TCSPC Setup with SiPM Readout for Volatile Organic Compound Identification

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Abstract: A TCSPC setup has been assembled with custom designed SiPM manufactured at FBK. The goal is obtain a fast and compact object capable of detecting Volatile Organic Compounds, which are important environmental markers.

Volatile organic compounds (VOC) detection in gas mixtures is crucial for air pollution monitoring as well as gaseous contaminants identification. A compact system able to quickly analyze the presence of such compounds could be deployed in a wide variety of environments. By exploiting gas fluorescence lifetime it enables applications such as sub-ppb gas quality monitoring.

An effective and innovative approach for gas analysis involves Time Correlated Single Photon Counting (TCSPC) technique, where the time-resolved fluorescence decay of the gas is acquired following pulsed excitation. The detector of a successful TCSPC setup must have a high detection efficiency to the emitted photons. Typical VOC fluorescence peaks occur in the near-UV (NUV) spectrum, where traditional photosensors have low quantum efficiency. This parameter is fundamental for single-photon detection in processes such as TCSPC.

This technique measures the time of arrival of the first emitted photon, which for VOCs such as Xylene is on the nanosecond scale, statistically reconstructing the fluorescence time decay histogram. For this reason, a detector with sub-nanosecond time resolution is required.

Silicon Photomultipliers (SiPM) are a good candidate for this task, thanks to their single-photon sensitivity and fast time response. At Fondazione Bruno Kessler, we developed a SiPM technology with enhanced sensitivity in the NUV range, with a photon detection efficiency higher than 55% at 400nm and a compact footprint. The metal-in-trench (MT) process, developed at LFoundry, drastically suppresses the correlated noise and a primary dark rate of about 50kcps/mm^2. Consequently, a larger area can be instrumented with an overall reduction in exposure time.

This device will be deployed in a setup where a sub-nanosecond pulsed LED (265nm) will excite a selectable gas sample (or mixture), and its fluorescence will be detected by the SiPM after passing through a band-pass filter to limit the stray light from the primary source.

Thanks to the modularity of the system, in a second phase, the filter/SiPM stack can be substituted by a dispersive grating coupled to an array of 16 SiPMs (pixels) read out by an in-house custom designed ASIC equipped with 16 time-to-digital-converters (TDC) reprogrammable as photon counters. The fully digital readout chain allows for a fast data stream to enable even higher excitation rates. With this upgrade, the setup will spectroscopically separate the different peaks present in the VOCs, acquiring in parallel their time-resolved fluorescence spectra, hence enabling the detection of multiple molecules using the same gas sample with a reduced measurement time.

A production run of MT-filled NUV-sensitive SiPM has been successfully completed, the characterization of the device with its electrical and optical functional measurements will be reported, along with its integration in the assembled TCSPC setup and some preliminary measurement.