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VUV SPAD Technologies for Neutrino Experiments

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Low background noble liquid-based experiments are among the leading world efforts in neutrino science and dark matter search. They rely on the development of large-scale photon counting technologies to detect noble liquid scintillation in the VUV range (argon at 128 nm or xenon at 175 nm) as a mean to quantify, position, and discriminate meaningful events.

The Université de Sherbrooke is leading the development of suitable detectors for these applications based on photon-to-digital converters (PDC), a digital version of silicon photomultipliers (SiPM). The very low sensitivity of silicon photodetectors at wavelengths below 250 nm (VUV range), caused by the short penetration depth of UV photons in silicon and by the trapping of photocarriers by surface potentials, represents some of the main design challenges.

For example, commercial SiPMs claim 20-24% efficiency at 175 nm but less than 2% at 128 nm, which is far from the demonstrated sensitivity for silicon detectors (> 50%). Indeed, high detection efficiency was demonstrated on CCD cameras in the 1990s by using delta-doping near the silicon surface. Other methods, such as PureB, "black silicon"or the use of passivation layers are all existing techniques yet to see large scale implementation in SiPM technologies.

In collaboration with the Lawrence Berkeley National Laboratory (LBNL), we follow this path by developing a delta doped surface layer as a post fabrication process on front-side illuminated single photon avalanche detectors (SPADs). Our goal is to surpass the current state-of-the-art SiPM sensitivity below 350 nm. The presence of metals in the device limits the attainable processing temperature to below 450℃. This low thermal budget greatly complexifies the surface preparation and growth process.

This talk will review our latest work on the delta-doping of frontside illuminated SPADs.

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