Детектор тепловых нейтронов на основе сцинтилляционного литиевого стекла и кремниевого фотоэлектронного умножителя.

Detector of thermal neutrons on the base of lithium scintillation glass and SiPM

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Here we report the performance of recently developed silicon photomultipliers (SiPMs) with 3x3 mm^2 sensitive area as a readout for small 3x3x2mm^3 scintillation elements made of lithium ^{6}Li scintillation glass. Energy spectra were measured using neutrons from ^{241}Am-Be, alphas from ^{241}Am, and gamma quanta from ^{137}Cs.

SiPM geometry and basic parameters

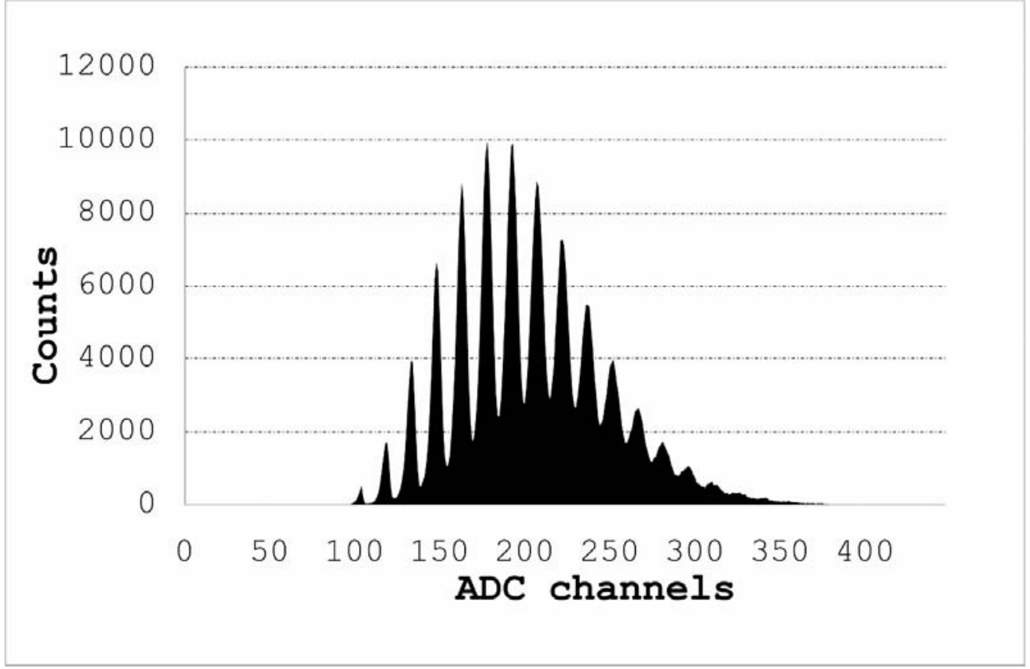
Multi-pixel Geiger mode avalanche photodiodes (G-APDs) (also known as silicon photomultipliers (SiPMs)) are comprised of an array of limited Geiger mode silicon avalanche photodiodes connected in parallel. In this work we have studied the performance of recently developed SiPM_PM3350_Trench from KETEK GmbH (www.ketek.cnet) as a readout for small, $3x3x2mm^3$, scintillation elements made of ^6Li lithium glass with characteristics close to GS-20 (www.detectors.saint-gobain.com).

SiPM geometry and basic parameters

Internal design of the SiPM is based on the p^+-p-n^+ structure optimized for blue/UV light detection. It has a 3x3 mm^2 active area, which is subdivided into 3600 pixels having size of 50x50 microns. These pixels are separated by grooves filled with an optically nontransparent material to suppress an optical crosstalk between pixels and to reduce the SiPM multiplication noise. SiPM sensor is mounted on a non-magnetic PCB package with back-side pins. Sensitive area of the device is protected with a 50 micron layer of transparent epoxy resin (n = 1.58).

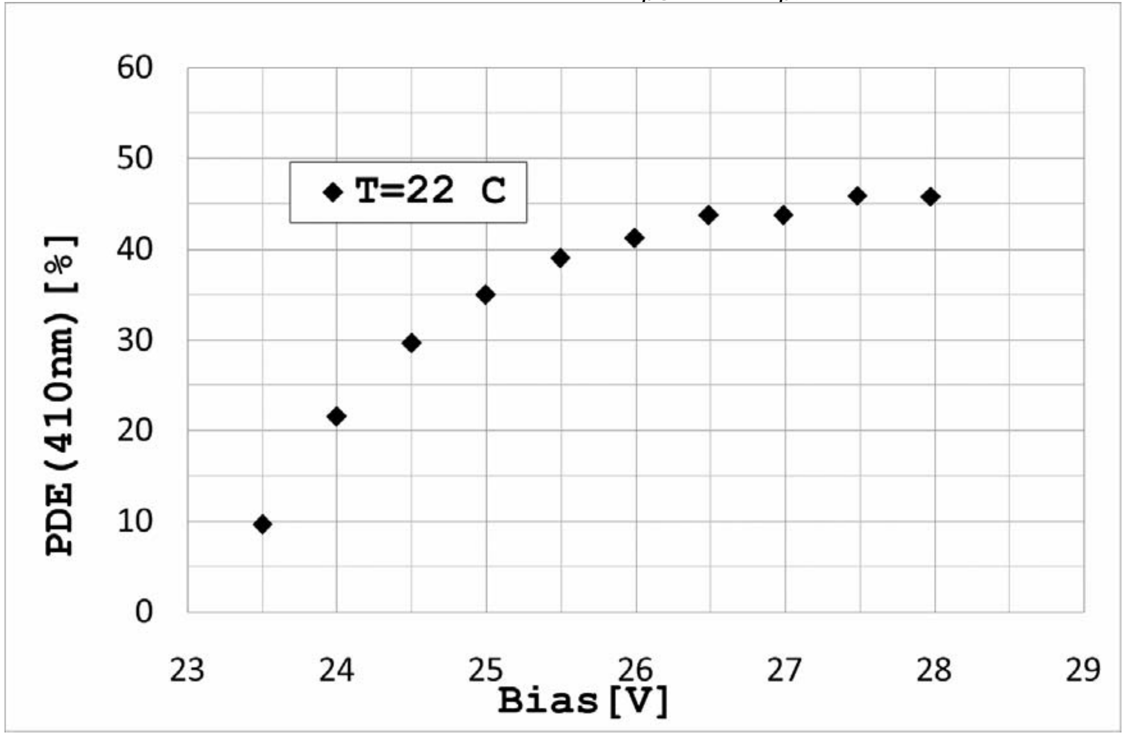
Dependence of photon detection efficiency on the bias voltage

The dependence was measured using a fast 410 nm UV LED operated in pulsed mode. SiPM was illuminated with low light intensity LED pulses (~20 photons/pulse) via a 1 mm collimator. Number of photons N_{ph} in the LED pulse was measured using a calibrated XP2020 photomultiplier (QE_{XP2020}=21% at 410 nm). Signals from the SiPM were amplified with a fast transimpedance amplifier and digitized with a Picoscope 6403 digital oscilloscope.



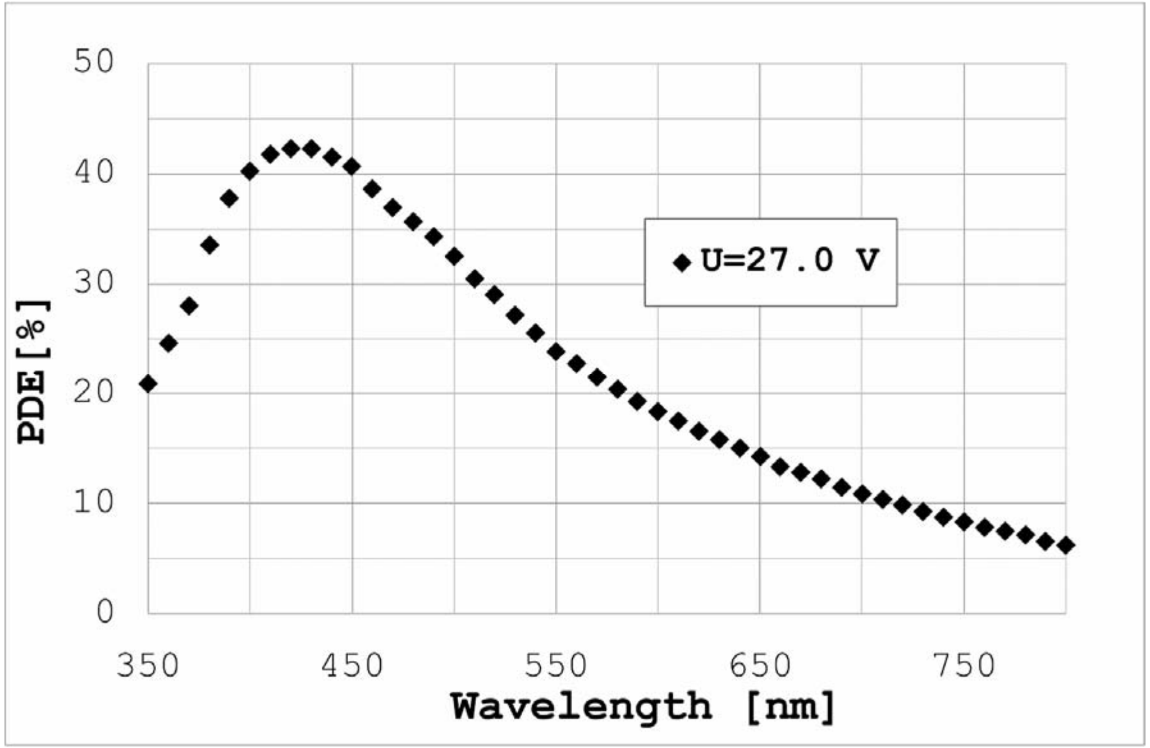
Dependence of photon detection efficiency on the bias voltage

The measured LED low light intensity pulse height spectra can be compared with the Poisson distribution and the mean, N_{pe}, can be calculated using property of this distribution: $N_{pe} = -ln(P(0))$, where P(0) is the probability to observe the "pedestal" events. Accordingly, the SiPM PDE as a function of voltage is: $PDE(U) = N_{pe}(U)/N_{ph}$.



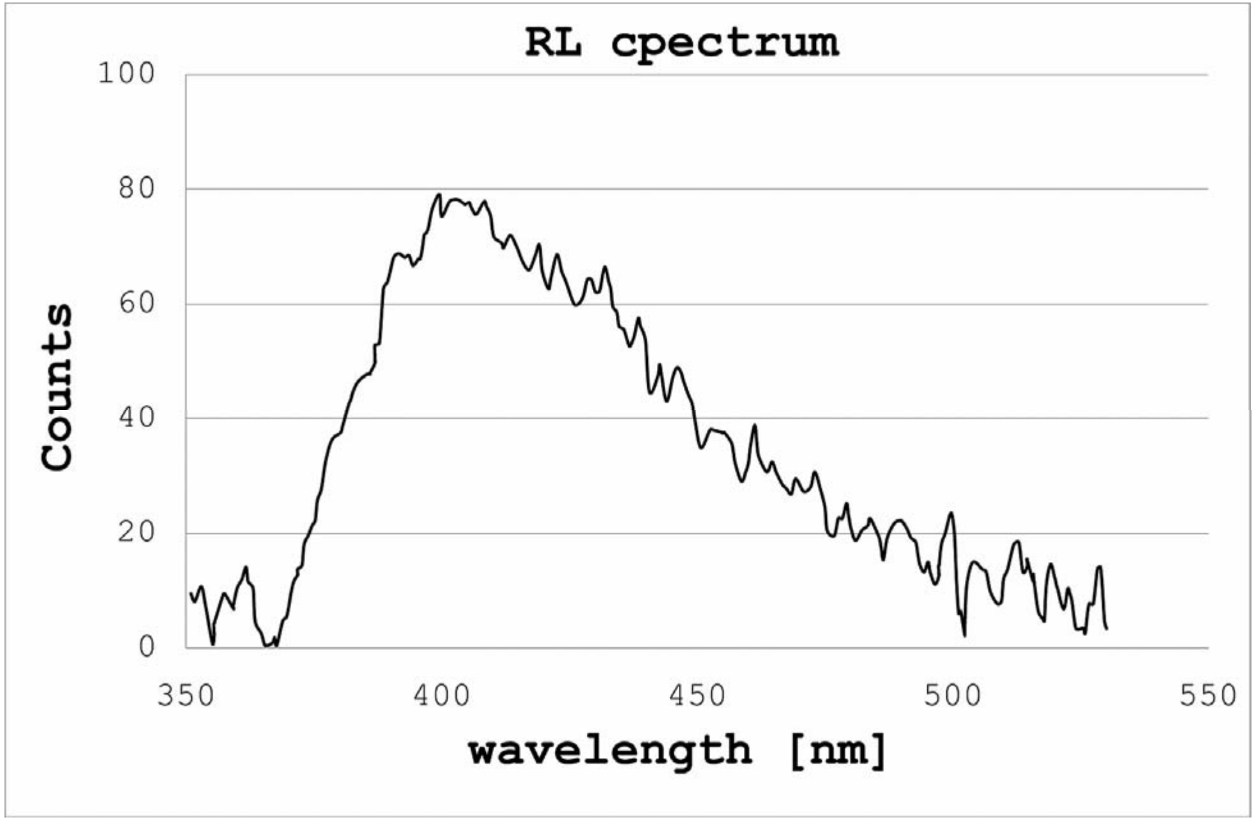
SiPM spectral response

For this measurements, an “Optometrics” SDMC1-03 spectrophotometer was used. The spectrophotometer light intensity was significantly reduced using ND filters to avoid non-linearity effects caused by high pixel illumination.



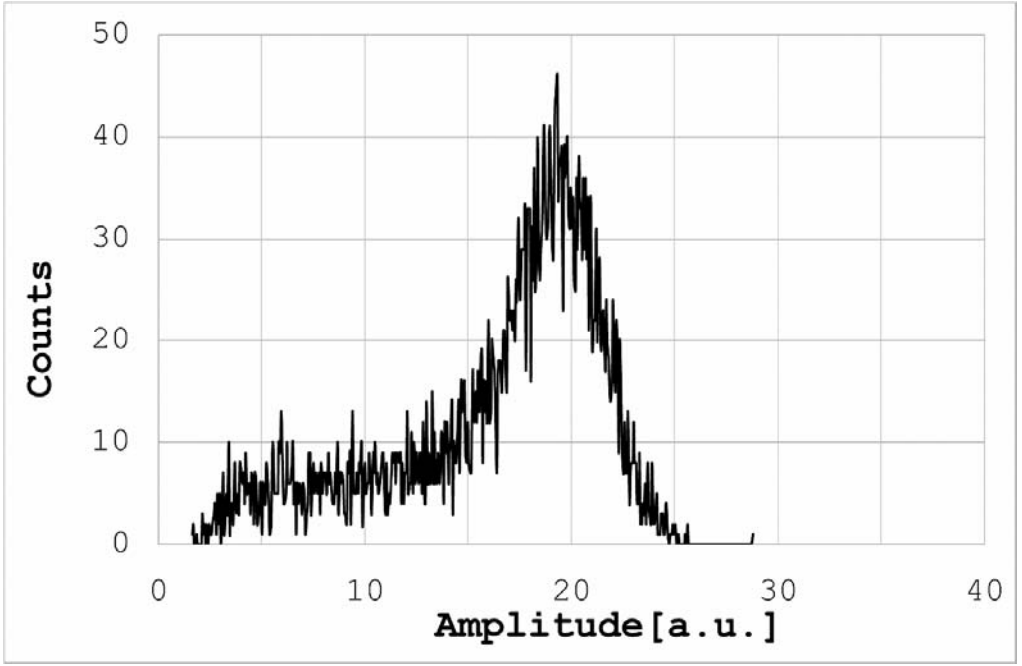
SiPM spectral response

One can see that spectral response of PM3350 SiPM fits well the scintillation spectrum of lithium glass scintillator used in this study.



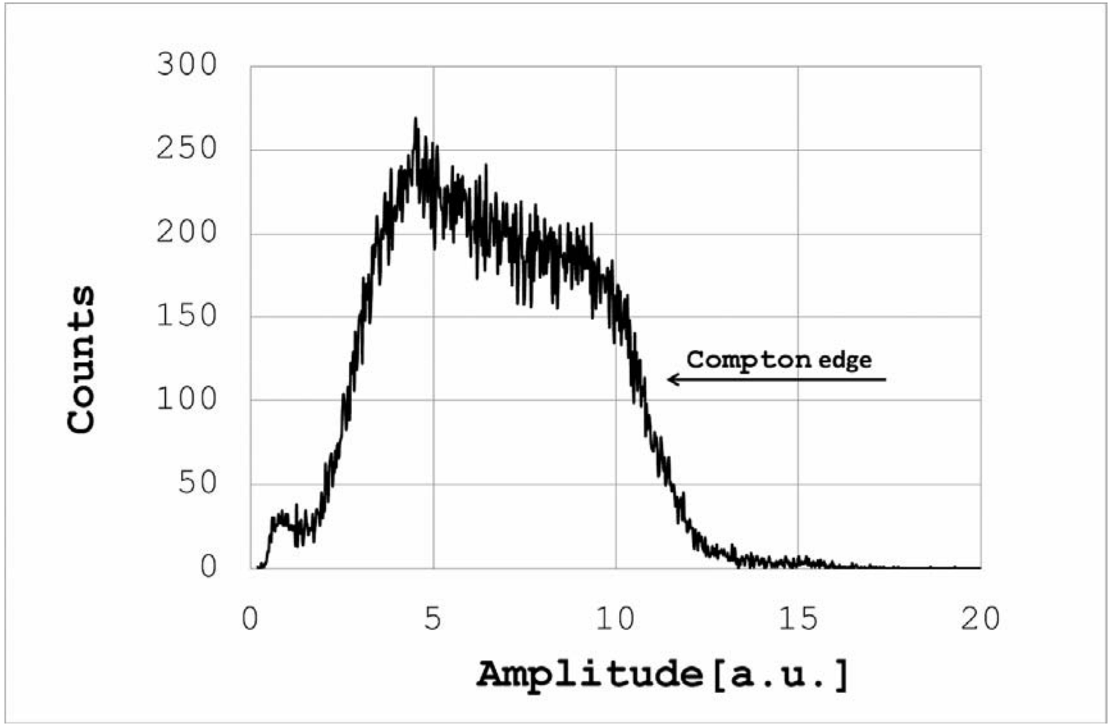
Results of measurements

While lithium glass scintillation element was used with SiPM, it was wrapped with 4 layers of Teflon tape and attached to it using Dow Corning optical grease. Small 0.5 mm hole was made in the Teflon wrapping to allow measurements using ^{241}Am alpha source. Signals from the SiPM were amplified and digitized with a Picoscope 6403. Signal integration time was 500 ns during all measurements. Figure below shows pulse height spectrum of ^{241}Am α-particles.



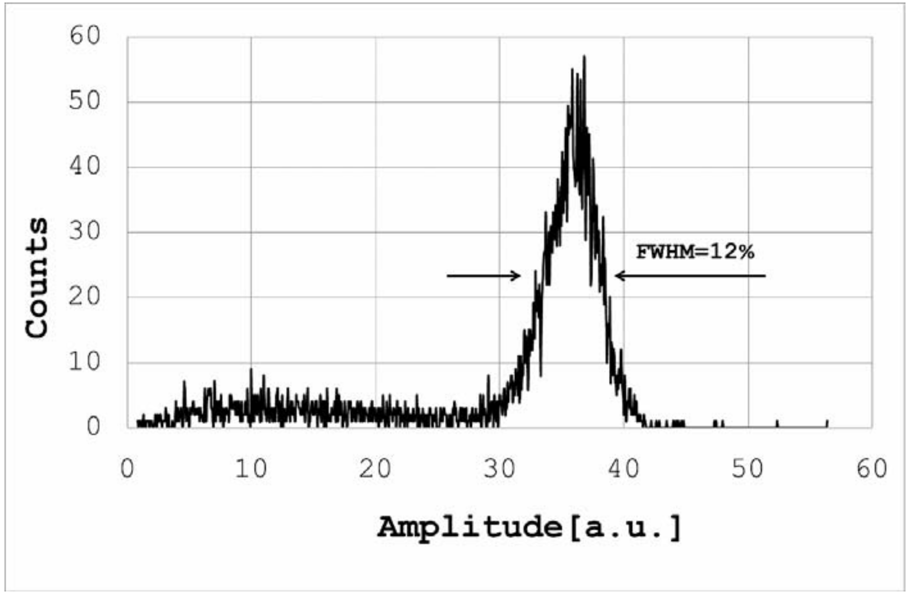
Results of measurements

Figure below shows ^{137}Cs pulse height spectrum. Due to low effective atomic number of lithium glass, only Compton edge with energy E≈470 keV is clearly visible in the spectrum.



Results of measurements

Figure below shows pulse height spectrum from ^{241}Am-Be neutron source. Total energy deposition from neutron reaction with ^{6}Li is 4.8 MeV from triton and α-alpha particle. Due to longer triton range in glass resulting light yield under neutron excitation is noticeably higher than under α-particle excitation. Energy resolution was found to be FWHM=12%, which is better than typical 14% energy resolution of GS-20 scintillation glass with a PMT.



Taking into account position and energy of Compton edge from figure above, energy equivalent of neutron peak measured with lithium glass scintillator in gamma energy scale was found to be 1.7 MeV.

Conclusions

We studied performance of the detector made from recently developed silicon photomultiplier (SiPM) with 3x3 mm^2 sensitive area and lithium glass scintillator with dimensions 3x3x2mm^3. It is shown that lithium glass with SiPM readout can form an excellent detector for thermal neutrons. This detector module can find a wide application for neutron detection with high spatial and time resolution.

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