Development of high-resolution and high-speed camera system for a Cherenkov telescope using image intensifiers

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Abstract

Cherenkov telescopes are very useful instruments for observing gamma rays with energies around TeV. Imaging resolution of telescope optics and camera for recent Cherenkov telescope is usually limited to be only about 0.1 degree. To observe small size images of the air showers generated by low energy gamma rays, it is effective to make the resolution better. As the gamma-ray flux at low energies is expected to be large, high frequency data acquisition system is also required. Therefore, we have developed a new camera system with image intensifiers. We have measured the spacial resolution of the system and obtained a good angular resolution of the telescope with the image intensifier camera system.

1. Introduction

Imaging Atmospheric Cherenkov Telescopes (IACT) are the most effective experiments for TeV gamma-ray observations. The angular resolution of the IACT systems are today limited to be about 0.1 deg. This limitation is due to the resolution of telescope optics made of a principal reflector consisting of many number of segmented mirrors, and that of camera system with limited number of pixels made of photomultiplier tubes.

It is suggested that the high-resolution Cherenkov telescopes are effective for the observation of high-energy gamma rays around 100 GeV or less energies [2]. To achieve it, better resolution for the telescope optics and imaging cameras than the present ones is required.

Photomultiplier tubes are popular devices used for the camera system of the IACT experiments. A test experiment to detect atmospheric Cherenkov light in ultraviolet region using an image intensifier was carried out at Mt. Norikura from 1991 to 1993 [4].

In order to show that the idea of the high-resolution telescope for observing high-energy gamma rays, we have been developing a new telescope optics and high-resolution camera using image intensifier devices.[2,3]

Design principle of this new camera system and some experimental results measured by an LED light source are described in this paper.

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2. New Camera System with Image Intensifiers

The new camera system is designed to accommodate the Cherenkov telescope with 3m diameter at Konan University for testing the idea of the high-resolution telescope. The camera system consists of a large image intensifier with 10cm diameter, a high-speed gated image intensifier, a high-speed CCD camera and a high-speed trigger circuit. Basic elements of the camera system are shown in Fig.1.

Cherenkov light emitted by air showers are focused by the telescope on the camera surface in principle.

We have examined the camera system by a collimated LED light source to find the spacial resolution, output linearity, etc. of the camera system.

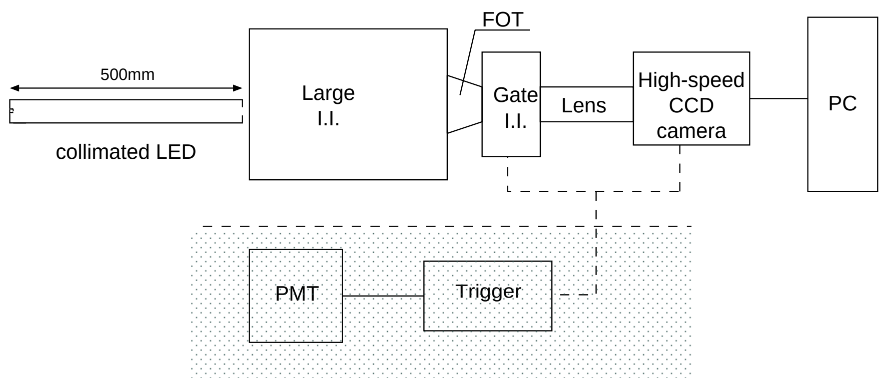

Fig. 1. Schematic view of the camera system using image intensifiers.

Test method using the light source is also shown in Fig.1. A blue LED ($\sim$470 nm) was set in the end of the collimator and a plate with a square pin hole with a size of 0.3 mm $\times$ 0.3 mm. was attached at the other end to produce well collimated light beam.

Window surface of the large image intensifire (LII) is irradiated by collimated pulsed light, which transmits a fiber optic plate and is converted to photoelectrons at the photoelectric surface whose quantum efficiency is 20% at 430 nm. The photoelectrons are accelerated by applied high voltage of 16.2 kV. They are focused by electric lens system on the phosphor (P-46) of the LII and emit about 100 photons/photoelectron with wavelength around 530 nm. The photons are led through fused fiber optic taper (FOT) made of glass fibers of 6 μm diameter to the gated image intensifier(GII). Size of the FOT is 19.7mmϕ(entrance aperture)$\times$12.7mm. The photons are converted to photoelectrons at the phtoelectric surface, amplified by a micro-channel plate and emit photons at the phosphor (P-43) in the GII.

They are focused by a lens system on a high-speed CCD camera whose data are recorded onto hard disks of a PC with the maximum rate of 250Hz. Random event trigger can be possible for this CCD system. Number of pixels of the CCD is 512×544.

3. Measurements of Dynamic Range and Output Linearity

For the energy calibration of the IACT system, it is essential to measure the relation between incident photon flux and ADC counts of images. Single photoelectron measurement is needed to obtain the number of photons in a measured image on the camera system[1,2,4].

We have calibrated the collimated LED light source by using a PMT to obtain the number of photons in a pulsed beam as a function of applied voltage to the LED. Then the II system was irradiated by the light source. As a result we obained that a single photoelectron emitted at the LII corresponds to 20 ADC counts.

Fig.2 shows sum of the ADC counts in a image of the pulsed light measured by the high-speed CCD camera as a function of number of input photons. This figure shows well that dynamic range of this system is at least about 3 orders of magnitudes with good linearity.

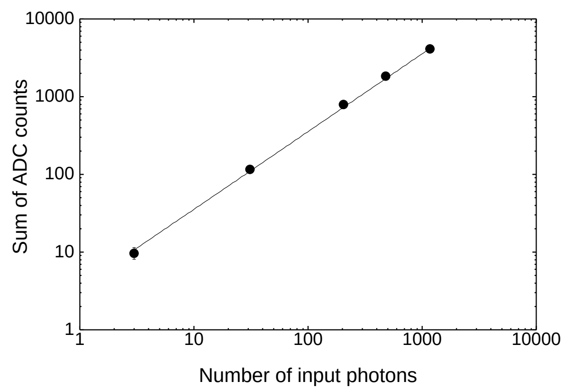

Fig. 2. Sum of ADC counts in an image of CCD as a funcion of the number of input photons for the II camera system.

4. Measurements of Spacial Resolution

Image spread of point like light source was measured by the II camera system using the LED light source. Measured ADC counts in respective CCD pixels are plotted as a function of the distance from the center of the images for various number of input photons in Fig.3. Their peak values are normalized to a unit number, respectively. It is shown that the lateral distribution for various number of incident photons agrees each other very well. Image spread of this distribution is calculated to be 8.7 pixels in rms.

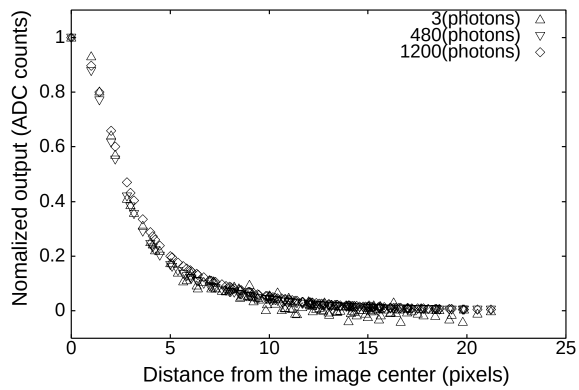

Fig. 3. The distribution of images measured by the II camera system for various number of input photons.

Angular resolution of the telescope with this II camera system can be estimated by the image spread (rms). One pixel of the present CCD camera system corresponds to 0.16 mm which corresponds to 3.3×10^{-3} deg for our Cherenkov telescope with 3m diameter. Therefore, the angular resolution of the telescope with the II camera system is estimated to be 0.028 deg for the image spread in rms. This value will be improved by using better light source in near future.

5. Acknowledgements

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6. References

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