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Development of a luminescence planetary surface dating instrument

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Luminescence dating (LD) is uniquely positioned for absolute, in-situ, dating of recent (< 1Ma) events on Mars such as the formation of sedimentary landforms, volcanic rocks and salt precipitates. These data can in turn help understand and predict the impact of climate-driven changes on Mars, for example, atmosphere-land interactions, global sand and dust movements and redistribution of volatiles (H_2O and CO_2). This understanding is critical for any manned mission to Mars and for our understanding of the planetary surface evolution.

Despite this potential, the technology transfer from terrestrial to in-situ Martian dating is not trivial. Here we first provide a brief overview of the scientific issues involved in luminescence dating on Mars (e.g. dosimetric characteristics of Martian materials and modelling of cosmic-ray dose rate) and then the technical constraints on an instrument design appropriate for remotely-programmable mobile use on the Martian surface. The challenge is to develop a miniaturised portable luminescence reader that is as sensitive as a laboratory-based instrument and at the same time has sufficient flexibility for fully automated performance. Such an instrument could provide stratigraphic ages if deployed on a rover with a sub-surface drilling capability, or provide a survey of surface chronologies over extensive areas. To this end we have designed and manufactured an 'elegant breadboard' Planetary Surface Dating Instrument (PSDI) in a project supported by ESA. The PSDI is light weight and compact ($\sim$1 kg, $\sim$1.4 litres) and has 3 different reloadable sample positions which can be rotated to sit under 3 different optical subunits or an x-ray irradiator. The optical subunits consists of three different detection channels (one red and two UV/blue) each based on a miniature photomultiplier tube, and three types of laser light stimulation sources (two 915 nm, one 530 nm and one 405 nm) that can be operated in continuous-wave or pulsed mode.
The samples can be heated using an innovative heating concept where the sample disc (aluminium) absorbs energy from an IR laser below and a thermopile detector ensures the temperature control. The samples can thus be heated in a controlled manner to $\sim$300°C for thermoluminescence (TL) or to $\sim$250°C for elevated temperature optically stimulated luminescence (OSL) measurements. Calibration doses are given by a miniature X-ray tube, although to reduce power consumption the irradiator may be replaced by an unshielded beta source in a flight model. There is an artificial phosphor chip fixed to the rotating plate for checks on 'in situ' performance, calibration or surface dose-rate measurements. The rotation of the samples is automatically controlled to ensure correct positioning for dose measurements, and for sample loading or unloading. The luminescence signals can be measured in 3D time-resolved mode; these signals give information on mineralogy as well as age.

The PSDI has been tested thoroughly and the results show a standard deviation of 1-2% for repeated measurements using different optical schemes. In terms of measurements of Martian analogue basalt samples, the sensitivity of the PSDI is better than the standard laboratory reader that weighs $\sim$80 kg. Moreover, the PSDI has a greater number of measurement schemes which can all be programmed and run remotely. This combination offers the flexibility required to date deposits of previously unknown luminescence/dosimetric characteristics. We conclude that this instrument is a very promising candidate for a future Mars mission.