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Digital SiPM array for photon detection in next generation Xenon based rare event search experiments

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Approaching the kiloton mass scale in rare event search experiments using Xenon places new, stringent demands on the light detection system. Aspects such as high radiopurity, low power consumption and simple mechanics are becoming as important as low noise and excellent quantum efficiency. Digital SiPMs is a light detector technology that meets all these requirements. In this technology, SPADs and CMOS logic are fabricated on the same silicon substrate so that the SPAD hits can be processed on-chip and the chip output signals are purely digital. No further readout ASIC is required and only few passive electric components are needed. This greatly reduces power consumption, system complexity and radioactivity. For rare event search experiments we developed a dedicated large area large area $(8 \times 9\,\mathrm{mm}^2)$ and high high fill factor (77%) digital SiPM array. It allows to build large detector modules controlled by seven signals. Our chip consists of a pixel matrix of 30×32 so-called macropixels of $240 \times 291\,\mu\mathrm{m}^2$ and a narrow band of synthesized readout logic. Each macropixel contains 9 SPADs and some CMOS logic which allows for disabling each SPAD in case its noise rate is too high, and a logical OR combining all SPAD signals to create a common macro-pixel hit signal. The hit signal is stored in the pixel, so that multiple coincident hits in the matrix are possible. The logic in the periphery searches the matrix for hits and stores their X- and Y-addresse as well as an associated column-wise time information $(\Delta T = 10\mathrm{ns})$. Up to 64 Chips build a serial data chain, in which the chips inject their data for readout. In total, a chip chain needs only seven signals: 3 analogue signals for power, ground and SPAD bias and 4 digital signals for clock, command and serial input and output. The SPADs are of excellent quality, offering a dark count rate of $0.02\mathrm{Hz}/\mathrm{mm}^2$ at liquid xenon temperature $(T = 165\mathrm{K})$ and $25\mathrm{kHz}/\mathrm{mm}^2$ at room temperatures. The quantum efficiency at blue light is about 40% and the manufacturer is currently optimizing it for deep VUV light.

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