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MAPMT Ageing Tests for High-Intensity Incident Lights and High Voltage Switching

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Some experiments to test the reliabilities of MAPMT(Multi-Anode PhotoMultiplier Tube) which will be used for EUSO mission, have been carried out, namely in the cases of high intensity incident light assumed from night-sky background photons, high voltage switching and strong light intensity of atmospheric lightning flashes. UV LED was used as a light source and illuminated to MAPMT. No apparent gain change more than ±5% of MAPMT could be found after illuminating well over expected background photons(2.3×10^{14} photons/pixel) in comparable to 3.5 times of background photons expected in 5 years EUSO mission. Also, MAPMT gain has been stable for frequent high voltage switching of 56076 times between -850V and -300V.

1. Introduction

EUSO mission is planed for observing UHE cosmic rays(Eo>$10^{19.5}$eV) by a satellite-based telescope and it will detect faint lights accompanied with air shower development. Japanese EUSO group has been making for R&D on the photo-sensitive device(MAPMT) installed at a focal surface of the telescope. The characteristics of MAPMT(typically, its gain) could be deteriorated due to night-sky background lights and also frequent sudden-lights like as atmospheric lightning flashes during 5 years mission. In addition, high-frequency high voltage switching between observation and quiescent period in an orbital period, will be possible to cause electrical stress to MAPMT. The temporal stability of MAPMT gain under high intensity light and high voltage switching procedure has been examined in current experiments. MAPMT ageing test has been carried out by UV LED light and programmed high voltage switching between high and low voltage states, as a frame work of MAPMT's R&D.

2. Experiments

2.1. Experiment(A): High-Intensity Incident Lights

UV LED light source (NSHU550: a maximum intensity at a wave length of 370nm with FWHM of 10nm) and MAPMT (R8900-03-M36 with 6×6 pixels: HAMAMATSU) were installed in the black box with a size of 60cm×51cm×47cm as shown in Figure 1. LED was just set in front of MAPMT surface with a distance of 6cm, and it illuminated MAPMT with a uniformity of LED light intensity less than 10% at MAPMT surface. Each output from 36 pixels led to 12bit Charge ADC (RPC-022:Repic) mounted in CAMAC system. Accumulated charge within a gate time of 800ns was measured by a synchronized signal with LED flash. Voltage of -850V was loaded to MAPMT to obtain a gain of 2×10^{6}. Expected background photon intensity during 5 years EUSO mission was estimated with assumptions[1] of ,

(1) Average background photons : 500 photons/m^2/ns/sr
(2) An altitude of EUSO orbit : 420km
(3) A diameter of optical lens : 2.3m
(4) Atmospheric throughput : 0.8
(5) Optics throughput : 0.3
(6) A pixel size of MAPMT : 4.3mm
(7) MAPMT's quantum efficiency + collecting efficiency : 0.14
(8) A time unit : 1GTU(=2.5×10^{-6}sec)

Background photon intensity was estimated as 5 photons/pixel/GTU at a focal surface of EUSO telescope. The integrated number of incident photons will be 6.5×10^{13} photons/pixel for 5 years observation on the assumption of a duty cycle of 0.2.

2.2. Experiment(B): High Voltage Switching

Programmed high voltage supply was used, and two voltage levels of -850V and -300V have been loaded to MAPMT alternately with an interval of 14 sec. Same LED light intensity but shorter (5%) flash duration compared to experiment(A) has illuminated MAPMT in this experiment. Data taking procedure was same with one of experiment(A).

2.3. Experiment(C): Atmospheric Lightning Flash

In order that high intensity light as an emission of lightning flashes illuminated MAPMT, supplied voltage of LED was increased in this measurement. Photo-diode(silicon-photodiode: HAMAMATSU-S2281) was set in front of LED and a relation between LED supplied voltage and Photo-diode output voltage was calibrated. Determined light intensity of LED was just 100 times higher than that of experiment(A). LED was set in front of MAPMT surface with a distance of 6cm and was lightning by a drive signal with a duration of 6ms and 10ms repetition. Supplied high voltage to MAPMT was -850V and the same data taking procedure with experiment(A) was used in this measurement.

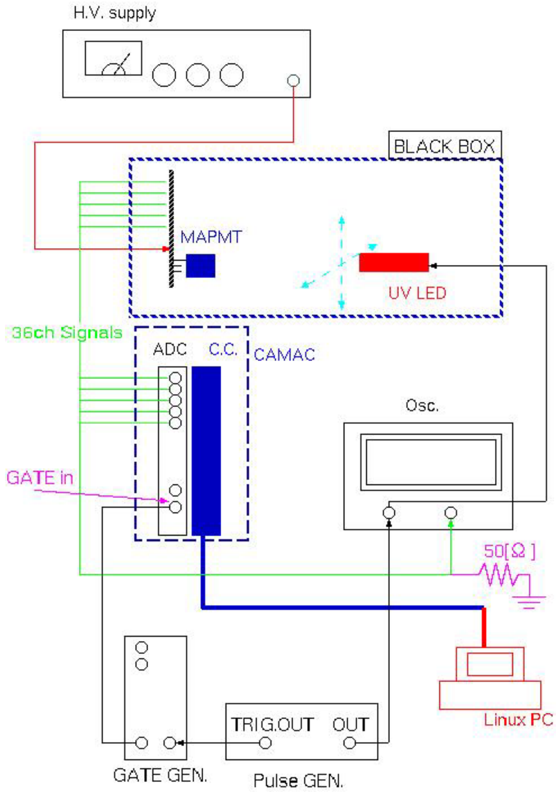

Figure 1. Experimental setup in these experiments. LED and MAPMT were installed in the black box and data was taken by CAMAC system.

3. Results and Discussion

3.1. MAPMT Test for High-Intensity Incident Lights

In this measurement, LED flashes with a constant intensity which were triggered by external drive signals with a width of 6ms and a repetition rate of 100Hz, illuminated MAPMT. Average ADC count from each pixel was 30/pixel within a 800ns gate width of ADC after subtraction of pedestal counts. A dynamic range of ADC(12bit) is up to -1000pc, therefore 163 photons/pixel/800ns was estimated as an average incident photon intensity by this LED lights, taking into accounts of MAPMT gain of 2×10^6 and MAPMT's throughput of 0.14. This gives 1.2×10^6 photons/pixel as the total incident photons of one LED flash with a width of 6ms. With 100Hz repetition rate of LED light, 23.3hours measurement was equivalent to the illumination of 1.0×10^{13} photons/pixel. A typical ADC count variation in an experimental period of 31766 min. is shown in Figure 2. The integrated incident photons to MAPMT were measured up to 2.3×10^{14} photons/pixel in this period. This is nearly 3.5 times of expected background photons during 5 years EUSO mission as mentioned in 2.1. Moving averages of ADC counts for each pixel were calculated over a measuring time of 31766 min. . Overall averages of ADC counts and maximum/minimum deviation in the moving averages were listed in Table 1. Variations of MAPMT pixel gains are less than ±5.0%, which shows that no apparent change of MAPMT characteristics is found due to high intensity incident photons which corresponds to 3.5 times of expected total photons in 5years EUSO mission under the assumption of standard background photon intensity.

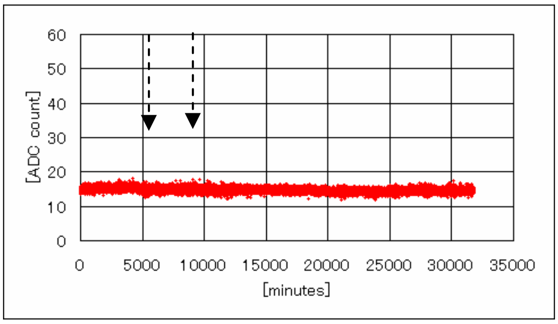

Figure 2. An example of ADC time variation of a pixel in experiment(A). Left and right arrows show the times, correspond to the integrated standard background photons in 3 and 5 years EUSO mission, respectively.

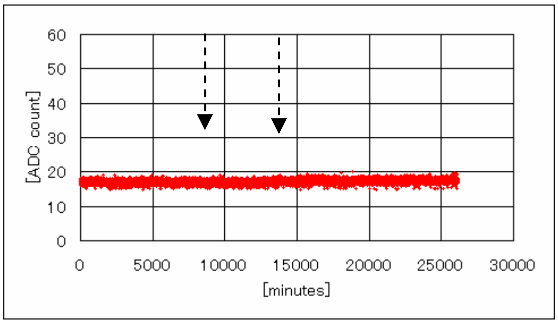

Figure 3. An example of ADC time variation of a pixel in experiment(B). Left and right arrows show the times, correspond to assumed switching frequencies in 3 and 5 years EUSO mission, respectively.

3.2 MAPMT Test for High Voltage Switching

EUSO will observe air scintillation and Cerenkov lights from air shower phenomenon initiated by UHE cosmic ray in the night time, and it will sleep in the daylight region along the satellite orbit. Repetition of each status will be in every 45min. between day and night, therefore photosensitive device should be protected by an additional auto-gain controller in HV divider of MAPMT[3] or should be in shutdown by high voltage controller to be lower safety voltage. In the latter case, high voltage switching will be required in every 45min. , therefore 29200 switching will forced to MAPMT over 5 years EUSO mission. In this experiment, high voltage switching between -850V and -300V was repeated in every 14sec. by programmed high voltage supply. A LED light emitted with a time width of 4×10^{-6} sec. and 100Hz repetition by external drive signals, and ADC counts from each pixel were also recorded by gate signals with 800ns width. A typical ADC count variation in this experimental period is shown in Figure 3, and moving averages of 36 pixel's ADC time variations and maximum/minimum deviation in the moving averages were also listed in Table 1. Though frequent high voltage switching of 56076 times in this measurement is just equivalent to 9.6 years EUSO mission, each pixel gain has been stable within ±5.2% deviation from averages.

3.3. MAPMT Test for Atmospheric Lightning Flashes

As mentioned in 2.3 and 3.1, LED light intensity was equivalent to 1.2×10^{8} photons/pixel in a time duration of 6ms (5.0×10^{4} photons/pixel/GTU) in this experiment, which is just 100 times and 10000 times higher intensities than those of experiment(A) and standard background photons, respectively. Expected light intensity from an atmospheric lightning flash could be assumed as a photon intensity of 1.8×10^{5} photons/pixel/GTU with a flash duration of 0.2ms.[4][5], which was 3.6 times larger intensity than that of used LED light. However, the total number of photons in a LED flash, i.e. 1.2×10^{8} photons/pixel/6ms, is 8 times larger than that of an assumed atmospheric lightning in a duration of 0.2ms. This light intensity produced nearly 7000 photoelectrons/pixel/GTU in consequence, therefore actual MAPMT gain was dropped due to linearity saturation. Overall gain check of MAPMT was done before and after the measurement, by illuminating at MAPMT surface with relatively faint LED light intensity to assure of MAPMT linearity. Expected frequency of standard lightning flashes was 700 per an EUSO-orbit and then the total number of lightning flashes in 5 years EUSO mission will be 2×10^7. In this experiment, 5.8×10^7 times LED flashes were shot to MAPMT in a measuring time of 160hours. Preliminary result shows that a decrease of MAPMT gain by 70% was observed after the illuminations of LED light though output signals from all pixels were found, so far. Gain decrease caused by high intensity light has to be confirmed by a successive measurement with another MAPMT, and a temporal feature of gain decrease should be examined quickly.

4. Acknowledgements

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Table 1. Overall averages of ADC counts in each pixel and maximum/minimum deviation in the moving averages are listed for experiment(A) and (B). Output signal of ch22 was disconnected with ADC and was used for signal monitor by oscilloscope.

	Experiment(A)		Experiment(B)			Experiment(A)		Experiment(B)	
Pixel No.	mea n	Dev.(%) Max/ Min	mean	Dev.(%) Max/ Min	Pixel No.	mean	Dev.(%) Max/ Min	mean	Dev.(%) Max/ Min
ch1	14.8	+4.5/-3.9	17.2	+3.8/-3.2	ch19	20.6	+4.5/-4.9	27.7	+1.6/-1.7
ch2	29.4	+3.4/-5.0	34.8	+2.9/-2.7	ch20	43.4	+2.5/-2.8	49.9	+1.5/-2.2
ch3	27.6	+2.9/-3.8	33.8	+4.3/-3.3	ch21	36.2	+3.2/-2.2	39.5	+1.9/-1.4
ch4	35.9	+2.9/-4.1	40.1	+2.0/-2.2	ch22	NA	NA	NA	NA
ch5	44.9	+3.7/-2.9	50.5	+1.6/-2.2	ch23	47.9	+3.0/-2.8	56.4	+1.4/-1.0
ch6	14.3	+4.0/-3.3	16.1	+2.3/-1.9	ch24	17.4	+3.7/-3.0	24.7	+3.2/-0.6
ch7	19.9	+3.8/-4.4	25.0	+2.3/-1.4	ch25	20.8	+4.3/-2.9	24.0	+4.4/-3.0
ch8	36.6	+3.4/-2.9	40.3	+1.3/-1.7	ch26	38.2	+2.8/-1.9	44.2	+2.4/-1.7
ch9	32.5	+3.4/-1.9	37.8	+1.7/-1.8	ch27	33.7	+3.7/-3.3	37.7	+2.1/-2.7
ch10	39.7	+3.7/-2.4	41.7	+0.9/-1.6	ch28	33.8	+2.9/-2.7	38.3	+1.8/-2.1
ch11	48.8	+2.7/-2.5	51.9	+2.2/-2.2	ch29	44.3	+2.0/-2.4	48.4	+1.6/-1.6
ch12	20.4	+3.0/-1.8	21.3	+1.8/-3.0	ch30	19.9	+2.2/-3.6	23.7	+2.4/-2.3
ch13	24.2	+2.2/-2.0	28.2	+4.5/-2.6	ch31	10.9	+3.6/-3.1	13.2	+6.1/-3.8
ch14	44.6	+3.5/-2.2	47.5	+2.5/-1.3	ch32	28.3	+2.3/-1.5	32.1	+2.3/-2.3
ch15	34.2	+1.7/-1.8	40.0	+1.6/-0.9	ch33	24.5	+2.1/-2.3	27.1	+1.6/-2.2
ch16	40.6	+3.2/-3.3	44.0	+2.5/-1.8	ch34	26.8	+2.1/-2.5	26.7	+2.9/-2.8
ch17	47.3	+3.3/-3.3	58.7	+1.4/-1.9	ch35	29.0	+3.6/-3.3	34.6	+2.0/-2.4
ch18	20.3	+1.9/-4.1	23.0	+2.4/-3.3	ch36	11.9	+2.7/-2.7	13.1	+5.2/-2.9

References

[1] EUSO Collaboration, EUSO Report on the Phase A study (2004). http://www.euso-mission.org/
[2] Y.Kawasaki et al., This conference proceedings (2005).
[3] M.Sato et al., This conference proceedings (2005).
[4] M.A. Uman, The lightning discharge, Dover Publication, Inc., New York, (2001).
[5] V.A. Rakov and M.A. Uman, Lightning, Cambridge University Press, 108-213, (2003).