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

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Introduction: The availability of thermal vacuum chambers (TVC) represents a need in today´s planetary research [1,2]. A TVC must be capable of operate under representative conditions (temperature, gas composition, pressure, radiation flux …) of space exploration targets, but also have an useful volume compatible with the performing experiments and the testing of equipment under mimicked scenarios.

Stand-off spectroscopies and imaging techniques have gained a proper niche within the modern tools in remote compositional analysis for space exporation using rovers. Particularly, Laser-Induced Breakdown Spectrometry (LIBS) and Raman spectroscopy are currently key tools in the understanding of mineralogy and geochemistry of planetry surface as they obtain to date real-time information at distances up to 12 meters [3]. The convenience of a TVC capable of performing stand-off spectroscopies under the current analysis range is evident as it allows reproducing the results obtained in the rovers, gaining insights about data treatment and data modelling, and also anticipating experiments on Earth before being commanded.

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 meter, 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 figures and dimensions turns the TVC of UMALASERLAB a powerful and versatile tool for space-related studies in chemistry, biology and engineering.

Fig. 1. Panoramic view of the simulation chamber at UMALASERLAB facilities.

Specifications. Figure 1 shows a picture of the TVC at UMALASERLAB. It is an stainless-steel cylinder of 22 m^3 made of four independent on-wheels units. The external cylinder-shaped vessel is made in 304L stainless steel. All the internal surfaces are electropolished while in the outer surface the finishing is sand-blasted. The vacuum vessel ensures an overall leak range < 1x10^{-6} mbar.l/s. Such value is exclusively limited by the Viton™ O-rings connecting the four units of the cylinder as well as the all the different flanges of the 50 auxiliary ports in ISO K and ISO KF type positioned at different positions of the wall for multipurpose use.

The interior of the chamber is manned accessed by two hinged-doors at the ends of the chamber with a diameter of 1.6 meter, as well as by two lateral hinged-doors with a 1 meter diameter for convenient access to the instruments and the samples. The four doors are equipped with large hinged DN 500 ISO-K flange that included a DN 250 ISO K inspection windows.

The chamber thermal jacket is made of two thin TIG welded stainless steel 304 L sheets according to a “spot-grid” figure. An air-blowing pressurization applied after the welding, causes a controlled blistering creating a set of channels for the cooling fluid, that covers the entire surface of the heat exchanger ensuring very good temperature uniformity, savings of raw materials, greater efficiency in heat transfer and lower thermal inertia. The temperature changing rate of the chamber is 1 ºC/min.

The internal surface of the shroud is black-painted with a special enamel to improve the thermal emission of the surface itself and maximizing light absorptivity (> 95 %) at any angle) to reduce flares os ghost effects in the recorded spectra. The painting exhibit a degassing rate < 10^{-6} mbar.-l/s.

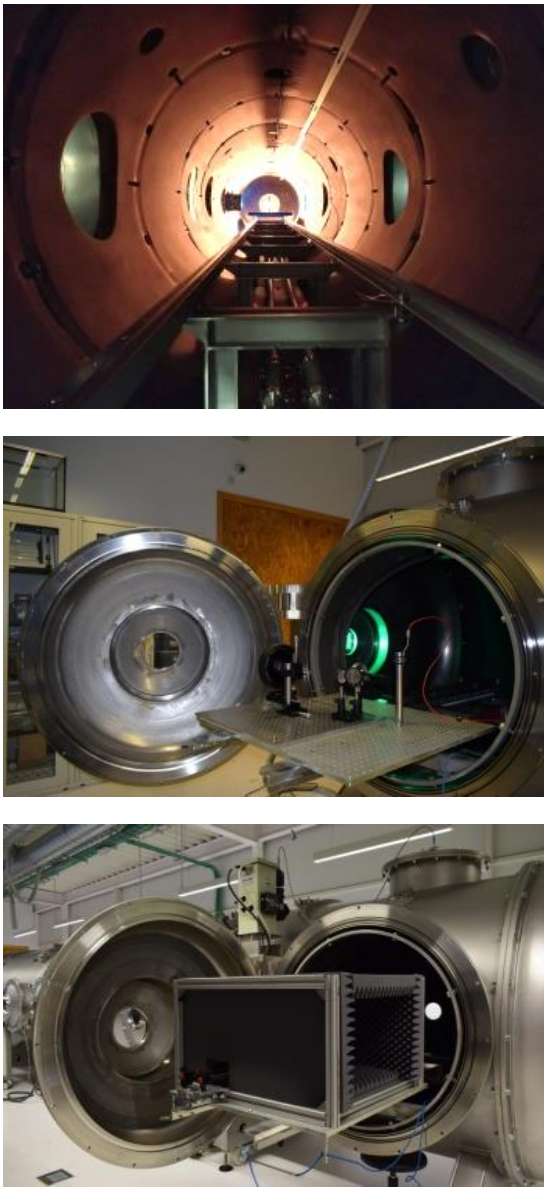

Fig. 2. (Top) Detail of the rails crossing the entire length of the chamber. (Middle and bottom) Details of the two lateral ports of the chamber allowing the loading of an optical table for laser spectroscopy experiments on one side (middle) and the loading of an anechoic chamber on the other end (bottom).

Two stainless steel rails placed along the major axis of the cylinder allows the displacement of three grid patterned threaded plates fixation along the interior of the chamber as shown in Fig. 2, top. A second set of telescopic rails allow the plates to get out of the chamber for convenient loading and handling of instruments and samples. See Figure 2, middle and bottom. The plate will permit the fixation of test specimen thanks to a grid of threaded

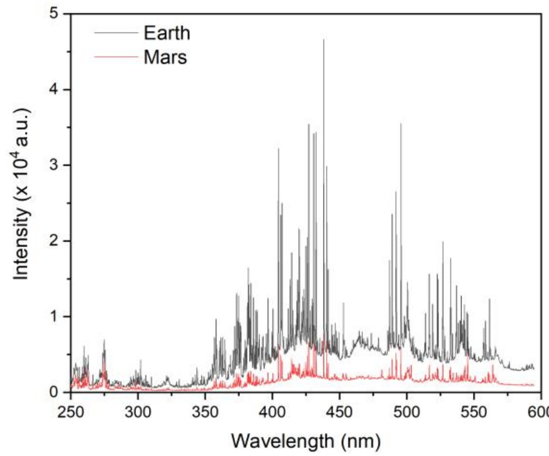

Fig. 3. Stand-off LIBS spectra of pyrite sample placed 11 meters away the laser head under standard Earth conditions (black line) and Mars-like atmospheric conditions at -10 ºC. Other conditions: 100 accumulated shots; laser energy: 40 mJ/pulse; laser wavelength: 1064 nm; spot diameter: 500 microns; delay: 0 ns; acquisition window: 1,28 ms. Detector: Avantes multichannel spectrometer.

holes drilled on the full surface. The plates are placed directly on rails supported by the vessel, in order to avoid any mechanical stress on the shroud. In the loading position outside the chamber, the plates allow a maximum weight of 70 kilograms. For experiments demanding deep UV illumination, a fiber-optic connected to a high-power Xe lamp provides illumination conditions similar to those at Mars surface in the UV-A, UV-B and UV-C spectral regions over an area of 1 cm^2.

A graphic user interface allows visualization, control and data logging of the vacuum pumps, the cooling/heating system, the pressure gauges, the thermocouple gauges, and the motorized butterfly valve and a mass flow controllers for gas mix load in the chamber.

As a performance test, Figure 3 shows two LIBS spectra taken under Earth and Mars-like con ditions of a pyrite. The commercial laser and spectrometer were external to the chamber due to non-compatibiity of the electronics with the temperature. The rest of the elements were placed inside the chamber.

References: [1] Mateo-Martí E. (2006) Meas. Sci. Technol. 17 2274. [2] Rabbow E. et al. (2016) Microgravity Sci. Technol. 28, 215. [3] Bishop J.L. et al. (Eds), Remote Compositional Analysis (2020), Cambridge Unversity Press.