EPSC Abstracts
Vol. 11, EPSC2017-888-1, 2017
European Planetary Science Congress 2017

A compact low-temperature reflectance chamber for FT-spectroscopy experiments at the PSL

Y.M. Rosas Ortiz[1,2], A. Maturilli[1] J. Helbert[1] and D. Wendler[1]
(1) Institute of Planetary Research, German Aerospace Center DLR, Berlin, Germany, (2) Technische Universität Berlin, Department of Aeronautics and Astronautics, Berlin, Germany (yaquelin.rosasortiz@dlr.de)

Abstract

We report on the ongoing development at the Planetary Spectroscopy Laboratories (PSL) group of a compact low-temperature, high vacuum, reflectance chamber; which, in combination with the existing high temperature setup and a Fourier transform infrared (FTIR) spectroscopy instrument will expand the PSL current unique capability of measuring emissivity spectrum of fine-grained powder materials from 1 to above 100 µm, bulk materials and coatings at temperatures up to 1000K across the whole infrared wavelength range.

After this update, the PSL will cover an extremely wide range of temperatures; from emissivity spectra measurements up to 1000K and in the future for reflectance spectrum measurements down to cryogenic temperatures.

1. Introduction

The Institute for Planetary Research of the German Aerospace Center (DLR) has an expertise in spectroscopy of minerals, rocks, meteorites and organic matter, built up in more than 3 decades. In its facilities at the Planetary Spectroscopy Laboratories (PSL) a wide range of planetary analogue materials are routinely analyzed, with the available equipment the PSL having a unique capability to measure emissivity of fine-grained powder materials over a very wide spectral range, bulk materials and coatings at temperatures up to 1000K across the whole infrared wavelength range. Most of its previous work is based on emissivity measurements.

Following user demands PSL extended in the last years its spectral coverage down to the UV allowing now to measure bi-directional reflectance from 150nm to 300 microns with two identical Bruker VERTEX 80V spectrometer [2],[7].

At the PSL measurements for the characterization of asteroid and comet analogues by means emission and reflectance spectroscopy have already been performed [5] and reflectance spectra at room temperature has been measured [4].

The PSL now aims to extend its capability to perform reflectance measurements at low-Temperature environments, especially on the characterization of asteroid, cometary or solar system small bodies (SSSB) analogues. In the case of the main-belt asteroids and dwarf planet Ceres, the daytime surface temperature is between 200 and 300K (-73.15°C to 26.85°C) [11].

2. Low temperature: spectroscopy

Objects in space are subjected to its almost perfect vacuum, cold and solar radiation. For instance the maximum day-light temperature of the dwarf planet Ceres was estimated to be 235K [10], the surface temperatures distributions of Vesta is from 40K to 248K [3] and the surface temperatures of Asteroid 21 Lutetia reaches a maximum value of 245K [1].

Pronounced spectral effects at the lowest temperature of 80K are shown by Moroz et al. [8] in a reflectance spectra measurement of Olivine and orthopyroxene, which are very common rock-forming minerals in the Solar System. A measure of the temperature dependence of the reflectance spectra at the primitive surface of Ceres has been addressed by Beck et al. [12] to investigate the reflectance spectrum under decreasing temperatures (down to 93K).

Setting up a system for reflectance spectroscopy experiments at cryogenic temperatures represents a unique opportunity for the PSL.

3. Technical Approach

In the first concept phase various cooling systems have been evaluated. The cooling system has the main objective to cool down the sample surface down to cryogenic temperatures. The possibility of using a closed based cycle cooling by helium gas or liquid nitrogen with typical temperatures of 70-90K, to provide distributed cooling power for a cooling surface, is discussed. The nominal cooling capacity of the miniature cryocooler system currently at use at DLR is for example 65K [9]. It is expected to reach a cryogenic temperature within the range of 70K – 100K.

4. Experimental setup

At PSL, there are currently two instruments equipped with external chambers to measure emissivity. One of them is a vacuum chamber built to measure at very high temperatures and the second chamber (that can be cooled down to 0° C) is for measurements at low to moderate temperatures [6]. In the latter samples can be heated from room temperature to 150°C in a purging environment.

The new low-T chamber will be coupled to the newest Fourier transform infrared (FTIR) spectroscopy instrument Bruker Vertex 80 V equipped with aluminum mirrors for high efficiency down to the UV spectral range.

5. Summary and Conclusions

In summary, laboratory-spectroscopy investigations of minerals are key to support the interpretation of remote sensing data returned by the interplanetary missions.

A compact low-temperature reflectance chamber for FT-spectroscopy experiments at the PSL is currently under development. The expected cryogenic temperature to reach is approximately within the range of 70K – 100K. The potential experiments are promising. The current and future missions (e.g., NASA/DAWN and ESA/ExoMars 2020, NASA/EUROPA Multiple Flyby Mission, ESA/JUICE respectively) indicate the high potential usage of this development, which may result in many scientific or even commercial applications.

References

[1] Coradini, A. et al.: The surface composition and temperature of Asteroid 21 Lutetia as observed by ROSETTA/VIRTIS, Science 334 (6055), 492–494, 2011.

[2] Helbert, J. et al.: Planetary Sample Analysis Laboratory at DLR, EPSC2017, this meeting

[3] Leyrat, C. et al.: Thermal properties of (4) Vesta derived from Herschel measurements, Astronomy and Astrophysics, 539, 2012.

[4] Maturilli A. et al.: Komatiites as Mercury surface analogues: spectral measurements at PEL. EPSL 398:58–65, 2014.

[5] Maturilli, A. et al.: Characterization of asteroid analogues by means of emission and reflectance spectroscopy in the 1 to 100μm spectral range, Earth, Planets and Space, 68:113, 2016.

[6] Maturilli, A. et al.: The Berlin emissivity database (BED), Planetary and Space Science, 56, 420-425, 2008.

[7] Maturilli, A. et al.: The planetary Spectrocopy Laboratory (PSL), EPSC2017, this meeting.

[8] Moroz, L., et al.: Reflectance Spectra of Olivine–Orthopyroxene-Bearing Assemblages at Decreased Temperatures: Implications for Remote Sensing of Asteroids, Icarus 147, 79-93, 2000.

[9] Richter, H., et al.: A compact, continuous-wave terahertz source based on a quantum-cascade laser and a miniature cryocooler, Optics Express, Vol. 18, No. 10, 2010.

[10] Tosi, F. et al.: Dwarf Planet Ceres: Preliminary Surface Temperatures from Dawn, Geophysical Research Abstracts, Vol.17, EGU2015-11960, 2015.

[11] Tosi, F. et al.: Thermal measurements of dark and bright surface features on Vesta as derived from Dawn/VIR, Icarus 240, 36-57, 2014.

[12] Beck, P., at al.: Low-temperature reflectance spectra of brucite and the primitive surface of 1-Ceres?, Icarus 257, 471–476, 2015.