Uniformity of the APD response after irradiation

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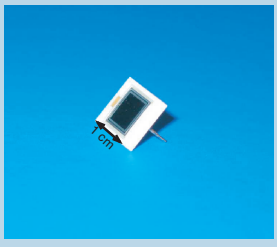
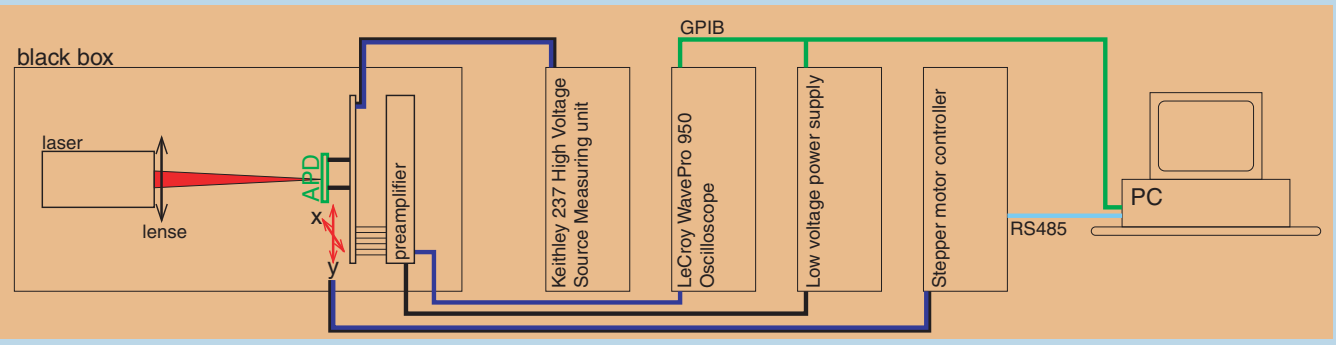


Avalanche Photodiodes (APDs) will be used to detect light from lead tungsten crystals in the barrel part of electromagnetic calorimeter (ECAL) in the CMS experiment. These APDs are silicon photodiodes operated in the avalanche mode. The diode structure is embedded in about 40 μm thick epitaxial layer grown on a low resistivity silicon base. The diode has an active area of 5x5 mm^2. In the CMS experiment it will be operated at the gain of 50 which is achieved at an operating voltage of about 350 V.

In 10 years of operation in the CMS ECAL the APDs will be exposed to 1 MeV equivalent neutron fluence of 2 10^{13} n/cm^2 and total ionisation dose of 0.25 Mrad. Extensive irradiation studies have shown that these APDs can survive such radiation levels.

To explore the possibility of usage of these APDs in even harsher radiation environments they were irradiated with reactor neutrons to 1 MeV equivalent fluence of 2.5 10^{14} n/cm^2 and 5 10^{14} n/cm^2. This contribution reports on measurements of current voltage characteristics and scan of surface uniformity prior and after irradiation. It was shown that surface uniformity of the APD response after irradiation is not compromitted. After the irradiation the dark current increased to several 10μA at 300 V for APDs exposed to lower fluence. The APDs exposed to higher fluence could not be operated at 300V at room temperature (self heating). In this case the voltage was reduced to 250 V.

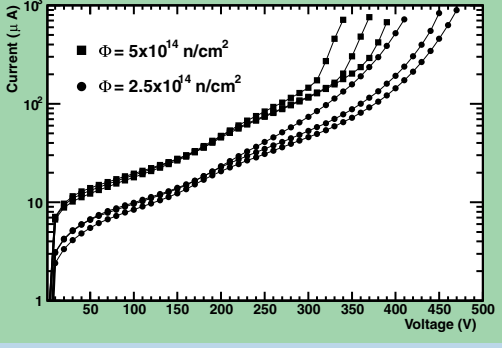
Setup



Irradiation

- done at 250 kW TRIGA reactor facility of the Jozef Stefan Institute
- APDs placed in a tube at the outer radius of the reactor core
- exposed to neutrons with E from thermal to 10 MeV
- NIEL equivalent flux determined from leakage current in reference Si diodes
- reactor was running at reduced power of 2.5 kW (equivalent flux 4.5 10^{10} n/cm^2 s)
- two sets of 3 APDs irradiated to 1 MeV equivalent fluence of 2.5 10^{14} n/cm^2 and 5 10^{14} n/cm^2 + approx. same flux of thermal and epithermal [0.5ev<E<100keV] neutrons and approx. 1 Mrad of gamma background
- after irradiation APDs were stored at room temperature

Dark current vs. bias voltage for 6 different APDs after irradiation with two different fluxes



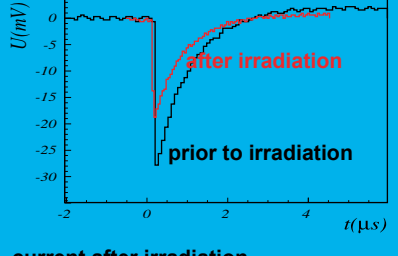
Current Voltage Characteristics

- dark current vs. bias voltage measured with Keitley 237 High Voltage Source Measuring Unit.
- done at room temperature
- current of non irradiated APDs was below 100 nA at highest voltage

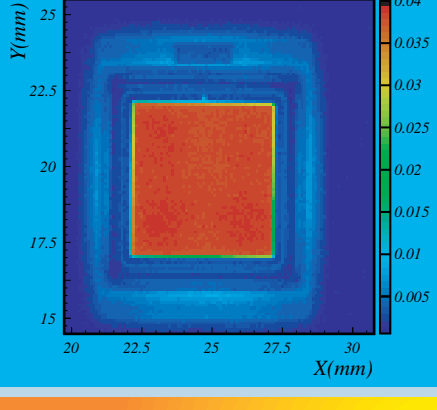
Surface sensitivity

- APDs illuminated with red laser diode (pulsed)
- bias voltage of 300 V was applied (250 V in case of higher fluences)
- light was focussed to a spot smaller than 100 μm
- APDs were moved with respect to light spot in 2D with step size of 100 μm, the stepper motors were controlled by a PC via RS485
- at each point two types of measurements were done:
  - current measured with Keithley 237 unit and
  - the shape of the pulse from a common base preamplifier was recorded by LeCroy WavePro Oscilloscope
- both measurements were recorded by a PC via GPIB
- measurements done prior to and after the irradiation for two different fluences

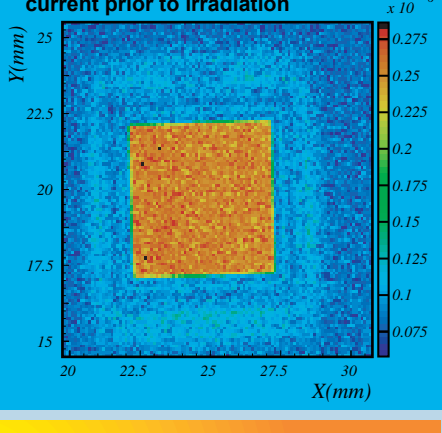
example of a waveform



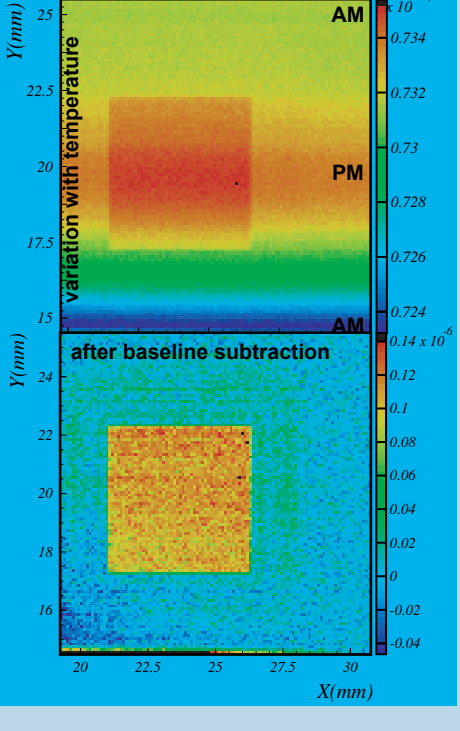
waveform height prior to irradiation



current prior to irradiation



current after irradiation



Conclusions

- in all cases the homogeneity of the surface response was not compromitted by irradiation
- dark current was increased for two orders of magnitude and was very sensitive to temperature variations
- the pulse height was reduced to approx. 70% of the original height after lower fluence irradiation (the APDs exposed to higher irradiation could not be operated at the same bias voltage at room temperature due to self heating - the bias voltage was reduced to 250V)
- the current was very sensitive to temperature variations after irradiation

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