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Recent developments on WALI for planetary exploration of PAH organics and micro-organisms

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Abstract

The Wide Angle Laser Imager (WALI) is being developed within the EU-FP7 PRoViScout project as a general purpose organic and life detection system for planetary exploration at UCL-MSSL. We show results of WALI being tested from an aerial platform for the detection of algae (cyanobacteria) in parallel to laboratory spectro-fluorimetric measurements of PAH organics both in pure form and doped onto Mars analog granules and with different varieties of cyanobacteria "extremophiles".

1. Introduction

Muller and co-workers [1] described the Wide Angle Laser Imager (WALI) proposed as an enhancement to the stereo PanCam on the ESA 2018 ExoMars-C rover. WALI is based on the use of the LIFE (Laser Induced Fluorescence Emission) principles described by [2, 3]. A Nichia 375nm UV laser diode with 20mW of output power is focused into a circular beam of diameter 5 cm at a distance of ≈2m. Previous laboratory tests using serial dilutions of 3 common PAH organics demonstrated that such a system could detect fluorescence at ppm solution. In this work, a commercial off the shelf (COTS) spectro-fluorimeter has been used to make measurements of Excitation-Emission Matrics (EEMs) from 300-800nm. These EEMs are being employed to select optimum wavelengths for the detection of PAH organics or biomolecules common to all terrestrial organisms (such as tryptophan, FAD, NAD(P)H) and light-harvesting pigments of photosynthetic cyanobacteria (phycocyanin, chlorophyll). Expected habitats on other planetary surfaces include in rock fissures and cracks, rock surface overhangs, cracks in rock faces and in drill core spillings from core drillers such as the one proposed for the ExoMars-C rover.

2. Laboratory measurements

A Perkin-Elmer LS-55 spectro-fluorimeter was used to measure EEMs of different PAH benzene ring molecules both in pure solutions and doped onto granules of Mars analog rock peridotite. An example is shown in Figure 1 below. Please note that the diagonal features are diffraction artifacts and should be ignored.

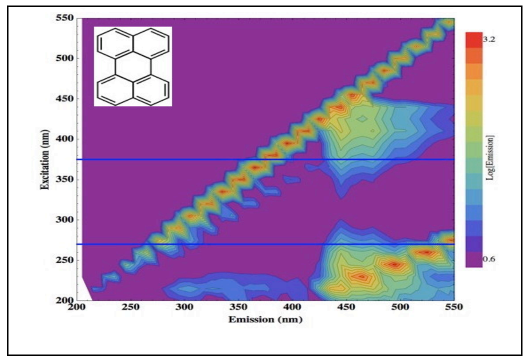

Figure 1. EEM of Perylene solute. Two key laser diode wavelengths are marked (270nm & 375nm) which both produce fluorescent peaks at larger wavelengths (≈430-530nm)

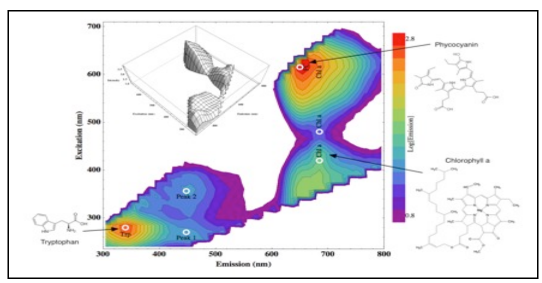

Figure 2. Excitation-emission matrix (EEM) of the fluorescent response of the cyanobacterium Synechocystis sp. PCC 6803. A variety of cellular

fluorophores can be identified at different excitation-emission wavelengths. Taken from [4]

The same instrument was also used to create EEMs of different cyanobacteria. Figure 2 shows an EEM of a cyanobacterium highlighting different biomolecules which can be detected at different wavelengths. In this case the diagonal artifacts have been removed to aid interpretability of the EEM. The amino acid tryptophan (Trp) and photopigment phycocyanin (PC) can be seen to be particularly intense. Again use of different excitation wavelengths for input laser diodes can be found.

3. Aerobot demonstration

Within the EU-FP7 PRoViScout project, a demonstration was staged of the UV laser diode imaging technology within the grounds of the UCL Mullard Space Science Laboratory. A picovet-based platform was designed and constructed to mount a Sigma Fovean camera with an UV filter (to screen any reflections from the 375nm laser light) alongside n UV laser diode and 4 web-cams to show nearby obstructions. The aerial platform used was a balloon. This was challenging to manoeuvre and control. Figure 3 shows an example of the experimental set-up whereas Figure 4 shows the fluorescent signal captured by the Sigma camera. Due to sensitivity limits, such outside imaging had to be conducted in dark night (less than a quarter Moon) conditions. Imaging was acquired for a spot-size of 5cm at a distance of 5m successfully demonstrating the potential of such a UV laser-based system to survey an area at dusk or dawn or in the shadow of a rover. Previous experimental work also demonstrated the capability of detecting a fluorescent signal in low light conditions through image differencing.

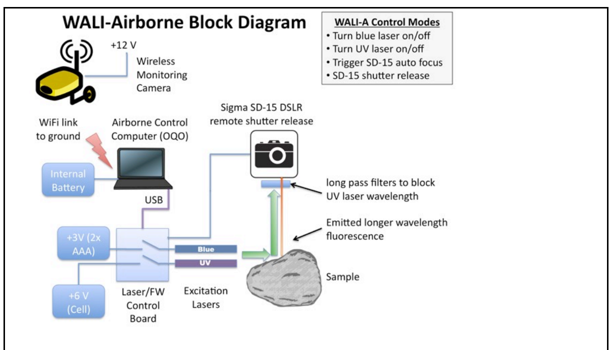

Figure 3. Block diagram of airbone WALI

6. Summary and Conclusions

Recent progress on the development of the WALI imaging system for the remote observation of PAH organics and microbial life has been shown including laboratory measurements to define relevant wavelengths for laser excitation and an aerial scouting test in the field.

Figure 4. Aerobot test controlling the balloon with the picavet with the instrument payload (upper) and result of imaging the fluorescence of blue-green algae with a 30s exposure.

Acknowledgements

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