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Study on SiPM breakdown voltage, dark current and gain from room temperature down to 50 K

M. Bonesini[1], T. Cervi[2,3], A. Falcone[4], A. Menegolli[2,3], M.C. Prata[3], G.L. Raselli[3], M. Rossella[3], M. Torti[1], A. Villa[2]

[1]Istituto Nazionale di Fisica Nucleare, Sezione di Milano Bicocca (Italy), [2]Università degli Studi di Pavia (Italy),

[3]Istituto Nazionale di Fisica Nucleare, Sezione di Pavia (Italy), [2]University of Texas Arlington (USA)

Introduction

Silicon Photo-Multipliers (SiPMs) at cryogenic temperatures are very promising for the realization of scintillation light detectors to be adopted in particle physics experiments dedicated to neutrino and Dark Matter searches. For these reasons, we tested several devices from different manufacturers with particular emphasis to breakdown voltage, dark current and gain changes at different temperatures. The system, based on a cryo-pump with a cold head, permits to scan the temperature from 300 K down to 50 K. A second system, based on a climatic chamber, was also used. We found that the breakdown voltage decreases with the temperature with a typical coefficient. Furthermore, the thermal component of the noise decreases at low temperature, thus allowing the use of the device at higher overvoltage.

Experimental apparatus

Two different experimental set-up have been used:

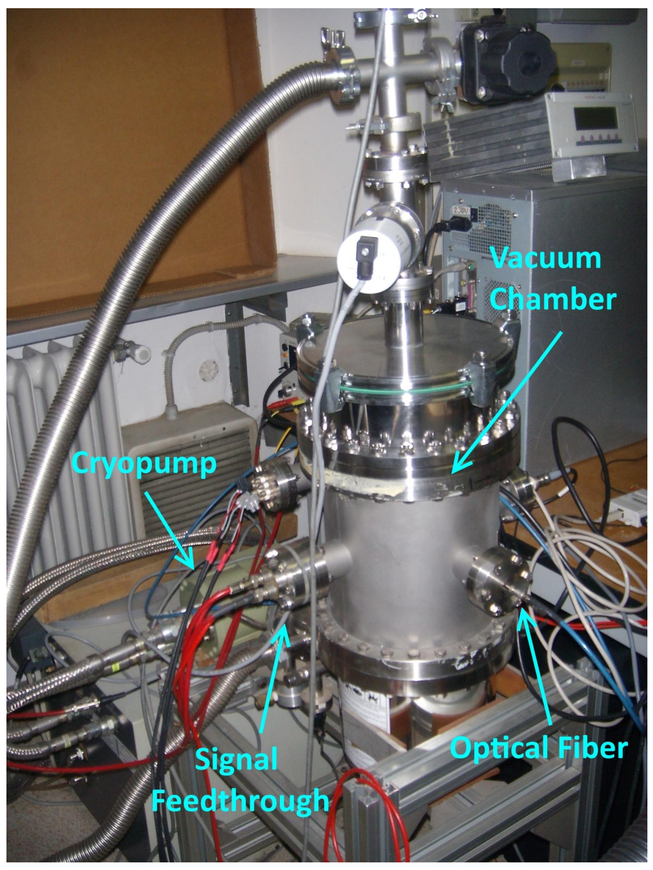

Fig. 1: picture of the first experimental apparatus.

The first one , shown in Figs. 1 and 2 is composed by a cryo-pump (Helix Cryo-Torr 8F) with a cold head and a vacuum chamber. The cold head is connected to a copper cylinder which allows to achieve the temperature of 87 K at the level of SiPMs placement.

The chamber contain also the SiPMs signal trans-impedance amplifier (model AdvanSiD ASD-EP-EB-N) far from the cold cylinder, an optical fiber and several temperature sensors (PT1000).

A light pulse generated by a laser diode at 405 nm is used to illuminate the SiPM, via an optical fiber and a vacuum optical fiber feed-through.

A pumping system (a primary scroll and a turbo-molecular) allows to reach a vacuum condition with a pressure $= 10^{-6}$ mbar inside the chamber, to isolate the cold head.

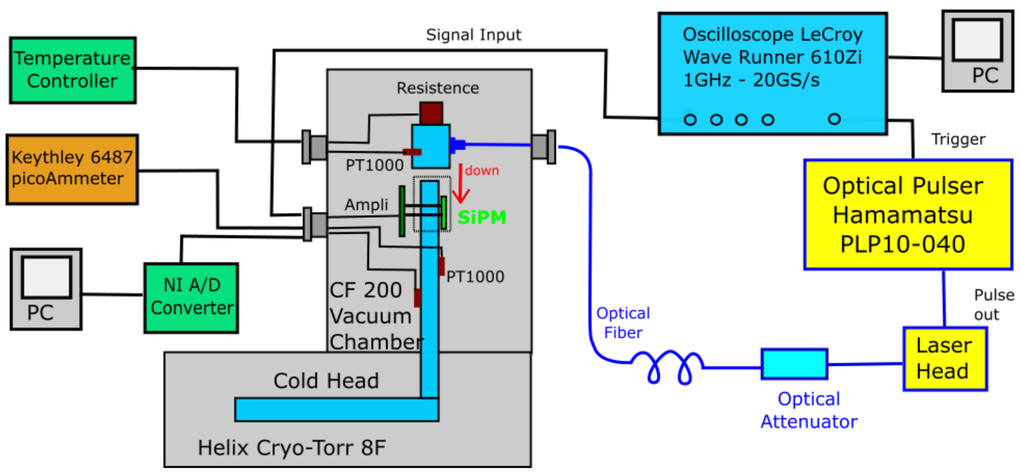

Fig. 2: sketch of the first experimental set-up.

The second setup consists of a Climatic chamber (F.lli Gallii model Genviro-030LC) with a temperature range from -60°C to +60°C that houses the SiPm t to be tested .

The inner part of the chamber can be connected to the external world by means of electrical and optical (optical fiber) feedthrough. A picoAmmeter is used to apply the voltage to the SiPM and to measure the current

An Hamamatsu PLP10-040, with an emission wavelength at 405 nm, pulse width of 60 ps (FWHM) and peak power of 200mW is used to illuminate the device.

Signals are acquired by means of a LeCroy digital Oscilloscope.

Fig.3: Climatic Chamber.

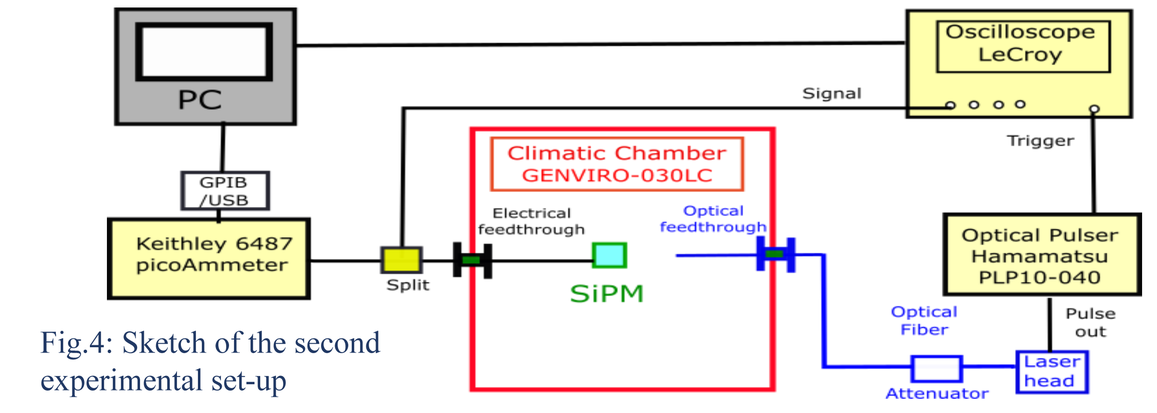

Fig.4: Sketch of the second experimental set-up

Devices under test

We decided to test some 3×3mm² SiliconPM produced by Hamamatsu (model S12512 and S13360), and AdvanSiD (model ASD-NUV3S-P and ADS-RGB3S-P) and the new VUV4 2×2 array, 6×6 mm² each from Hamamatsu. A picture of tested devices is presented in Fig. 5.

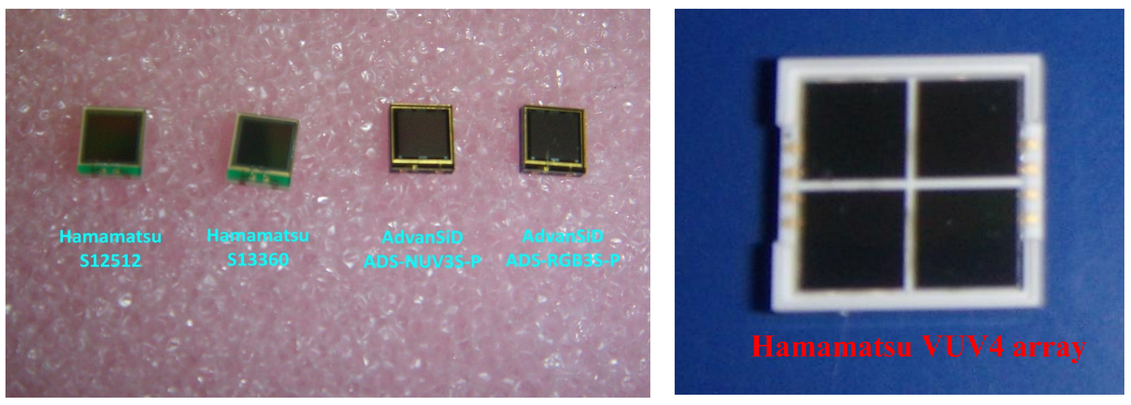

Fig. 5. Picture of tested devices.

Results

A number of tests has been carried out on the above devices. Here the preliminary results are shown.in terms of I-V curves, breakdown voltage, dark current and gain:

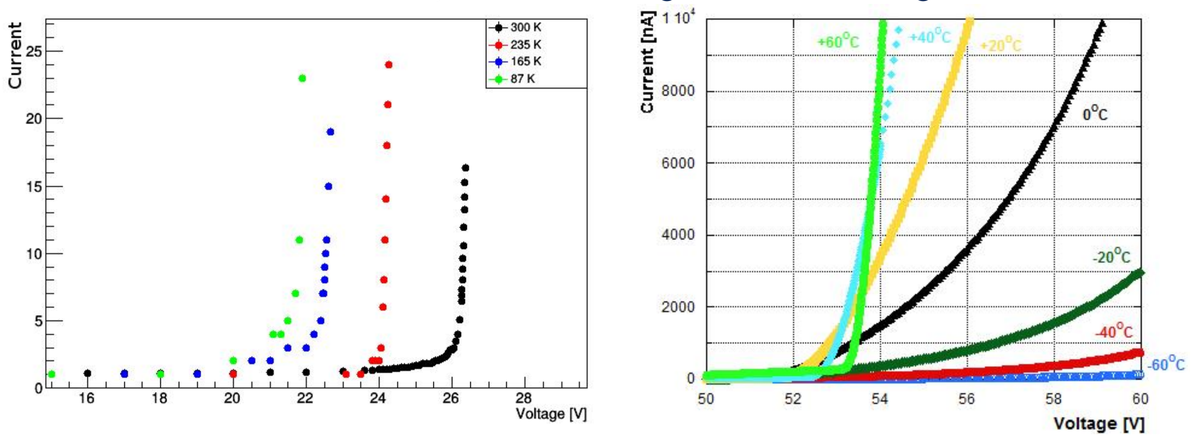

Fig. 6 : I-V curves at different temperatures. Left: AdvanSiD NUV. Right: Hamamatsu VUV4.

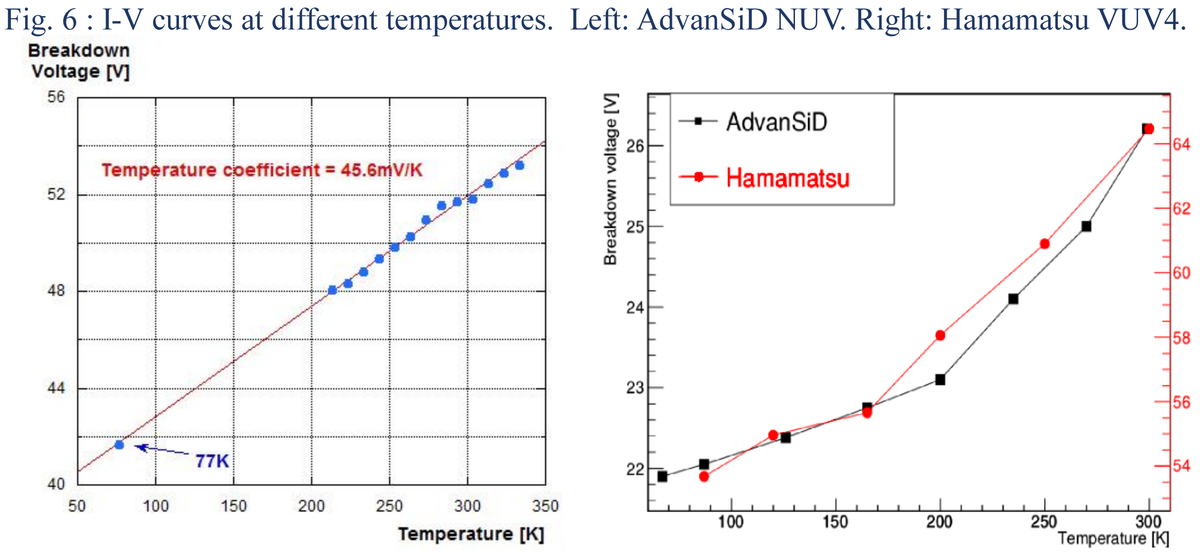

Fig. 7: BD voltage vs. T. Left: Hamamatsu VUV4. Right: AdvanSiD and Hamamatsu 3 x 3mm²

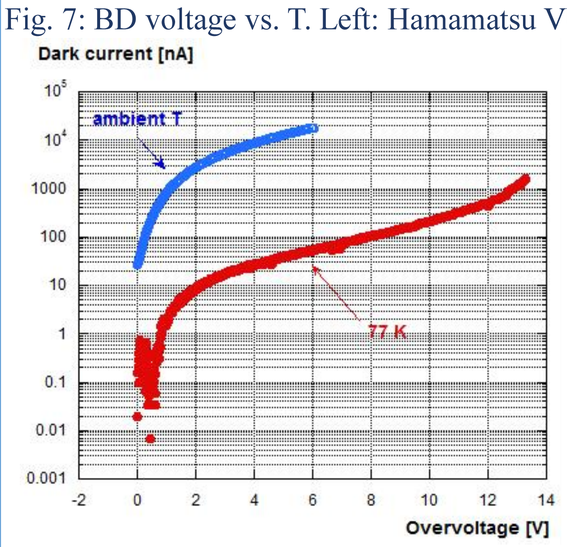

Fig. 8: dark current of Hamamatsu VUV4 at room temp. and at 77 K as noise measurement.

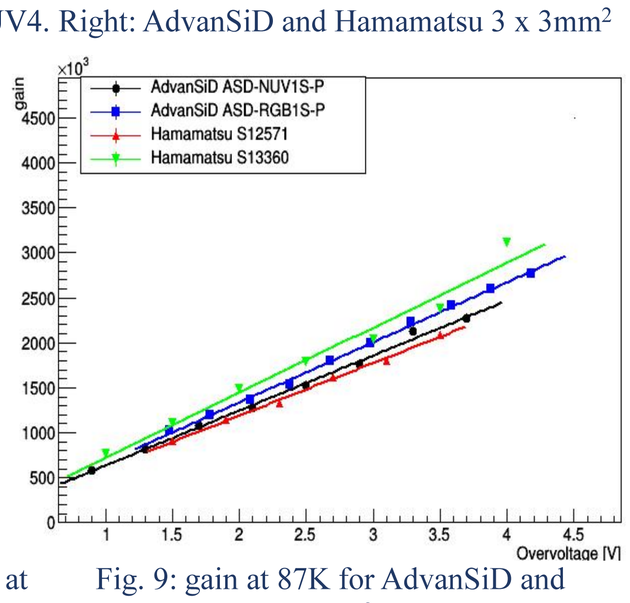

Fig. 9: gain at 87K for AdvanSiD and Hamamatsu 3 x 3mm²

Conclusions

These SiPM arrays have good performances in terms of breakdown voltage, dark current and gain once tested in cryogenic conditions. Therefore, they are suitable to be used for novel design scintillation light detectors dedicated to future neutrino and Dark Matter experiments.