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Silicon Photomultiplier's Gain Stabilization by Bias Correction for Compensation of the Temperature Fluctuations

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Measurements using the Silicon Photomultiplier (SiPM) as photon detector have required stable gain specially for a sensitivity on the level of a single photon. The temperature has a significant influence on the value of detector's gain. SiPM have been used in many applications, where heat is emitted mainly by other devices. In order to keep gain of a detector on a stable level, these applications would have to be kept in controlled, air conditioned rooms. Very often it is hard to control the temperature, especially in large systems.
The paper presents a method for compensation of SiPM gain variation caused by temperature fluctuations. Instead of stabilizing the temperature we can correct the bias voltage of the detector. Gain of the SiPM is a linear function of the temperature and the bias. Increase of the temperature leads to the decrease of gain. On the other hand, an increase of the bias makes value of the gain higher.
These dependencies have been bounded by linear function: G(V,T)=aT+bV+c, where G stands for gain, T for temperature and V for bias voltage. The values of the coefficients a, b and c depend on the SiPM model and have been calculated from set of measurements of the gain of SiPM. Using this function we have created a measurement setup where any fluctuation of the temperature has been automatically compensated by setting suitable bias voltage. Results of the measurements of three different types of SiPM (supplied by Hamamtsu, SensL and FBK) has been presented.

Optional extended abstract

The study has been performed with four Silicon Photomultipliers: SensL S1020, Hamamatsu S10362-11-100U (two models) and FBK 4020.
In order to verify whether this compensation method would be possible, the gain as a function of temperature and bias in a wide range of changes has been checked first. The measurements have been made with the temperature fluctuated in the range from -60℃ to +40℃. The bias voltage has been changed according to the specific detector: 62-71 V (Hamamatsu), 29-33 V (SensL) and 25-34 V (FBK). Gain of the detector has been determined from histogram of SiPM's signal taken for defined temperature and bias conditions. For each photo detector over 70 points have been determined. Values of gain determined in this way have been placed in the 3D graph. The measurement points have formed a plains because of the linear dependencies between gain, temperature and bias.
A fit function was implemented in order to determine how well measured points fit the model plain. Fit errors obtained in wide range of the temperature and bias changes are of the order of few percent (3,6% and 1,8 % - Hamamtsu, 3% - SensL, 9,8% - FBK).
The calculated coefficients for different sensors are following:
a = -5,82, b = 109,5, c = -7519,4 (Hamamatsu)
a = -5,20, b = 102,8, c = -7034,3 (Hamamatsu)
a = -0,485, b = 33,1, c = -955,6 (SensL)
a = -1,60, b = 20,9, c = -625,9 (FBK)
To confirm the idea of gain stabilization by bias correction measurement set has been established where the bias was automatically moderate depending of the temperature. During light measurement temperature of the detector was registered and the bias has been set according to equation aT + bV + c = G = constant.

Preliminary measurement results using this method of temperature compensation, has shown that the stability of the gain of SiPM can be keep with precision of few percent.

Apart from gain stabilization itself, the coefficients a, b and c allow better characterization of different type of sensors. This knowledge can be useful for choice of SiPM for different purpose.

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