Contribution ID: **10** Type: **Oral**

Development of Ultra-High-Density (UHD) Silicon Photomultipliers with improved Detection Efficiency

Wednesday, February 22, 2017 3:00 PM (20 minutes)

Silicon Photomultiplier (SiPM) is an arrays of many Single-photon avalanche diodes (SPADs), all connected in parallel. Each SPAD is sensitive to single photons and the SiPM gives an output proportional to the number of detected photons. It is becoming more and more popular in different applications, from high-energy physics to spectroscopy, and it has been significantly improved over last years, decreasing the noise, increasing the cell fill-factor (FF), thus reaching very high photon-detection efficiency (PDE).
Fondazione Bruno Kessler (FBK, Trento) developed, during last years, "high-density" (HD) Silicon photomultipliers (SiPM) technologies. They features narrow trenches to separate the SiPM microcells, obtaining small cells with high fill-factor (FF) and thus high Photon Detection Efficiency (PDE). Moreover, we pushed this technology further and developed the ultra-high density RGB SiPM (RGB-UHD), with extremely low cell size. The cell pitch is between 7.5µm and 12.5µm, arranged in a honeycomb configuration, corresponding to a cell density between 20500 and 7400 cells/mm2, respectively. The main issue of such small cells was the active area border effect which dramatically reduces the effective FF. Therefore, we recently developed a new version of UHD SiPM, with a "new guard ring" (NGR) structure with engineered doping profiles leading to a reduction of the border transition region. Thanks to this technology we were able to have functioning SiPM with 5µm-size pitch. This device features a cell density of 46190 cells/mm2 with a FF of ~40%, and a PDE reaching 15%. Moreover, also the cell recharge time constant is in the order of few nanosecond, further improving the dynamic range in photon detection.
This new UHD SiPM is very interesting in applications that require high dynamic range, like detection of high energy gamma rays, or applications requiring a good resistance to radiation damage. Indeed, the smaller the cell size the smaller is the effect of a damaged cell on the overall SiPM performance, thus the detector is able to operate up to a higher level of radiation damage.

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Planar Sensors

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Session Classification: Session 10: Technology and Applications (1)