Photon Counting Method for high flux Pulsed Laser-Compton Backscattered Photons based on Poisson model

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Abstract

We tested a new photon counting method based on Poisson model to evaluate the absolute photon flux of pulsed photon generated by the Compton scattering of laser light on high-energy pulsed electron. The Monte Carlo simulation code in which the pile-up phenomenon is taken into account is developed to avoid the under estimate of the photon flux. The calculated response functions of the BGO scintillation detector well agreed with measured ones.

1 Introduction

The Laser Compton backscattered (LCS) photons generated by the Compton scattering of laser light on electron are quasi-monochromatic and polarized ones and their energy is variable. Thus the LCS photons are applied for nuclear physics, detector calibration and so on. For these applications, it is very important to measure the absolute photon flux. But these photons are produced in a short period, and each pulses form radiation detector can't be separated, because electron bunch length is very short. Hence in this study a new photon counting method based on Poisson model are developed.

2 Principle of the calculation

The scattering probability of the laser photon on the electron is proportional to the cross-section of the Compton scattering. Hence probability of the photons are scattered follows the binominal distribution. The probability distribution of the number of the scattered photons is given

$$P(n) = \frac{N!}{(N-n)!} p^n (1-p)^{N-n} \quad (1),$$

where n is the number of the scattered photon, p is the scattering probability and N is the product of the numbers of particles contained in the photon and the electron bunch. In case of the LCS, p is very small and N is quite large, thus the binominal distribution are approximately written in the Poisson distribution,

$$P(n) = \frac{m^n}{n!} e^{-m} \quad (2),$$

where m is the average number of the scattered photons per pulse given by $m=Np$. Therefore the pulse height spectrums will agree with the Poisson distributions, if the energy resolution of the detector is infinite and the detection efficiency is 100%. Thus the absolute photon flux can be measured by fitting the measured pulse height spectrum with response functions. Response functions of the large BGO scintillation detector for the multi-photon injection in which resolution of the detector, the time interval of the each scattered photons and pulse response of the circuits are taken into account are shown in Fig.1.

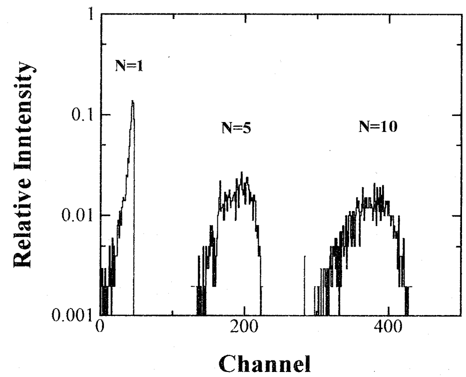

Fig. 1 The gamma ray response function of the BGO scintillation detector for the multi-photon injection. N is the number of the photon injected to the detector.

The response function for the LCS photons, which are given by adding the response functions for the multi-photon injection is shown in Fig.2.

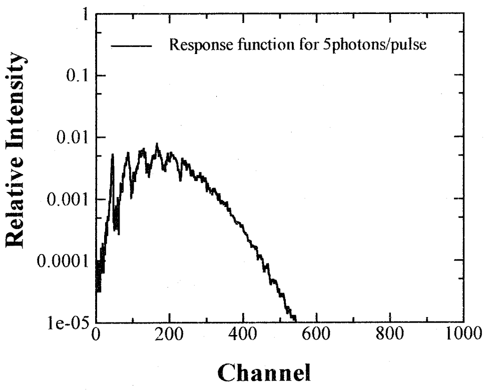

Fig. 2 The response function for the LCS photon. The average incident photons per pulse are 5.

3 Experiment and results

Experiment was carried out using 3.5MeV LCS photons provided by the storage ring TERAS[1] at Electrotechnical Laboratory (ETL) and Q-switch Nd:YLF laser[2]. Fig. 3 shows the experimental setup. The backscattered photons are collimated with lead collimator. The time difference of master clock of the Q-switch laser and the LCS photons was measured with thin plastic scintillation detector. The LCS photons were detected by the BGO scintillation detector with a diameter of 2 inches and a thickness of 10 inches.

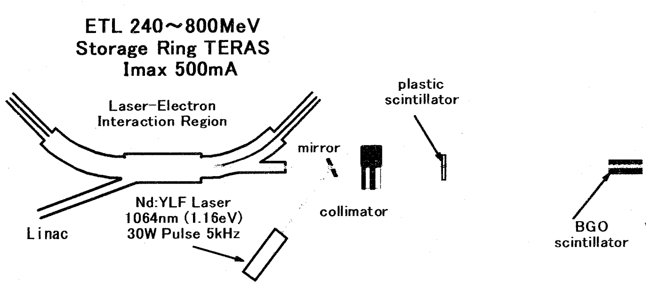

Fig. 3 Experimental setup

The time distribution of the LCS photons is shown in Fig.4. The width of the time distribution is concerned with the pulse width of the Q-switch Nd:YLF laser.

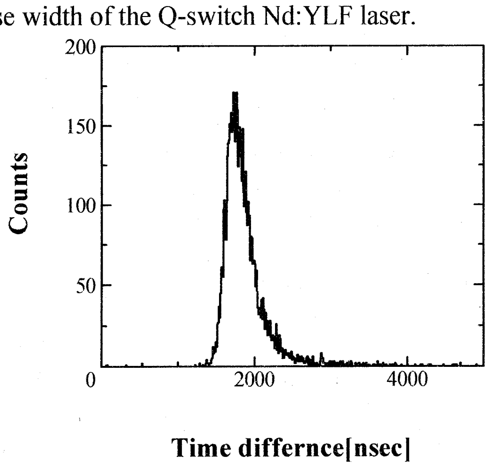

Fig. 4 Time difference between master clock of the Q-switch Nd:YLF laser and the scattered photons.

The pulse height spectrum measured by the BGO scintillation detector is shown in Fig.5 (thick line). The response function for the LCS photons is also shown in Fig.5 (thin line). In this case, the response function to minimise the residual error is that for 4.75 photos/pulse. As shown in Fig.5, the response function can reproduce the measured spectrum quite well.

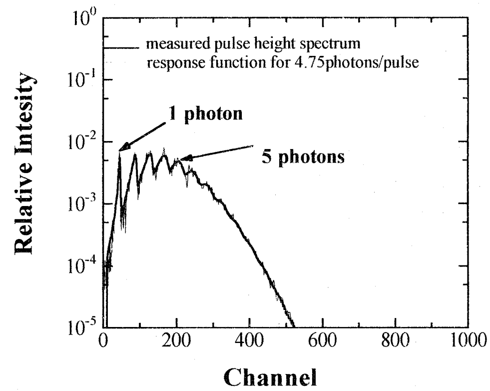

Fig. 5 Measured pulse height spectrum (thick line) and response function (thin line).

4 Conclusion

It is found that the response function based on the Poisson model can reproduce the measured pulse height spectrum of the BGO scintillation detector quite well. This method can be applied for the photon counting.

5 References

[1] T. Tomimasu et al., IEEE Trans., NS-30,3133(1983)
[2] H. Ohgaki et al., IEEE Trans., NS-38, 386 (1991)