A MULTIPURPOSE THERMAL VACUUM CHAMBER FOR PLANETARY RESEARCH COMPATIBLE WITH STAND-OFF LASER SPECTROSCOPIES

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1. ABSTRACT

Stand-off spectroscopies and imaging techniques have gained a proper niche within the modern tools in remote compositional analysis for in-situ planetary surface exploration using rovers. Laser-induced breakdown spectrometry (LIBS), Raman spectroscopy, time-resolved laser-induced fluorescence (LIF) and laser-induced shockwave acoustic monitoring are tools currently installed and used at the Curiosity and Perseverance rovers in the seek of understanding the mineralogy and geochemistry of Mars. as they obtain real-time information at distances up to 12 meters.

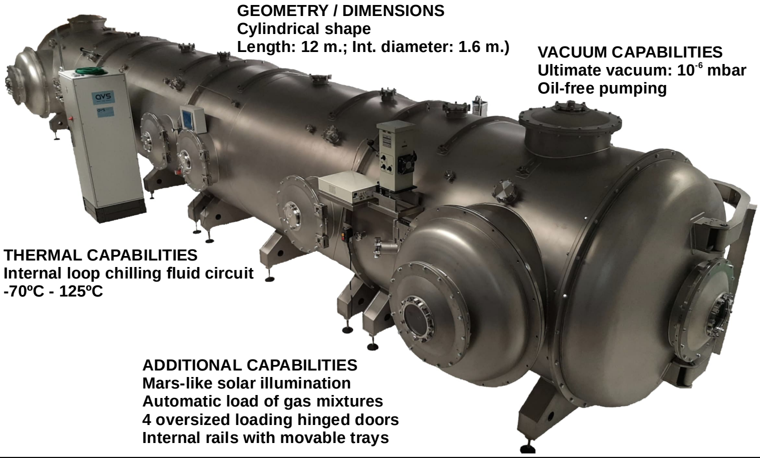
The abstract details the TVC designed and installed at UMALASERLAB to serve the astrochemical community. With a length of 12 meters and an useful internal diameter of 1,6 meters, the chamber operates in a temperature range between 200 K - 400 K and can be oil-free pumped down from atmospheric pressure to 10^{-4} mbar in the current configuration. Additional upgrades may extend the pressure range up to the 10^{-6} mbar range. Such dimensions and figures turns the TVC of UMALASERLAB into a powerful and versatile facility for space-related studies in chemistry, biology and engineering.

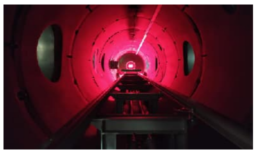
2. A THERMAL VACUUM CHAMBER COMPATIBLE WITH STAND-OFF SPECTROSCOPIES? WHY?

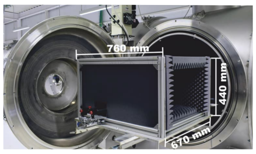
A TVC is a facility capable of operating under representative conditions and mimicked scenarios (temperature, gas composition, pressure, radiation flux …). Its use is required in the control and analysis of components in the aerospace field, as well as in specific research demanding working with mimicked environments.

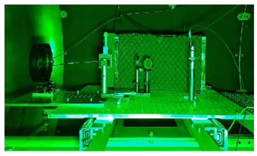
The successful landing of rovers to Mars equipped with a suite of laser-based spectroscopic techniques with capabilities to perform distant physical and chemical measurements (up to 12 meters in the case of the Perseverance rover), demands TVCs with specific dimensions, geometries and performances.

3. THE THERMAL VACUUM CHAMBER AT UMALASERLAB



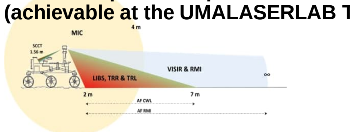






A pair of stainless steel rails and movable internal rails allow an easy handling and positioning of samples all along the mayor axis. It offers 24 m^3 of interior volume with no impediments, very compatible with the laser-based spectroscopies described, or with loading of large pieces to be tested. Telescopic rails in the lateral loading flanges allow easy transport of samples up to 80 kgr. to the interior of the TVC. For bigger samples, the end flanges accept samples with square sections up to 1 m^2. and 10 meters length.

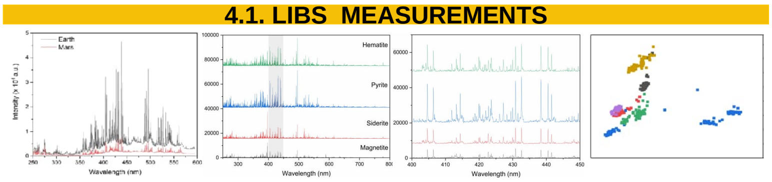
Stand-off spectroscopies at MARS 2020 mission (achievable at the UMALASERLAB TVC)



- **Laser-induced breakdown spectroscopy**
- **Raman spectrometry**
- **Time-resolved luminiscence**
- **Laser-induced plasmas acoustic monitoring**
- **Laser-inuced fluorescence**

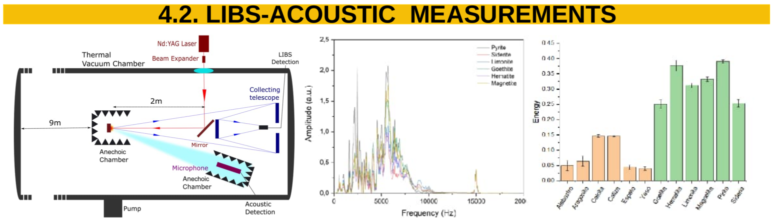
4. EXAMPLES OF MEASUREMENTS PERFORMED INSIDE THE TVC UNDER MIMICKED MARTIAN CONDITIONS

4.1. LIBS MEASUREMENTS



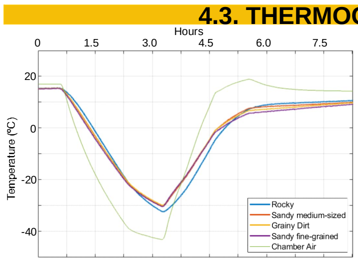
(From left to right). The **first panel** shows the diferences in the LIBS spectra of pyrite recorded under atmospheric pressure (100 mbar, air) and simplified Mars atmosphere (10 mbar, CO_2). The **second and third panels** show full-scale and zoomed LIBS spectra of four Fe-rich mineral recorded at mimicked Mars amospheric conditions at -60ºC. The richness in spectral features of the LIBS spectra allow the building of standard libreries an statistical treatment of the data to get high discriminative spectroscopical analysis. The **fourth panel** shows the discrimination of six Fe-based minerals from their LIBS spectra recorded under micimicked martian conditions.

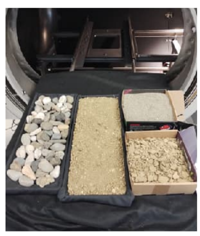
4.2. LIBS-ACOUSTIC MEASUREMENTS

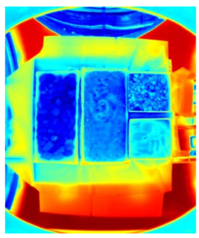


The acoustic monitoring of the laser-sample interaction during the LIBS analysis performed by the Perseverance rovers is providing new information. The shockwave associated to the laser-induced plasma is related to physical properties of the rocks that combined with the chemical information provided by LIBS are opening a new research field. The TVC at UMALASERLAB is being very active in such experiments. An anaechoic chamber has been designed to allow simultaneous LIBS-acoustic measurements under mimicked Mars conditions. **(From left to right).** The **first panel** shows a sketch of the experiment. An identical microphone to that installed at the Perseverance rover records the individual events generated by the laser plasma while recording thye LIBS spectra. Both the sample and the microphone are enclosed in semi-anaechoic chambers to avoid the presence of acoustic harmonics and reflections from the TVC interior walls. The **second panel** shows the spectra in the frequency domain from different Fe-based rock. The third panel shows the energy of the shockwave for different Fe- and Ca-rich rocks analyzed under mimicked Mars conditions.

4.3. THERMOGRAPHIC IMAGING

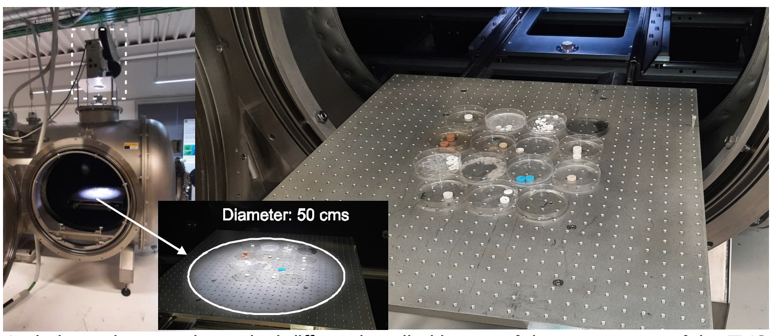






The possibility of simulate temperature cycles have been used to help in the precise programming of algorithms to remotely predict the traversability of a terrain based on its thermal inertia based on IR images. **(From left to right).** The first panel shows a typical thermal cycle from 15ºC to - 42ºC. As shown in the plot, the thermal inertia is pretty simmilar in the different terrains (rocky, sandy and grainy). The **second panel** shows the loading of the samples before starting the thermal cycle. The **third panel** shows a picture of the samples during the cycle. The dimensions of the TVC allow a large field of vision that exceeds an area of 50 x 50 cm^2.

4.4. UV IRRADIATION UNDER CONTROLLED CONDITIONS



An halogen lamp and a optical diffuser installed in one of the upper ports of the TVC allow an homogeneous irradiation inside the chamber over a diameter of 50 cms. At full power, the irradiance at the targets is equivalent to that at Mars. The large irradiated area and the retractable rails allow easy loading of many samples to be simultaneously irradiated under specific vacuum and themperature conditions as shown in the picture.

5. REFERENCES

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6. ACKNOWLEDGEMENTS AND CONTACT

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