Towards a time-gated Raman spectrometer with VIS-NIR SPAD camera for stand-off planetary surface exploration

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Single-photon avalanche diode (SPAD) arrays are solid-state detectors that offer imaging capabilities at the level of individual photons. Very recently, time-gated cameras based on solid-state CMOS SPAD technology have been proposed for improving the performance and field applicability of Raman spectrometers for on-surface planetary geoscience through addressing the largely unmet challenge of suppression of fluorescence interference in highly fluorescent rocks (e.g. minerals containing phosphate, one of the chemical nutrients thought to be essential for life).

The effectiveness of Raman SPAD cameras currently proposed in the literature, however, is at present restricted to a small subset of samples and regimes of operations. This is largely owed to two main limitations. Firstly, their performance is optimised only for the VIS spectral region (typically around 532 nm), where the fluorescence issue tends to be exacerbated due to increased likelihood of electronic excitation for most molecular species compared to Raman excitation above 775 nm. Secondly, their 2D architecture is limited to few pixel rows, which reduces their light-gathering capability and consequently the detection performance of the Raman spectrometer.

We present the preliminary work towards the development of a novel time-gated Raman spectrometer that relies on a large format NIR-optimised SPAD camera prototype with time resolution better than 200 ps. This technology promises to deliver unsurpassed dual-wavelength Raman detection capabilities that would be transformative for stand-off sample analysis in surface exploration of Mars and Icy moons.

A performance analysis model for predicting the fluorescence and ambient light suppression performance levels in relation to the properties of various samples, environmental conditions and specifications of the laser and camera is presented, followed by the preliminary designs of the SPAD camera module and Raman spectrometer.