer.

When no voltage is applied to the cell, the direction of the polarization of the light passing through the cell is unchanged and the light can not pass through the second polarizer. While, a certain high voltage is applied, the direction of the polarization of the incident light is rotated and the light can pass through the second polarizer [3]. We can operate this system as a light shutter by applying square, high voltage pulses to the cell. The output voltage and the rise/fall time of the high voltage pulser we prepared are 700 V and 1 ns, respectively.

Time profile of the light shutter measured with the visible component of the synchrotron radiation is shown in Fig. 2. Changing the trigger timing of the light shutter to open by 250 ps step, we measured the change of the intensity of the light pulse from a particular bunch in a bunch train by the photon counting system. The extinction ratio of the light shutter is defined as the contrast between the intensity of the output light with the shutter opened (high voltage is applied to the cell) and that with the shutter closed. The extinction ratio is affected by the alignment of the cell, the collimation and bandwidth of the incident light and the output voltage of the high voltage pulser. Typically, the extinction ratio for the wavelength range of 400 ~ 750 nm is larger than 200. The ringing of the profile which appears after closing the shutter (> 2 ns) is due to the undershoot of the high voltage pulses.

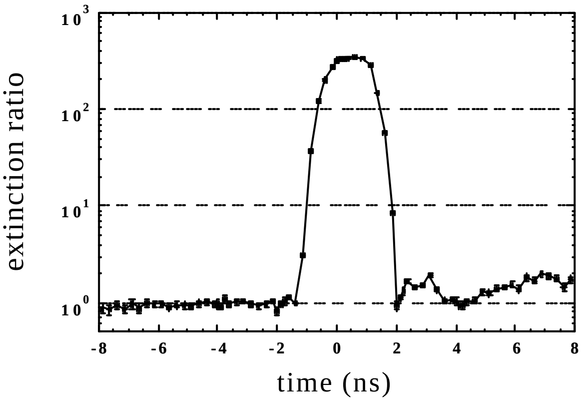


Fig. 2. Time profile of the fast light shutter. Full width of the light shutter is enough for extracting the light pulse from a bunch in a bunch train.

Table 1. Main parameters of the fast light shutter

Rise time (10 – 90 %)	0.9 ns
Flat top	1.1 ns
Fall time (90 – 10 %)	0.8 ns
Extinction ratio	> 200
Repetition frequency	209 kHz

Main parameters of the light shutter are listed in Table 1. The time response of the light shutter is dominated by that of the high voltage pulser. The repetition rate of the shutter was determined to be synchronized with the revolution frequency of the storage ring. Full width of the shutter is about 3.5 ns. This width is enough for extracting the light pulse from a bunch in a bunch train because the bunch spacing of the storage ring is about 2 ns and the bunch length is sufficiently shorter than 0.5 ns.

3. Measurement of Single Bunch Impurity

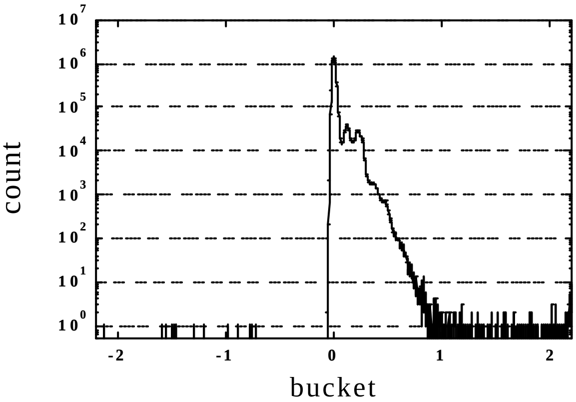
As an application of the light shutter system to the beam diagnostics, we installed the light shutter into the photon counting system at BL38B2. We can increase the detection rate of photons from a satellite bunch order of two more by adjusting the trigger timing of the light shutter to open to the satellite bunch.

Figure 3-a) is the time spectrum measured without the light shutter (measurement time: 1000 s). No satellite bunches were found around the main bunch. After the main bunch, we find many noise signals due to the photon detector (micro-channel plate type photo-multiplier tube: MCP-PMT, Hamamatsu Photonics R3809U-52). These noises limit the sensitivity of the impurity measurement without the light shutter to 7×10^{-7}. Fig. 3-b) is the time spectrum successively measured with the light shutter after the measurement of the spectrum in Fig. 3-a). The light shutter opens for 3.5 ns only in a revolution period of the electron beam. We measured the electron populations of four satellite bunches adjacent to the main bunch by changing the trigger timing of the shutter (measurement time: 500 s per satellite bunch). The time spectrum in Fig. 3-b) is obtained by combining the results of four measurements. The data of the main bunch is the average of four measurements. Contrasts between the electron populations of the satellite bunches and that of the main bunch are emphasized by a factor of about 200 by use of the light shutter. We recognize two satellite bunches of the impurity of $6 \sim 7 \times 10^{-8}$ before and after the main bunch. We also find a satellite bunch of the impurity of 7×10^{-9} at –2nd bucket. By using the light shutter, the sensitivity of the impurity measurement at +2nd bucket with respect to the main bunch of 1 mA has been improved to 4×10^{-9} for measurement time of 1000 s.

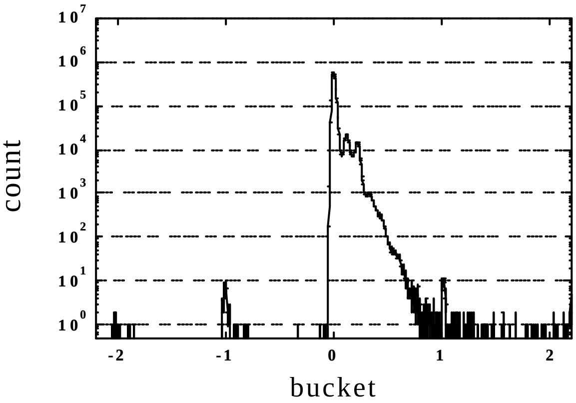
4. Conclusion

We developed the fast light shutter system for the beam diagnostics which operates in the bunch spacing. The shutter well picked out the light pulse from a particular bunch in a bunch train at the extinction ratio of larger than 200 in the visible light range, and the repetition frequency of 209 kHz which is the revolution frequency of the storage ring. We applied this light shutter to the bunch impurity measurement at the single bunch operation. We succeeded in the detection of a satellite bunch of the impurity of 10^{-9} order and confirmed that the sensitivity of the impurity measurement was improved to 4×10^{-9}.

We are planning to develop a high voltage pulser of long pulse width and high repetition rate more than 209 kHz so that we can use the light shutter not only at the single bunch operation, but also at the several bunch operation.



(a) time spectrum measured without the light shutter



(b) time spectrum measured with the light shutter

Fig. 3. Time spectra measured a) without the light shutter and b) with the light shutter. By using the light shutter, the detection rate of the photons from the satellite bunches was increased and three satellite bunches were found at -2nd, -1st and +1st bucket.

References

[1] K. Tamura and S. Takano, SPring-8 Annual Report 1994, 128 (1994).

[2] H. Ohkuma *et al.*, SPring-8 Annual Report 1997, 27 (1997).

[3] A. Yariv, QUANTUM ELECTRONICS, third ed., JOHN WILEY & SONS, Chap. 14.