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Incident position dependence of Si-APD temporal response for a single X-ray photon at 13.6 keV

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Detail of temporal response of a silicon avalanche photodiode for a single X-ray photon is investigated. We measured the temporal response of a Si-APD by changing the incident position of X-ray photons with 50 μm steps. Obvious difference is observed between the response at the outer region and that at the inner region: the response at the outer region has a tail structure.

1 Introduction

Silicon avalanche photodiode (Si-APD) is widely used for detection of a single X-ray photon in experiments using synchrotron radiation X-ray beams. [1] One of advantages of Si-APD is fast temporal response. We measured the incident position dependence of temporal response of Si-APD to investigate possibility to increase the fastness of temporal response by limiting the incident position of X-ray photons.

2 Experiment

The tested Si-APD is S12053-05 (Hamamatsu Photonics). The nominal sensitive area is 0.5 mm in diameter. The thickcness of the depletion layer is estimated to be 10 μm. The Si-APD is adopted because of the fast time response due to the small sensitive area and the thin depletion layer.

The beam line used in the measurement is BL-14A in KEK-PF. Figure 1 shows the experimental setup. The beam current in the storage ring is 450 mA. The energy of X-ray beam is tuned to 13.6 keV by using monochromators. The Si-APD is located directly head-on the beam and is able to be moved both horizontal and vertical by auto-stages. A plate with a pin-hole whose diameter is approximately 5 μm is placed in front of the Si-APD. The Si-APD is housed in a metal box which is an electromagnetic shield. The box is made of aluminum walls and a brass front collimator. The collimator has a hole the diameter of which is 3 mm. The Si-APD is located just behind the collimator hole so as to receive the X-ray photons directly. The bias voltage of 154 V is applied. A preamplifier that amplifies a Si-APD output signal is also embedded in the box. The preamplifier output signal is sent to a lab-build constant-fraction discriminator which converts the analog pulses to fast-NIM logic pulses. Finally the logic pulses are transmitted to a time-to-digital converter (MCS6, FAST ComTec) and digitized timing data is stored in a personal computer.

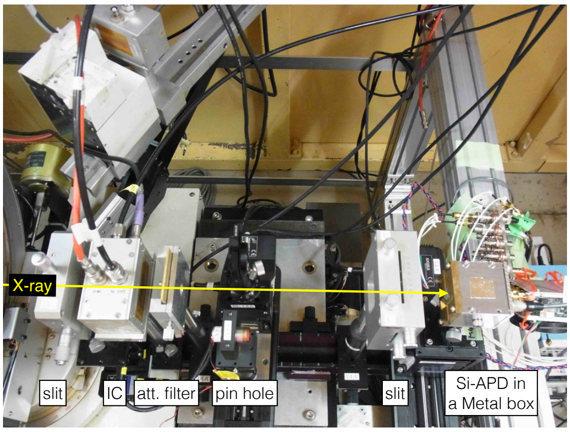

Fig. 1: Photo of the experimental setup around the Si-APD. IC is an ion chamber used to monitor the beam intensity. The pin hole is mounted on a three-axis auto stage. The Si-APD is housed in a metal box and is not shown in the figure. The two slits and att. filter are not relevant to this study.

3 Results and Discussion

During the measurement, the pin-hole is shifted with 50 μm step horizontally or vertically. Data take time for each position is 600 s. Data rate is 1.4×10^3 counts per second. Figure 2 shows the temporal response at eight positions in the Si-APD. While the nominal radius of the Si-APD is 0.25 mm, the single hit rate is uniform up to 0.3 mm along the radial axis from the center. The overall time resolution of 120 ps (full width at half maximum) is almost uniform independently of the incident positions. On the other hand, the temporal response within 0.25 mm is almost same but that at 0.3 mm has bigger tail component. The other three axes have the similar structure.

Figure 3 shows calculated time spectra based on the spectra shown in Fig. 2 by assuming X-ray photons are irradiated uniformly in the sensitive area. The difference between two spectra is whether outer region is included or not. Here the boundary between the outer and inner regions is defined as 0.25 mm from the center. It suggests that a guard ring that covers the edge region of the sensitive area can suppress the tail component and obtain a more gaussian like profile down to 10^{-6}. This method is used for visible light region. [2] It is not easy to make a guard ring against X-ray photons in comparison to visible photons because of the small crosssection; however, if the guard ring can be prepared, the time spectrum changes from the red spectrum in Fig. 3 to the black spectrum in the same figure. It would be useful if one needs to suppress the tail component.

The statistics in this study is limited only 10^5. An investigation with higher statistics is motivated for a future work.

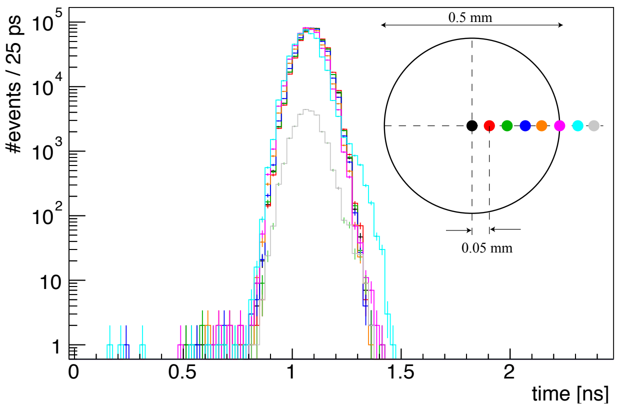

Fig. 2: Time response of the Si-APD for each position. The up-right circle represents the sensitive area of the Si-APD and the eight small colored circles indicate irradiated positions. The colors of histograms correspond to those of small circles.

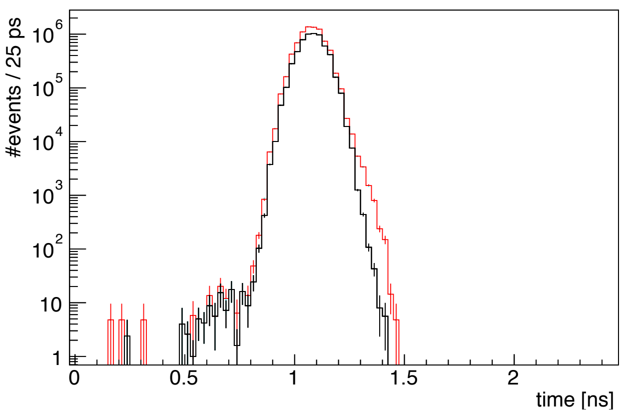

Fig. 3: Weighted time response of the Si-APD. The black histogram shows the time response with only inner sensitive region the radius of which is 0.25 mm. The red histogram shows that with the whole sensitive area.

Acknowledgement

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References

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