SUPERCAM VISIBLE/NEAR-INFRARED SPECTROSCOPY ONBOARD THE PERSEVERANCE ROVER

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T. Fouchet[1], J. R. Johnson[2], O. Forni[3], J.-M. Reess[1], P. Bernardi[1], R. T. Newell[4], A. Ollila[4], C. Legett [4], P. Beck[5], A. Cousin [3], C. Royer[6], C. Pilorget[6], F. Poulet[6], E; P. Pilleri[3], Cloutis[7], T. McConnochie[8], F. Montmessin[9], A.J. Brown[9], R. C. Wiens[4], S. Maurice[3], and the SuperCam VISIR Working Group, [1]LESIA, Meudon, France (Thierry.fouchet@obspm.fr), [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA. [3]IRAP, Toulouse, France, [4]LANL, Los Alamos, NM, USA., [5]IPAG, Grenoble, France, [6]IAS, Orsay, France, [7]University of Winnipeg, Canada, [8]University of Maryland, USA, [9]LATMOS, Guyancourt, France, [9]Plancius Research, MD.

Introduction: The Mars 2020 Mission was designed and implemented to address four overarching goals [1]: i) the investigation of the mineralogy and geology of the Jezero crater as representative of the ancient Martian environment, ii) the assessment of the habitability of this ancient environment, iii) the identification of rocks with a high potential of preserving biosignatures, iv) and the study of the current environmental Martian conditions in the preparation for human exploration.

As part of the Perseverance Rover payload, the SuperCam Instrument Suite [2, 3, 4], a US-French-Spanish collaboration, will nest and co-boresight four different spectroscopic methods to analyze the Martian surface and atmosphere in support of the Mars 2020 *in situ* investigations. In this poster, we will present the science objectives and performances of SuperCam passive visible/near-infrared (VISIR) spectroscopy, its implementation, and ground test and calibration. By the time of the conference, SuperCam should have acquired data on Mars, which will be the focus of the poster, in comparison with reference data acquired on Earth.

Science objectives: The SuperCam Instrument Suite was designed as one of the primary tools to remotely investigate elemental composition and mineralogy of rock and soil targets. It will also provide sub-mm context color imaging of outcrop textures, search for organics and volatiles, perform atmospheric characterization, and record sounds [3]. To achieve these objectives, SuperCam implements four nested and co-aligned spectroscopic techniques: laser induced breakdown spectroscopy (LIBS), Raman spectroscopy, time-resolved fluorescence spectroscopy, and passive VISIR spectroscopy.

The VISIR passive spectroscopy will be used to identify minerals at the mm-scale from the vicinity of the rover to distant outcrops. The wavelength range (0.385-0.465 μm, 0.536-0.853 μm, 1.3-2.6 μm) has been tailored to identify sedimentary minerals with a high biological potential already identified in the Jezero area, such as carbonates, phyllosilicates, and sulfates. Although SuperCam will not be sensitive at the center of the 1-μm band of iron-bearing materials, it will still identify igneous minerals like pyroxenes through their 2.0-μm band, while the broad 1.0-μm band of olivine will be sampled in its wings on the both the VIS and IR sides. Mastcam-Z also features a filter centered on this band. [5]. Finally, passive VISIR sky observations will measure column densities of H_2O, O_2 and CO, monitor water ice clouds, dust opacity, and constrain the dust scattering phase function [6].

Hardware implementation: The SuperCam Instrument Suite consists of three separate units: the Body Unit (BU) located within the Rover [2], the Mast Unit (MU) located at the top of the Perseverance Remote Sensing Mast [3], and the Calibration Targets [4] located on the deck of the Rover.

The Mast Unit comprises (1) the laser designed for the LIBS and Raman investigations, (2) the telescope focusing the LIBS laser beam on targets and collecting photons from the targets, (3) the remote micro-imager (RMI), (4) a microphone, and (5) the passive infrared spectrometer (IRS). The passive infrared spectrometer [7, Fig. 1] uses an acousto-optic tunable filter (AOTF) excited by a RF signal to diffract 256 different wavelengths ranging between 1.3 and 2.6 μm on two photodiodes to produce a single spectrum in about 80 seconds. The field-of-view of the IRS is 1.15 mrad and

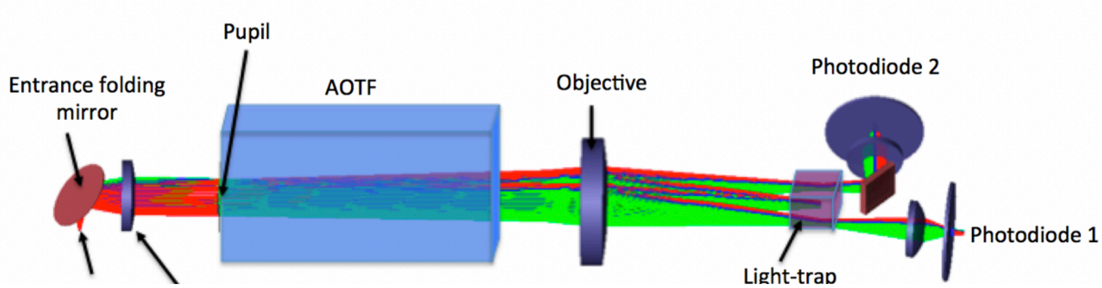

Figure 1: Optical design of the IRS. The light collected by the telescope enters from the left.

is co-aligned with the RMI boresight. The spectral resolution spans from 5 to 20 nm.

The Body unit comprises three spectrometers covering the UV (245 – 340 nm), the violet (385 – 465 nm), and the visible and near-infrared (VNIR, 536 – 853 nm) ranges needed for the LIBS, Raman and time-resolved fluorescence spectroscopy techniques. The spectrometers are fed by the light collected by the telescope in the MU through an optical fiber connecting the MU and BU. The violet and VNIR spectrometers can be operated independently of the laser to collect reflected solar photons to obtain passive VIS reflectance spectra. The violet spectrometer is a crossed Czerny-Turner spectrometer, with a spectral resolution of 0.12 nm, and the VNIR spectrometer is a transmission spectrometer with a spectral resolution of 0.35 – 0.70 nm. The VIS FOV is 0.74 mrad and co-aligned with the IR FOV.

Finally, several of the SuperCam calibration targets (SCCT) are dedicated to passive spectrometry or photometry, including an AluWhite white target (with a 98% uniform reflectance from 0.4 to 2.6 μm), an Aeroglaze Z307 black target, and red, cyan, and green color targets [4]. Several of the other targets whose primary purpose is for other techniques exhibit useful VISIR spectral features and will be observed as well [8].

Instrument test and performances: The IR spectroscopy function was extensively tested at Paris Observatory facilities. The spectral registration and resolution were measured at the IRS level using monochromators for several spectrometer temperatures (see [7] for details). The radiometric calibration was performed at the MU level to integrate the full optical path of the IRS function. The instrument transfer function (ITF) was obtained using a black body for several spectrometer and photodiode temperatures as detailed in [9]. The absolute radiometric calibration is better than 10% and relative calibration better than 1%. The signal-to-noise ratio was also characterized and shown to meet the requirement of being higher than 60 for a 80-second integration.

The VIS passive spectroscopy function was tested at LANL facilities, coupling the flight model (FM) of the BU and the qualification model (EQM) of the MU. The spectral registration and resolution were measured using several atomic emission lamps at various temperatures. The measurements showed a very small dependence with temperature, smaller than 0.2 nm across the wavelength range and temperature range. The instrument response function was obtained using a calibrated Labsphere integrating sphere (details can be found in [2]).

Finally, the VISIR passive spectroscopy function coupling the FM of the MU and BU was only tested in

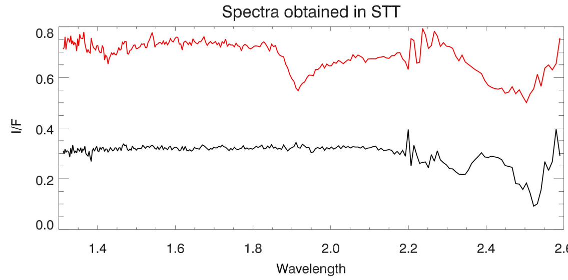

Figure 2: Spectra of Calcite (black line) and Gypsum (red line) obtained in STT. No absolute calibration was obtained.

System Thermal Test (STT) at the Rover level before shipping to Cape Canaveral for launch. Several spectra of mineralogical targets (either SuperCam calibration target or other mineralogical targets) were illuminated by a Superior Quartz xenon solar simulation lamps installed with the JPL Mars simulation chamber (Fig. 2). However, this setup did not allow us to cross-calibrate the VIS and IR functions, a goal that will await spectra at the surface of Mars.

Data Calibration. Using the instrument transfer function, [8] raw data will be converted to radiance ($W/m^2/sr/\mu m$) with calibrated wavelengths. Relative reflectance spectra will be generated by dividing the calibrated radiance spectrum by either (1) a Mars atmospheric transmission spectrum and then by the solar irradiance modeled at the time of the observation; or (2) a radiance spectrum of the white SCCT taken close in time to the surface observation, as is done with Mastcam-Z reflectance calibration [5]. Comparisons of these two methods on Mars will determine their efficacy as a function of observing conditions during surface operations.

First Mars Operations: By the time of the conference, SuperCam should have acquired data on Mars, which will be the focus of the poster. The first spectra will be compared with the test and performance data obtained at Paris Observatory, LANL, and JPL. As of this writing, planned observations in the first couple of weeks include a) IR spectra of the black, white, and other rover calibration targets, and an observation of the Mars surface. Additional Mars observations will be planned in parallel with rover check-out activities.

References: [1] Farley et al. (2020), *Space Sci. Rev.* 216, 142. [2] Wiens et al. (2021) *Space Sci. Rev*. 217*, 4,* [3] Maurice et al. (2020) *Space Sci. Rev*. 216,*in press,* [4] Manrique et al (2020) *Space Sci. Rev*. 216, 8 (2020), 1-27. [5] Bell et al. (2020) *Space Sci. Rev*. 216, in press [6] McConnochie T. et al. (2021), this conference. [7] Fouchet et al. (2021) Icarus, to be submitted. [8] Cousin et al. (2021) this meeting. [9] Royer et al. (2020) *Rev. Scient. Instrum.* 91, 063105.