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The Vacuum Silicon Photomultiplier Tube (VSiPMT): A new high-gain vacuum photomultiplier.

The necessity of detecting photons with high sensitivity from large surfaces and/or volumes, as typically needed in many particle and astroparticle experiments, but also the requirement of low level light detection for medical and biological applications compel towards devices ever more efficient. The Silicon Photomultipliers (SiPMs, MPPCs) are already replacing photomultiplier tubes in many applications but still the cost requirements restrict the application for the coverage of large detector area. We propose an innovative design for a modern, high gain, silicon based –Vacuum Tube Photomultiplier (VSiPMT), based on the multi pixel Geiger-mode avalanche silicon photodiode (G-APD). These devices have an excellent single ionization detection capability, in particular in the recently developed back illuminated version. In the proposed device hemispherical vacuum tubes allows the detection from very large active areas, whereas the recent Geiger-mode avalanche silicon photodiode is used as photoelectron amplifier overcoming the limits of the classical PMT dynode chain. The photoelectrons emitted by the photocathode are accelerated, focused and then amplified by Geiger junctions, which would substitute the classical dynode chain. These developments will offer an attractive response to the necessity of detectors characterized with small size, low cost, high gain. The concept of the proposed detector will be described and the preliminary results will be presented.

Summary (Additional text describing your work. Can be pasted here or give an URL to a PDF document):

High Quantum Efficiency (QE), single photon-counting capability, high gain and good time resolution, high linearity, robustness, compactness, no sensitivity to magnetic fields and low production cost are the required characteristics for a photomultiplier to be used in the next generation of fundamental and applied Physics.
To date, the photon detection capabilities of the Vacuum Photomultiplier Tube (VPMT) are unrivalled. Nevertheless standard photomultiplier tubes suffer from the following drawbacks:
- fluctuations in the first dynode gain make single photon counting difficult;
- the linearity is strongly related to the gain and decreases as the latter increases;
- he transit time spreads with large fluctuations;
- the mechanical structure is complex and expensive;
- PMTs are sensitive to magnetic fields;
- the need for a voltage divider increases failure risks and power consumption.

To overcome to these limitations, alternatives to VPMT, mainly concentrated on solid state detectors, are under study.
We propose to develop the new type of silicon photomultipliers, which are able to satisfy the most stringent experimental demands. The starting point of our research is the Silicon Photomultipliers (G-APD or SiPM), a novel type of photon detector for low level light detection based on arrays of avalanche photodiodes operating in Geiger mode for which a massive production is today available.
This innovative design is based on the idea of collecting and focusing the photoelectrons emitted by a photocathode on an array of G-APDs, which acts as the amplifier. The junction works as an electron multiplier with a gain of 10ˆ5-10ˆ6, equivalent to the dynode chain of a classical VPMT.
Thus the proposed Vacuum Silicon Photomultiplier Tube (VSiPMT) would consist of:
- a photocathode for photon-electron conversion;
- an electric field to accelerate and focus the photoelectrons on a small area covered by the G-APD array.

The present commercial production of avalanche Geiger mode photodiodes gives the starting point for a new photomultiplier age, based on p-n semiconductors. As an example, in the Hamamatsu production at least three types of n+pp+ MPPC (Multi-Pixel Photon Counter) exist: 1600 (25 micron x 25 micron), 400 (50 micron x 50 micron), and 100 (100 micron x 100 micron) pixels segmented onto a 1 x 1 mmˆ2 total active area. The achieved gain, 10ˆ5 –10ˆ6 at 70-80 V reverse bias voltage, makes the one photon level detection possible.
At present, the silicon wafer cost and the thermal dark current limit the dimensions of the G-APD photo detector at a few mmˆ2.
The proposed new device could overcome the difficulty to detect photons from large surfaces and/or volumes, as typically needed in many many particle and astroparticle experiments (like gamma air-showers, underwater

and under ice neutrino astronomy, Cherenkov telescopes, liquid Argon detectors, calorimeters and scintillator readout).

Preliminary results on the feasibility of the proposed device will be presented.

Details on this innovative design can be find in G. Barbarino et al., Nucl.Instrum.Meth.A594:326-331,2008.

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