Lunar Infrared Spectrometer (LIS) for Luna-Resurs and Luna-Glob missions

Space Research Institute (IKI)

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Raster Technology

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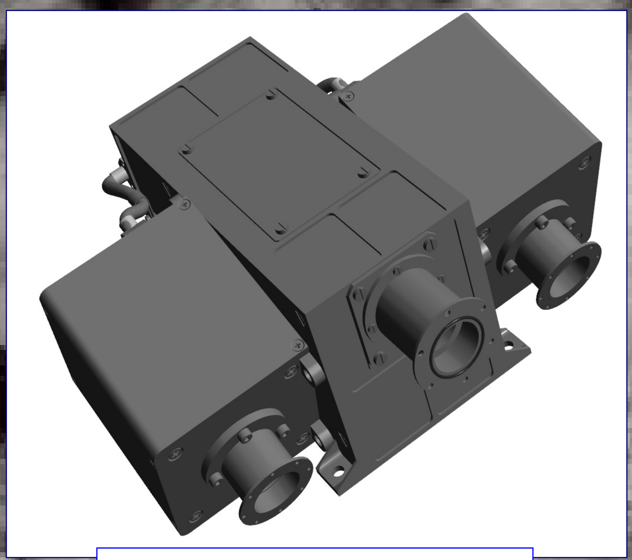


Fig 1. Optical box with installed stereo TV cameras

Abstract

Lunar Infrared Spectrometer (LIS) is an experiment onboard Luna-Glob (launch in 2015) and Luna-Resurs (launch in 2017) landers of Russian lunar missions. The spectrometer will provide measurements of selected surface region in the spectral range of 1.15-3.3 µm. The experiment is dedicated for the study of regolith hydration at 3µm, identifying hydration form, changes of surface hydration during the day, study of mineralogical composition. Also, LIS will be used for selection of soil samples to be analyzed by other instruments.

Milestones

Launch of Luna-Glob mission: **2015**

Launch of Luna-Resurs mission : **2017**

Water in the surface layer of the Moon

One of the most impressive results of recent Moon studies is the discovery of water in the surface layer. The M^3 spectrometer (Moon Mineragoly Mapper) onboard Chandrayaan-1 discovered that significant part of Moon surface contains small amount of H_2O and/or OH-bearing minerals on the uppermost layer [1]. The M^3 results are in line with earlier Moon observations made in 1999 with the VIMS optical spectrometer from the Cassini spacecraft and are confirmed by new SIM/Deep Impact mapping spectrometer observations [2]. M^3 was the first spectrometer, which carried out systematic mapping of the Moon in the IR and showed that hydrated mineral band at 3 µm is widely spread. The IR measurements detect H_2O and/or OH in the thin (few microns) surface layer of the Moon regolith.

Depletion of neutrons allows to estimate the hydrogen contents in the upper 1-2 meters of the lunar soil. First, the evidence for water ice was detected by Lunar Prospector [3], and the detailed neutron map of lunar hydration was obtained by LEND on Lunar Reconnaissance Orbiter [4]. The estimated contents vary from 0.5 to 4.0 % of water ice by weight, depending on geographic location and the thickness of overlying dry regolith layer. An attempt of measuring water abundance in the bulk of Moon regolith was made in experiment LCROSS (Lunar Crater Observation and Sensing Satellite) in 2009. The measured water vapor abundances are an equivalent of 2.7-8.5 % of water ice [5].

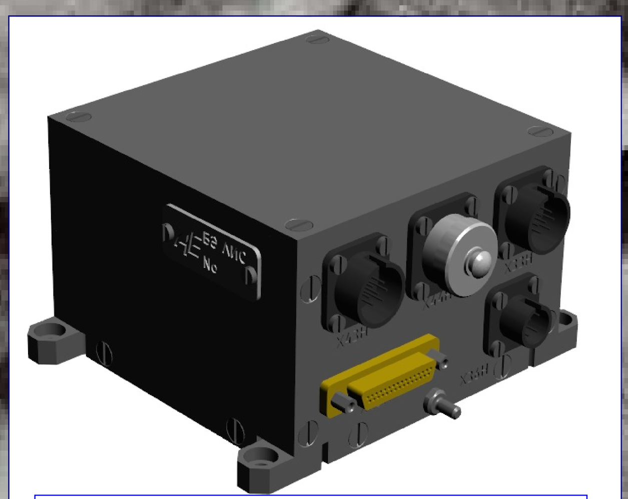


Fig.2 Electronics box of the spectrometer

Operational scenario

- ❑ measurements each time TV camera making shot
- ❑ raster images of interesting objects selected based on previous observations. In this case, each point of raster image will have measured spectra

Principles and key components of the spectrometer

LIS is an AOTF-based spectrometer working in the spectral range of 1.1-3.3 µm with spectral resolution better than 25 cm^{-1}. The field of view of the instrument is 1° (fig. 1-4). The instrument is mounted on the mechanic arm of landing module in the field of view (45°) of stereo TV camera (fig. 5).

The core idea of the design is using of an acousto-optical tunable filter (AOTF), already implemented on Mars and Venus orbit. This approach allows flexible access to any part of selected spectral domain, contains no moving parts, and has compact and low mass design.

❑ AOTF, made by domestic industry, is a crystal of paratellurite (TeO_2), specifically cut and oriented, providing a so-called wide aperture, wide passband configuration of an AOTF device (fig.6). The tuning of the wavelength selection is carried out by appropriate frequency and power of the ultrasound acoustical wave, applied to the AOTF crystal by an integrated piezotransducer. Passband 25 cm^{-1} (FWHM), work range 1150-3400 nm, aperture 4x6 mm, angular aperture ±3°, diffraction angle >6.6°.

❑ Entrance reflective telescope: lens ø17 mm, working F/# 3.6, field of view 1°.

❑ Point InAs detector, 1.1-3.45µm, two stage thermo-electrically cooled, by Hamamatsu.

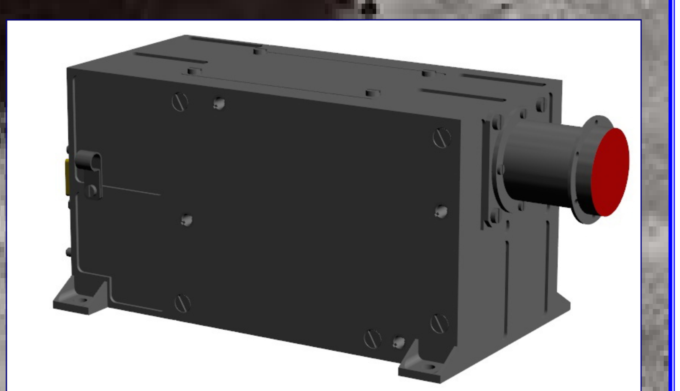


Fig. 3 Optical unit of the spectrometer

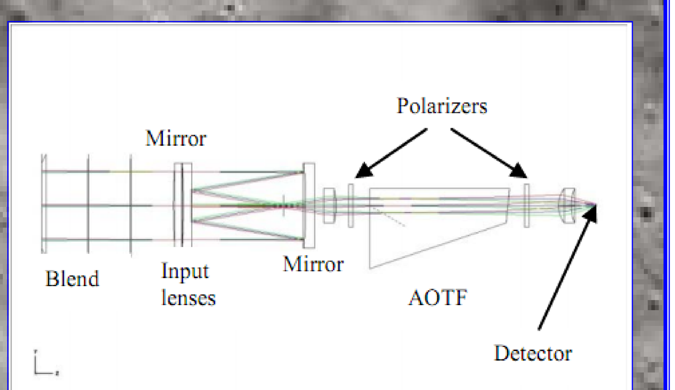


Fig.4 LIS optical layout

Technical characteristics

Spectral range	**1.15-3.3 µm**
Field of view	1°
Spectral resolution	better than 25 cm^{-1} (TBC)
Optical point detector	InAs (Hamamatsu P10090-21), Two stage thermoelectrically cooled. Ø1 mm
ADC	16 bit
Power consumption	10 W
Power supply	28 V
Operating temperatures	From minus 40 to plus 20° C.
Storage temperatures	From minus 60 to plus 60° C.
Output interface	RS-485
Overall dimension	170x65x76 mm (optical box) 84x84x55 mm (electronic box)
Mass	0.9 kg (optical box including cable) 0.4 kg (electronic box)

Stereo TV camera

Resolution, pixels	1024x1024
Field of view	45 °

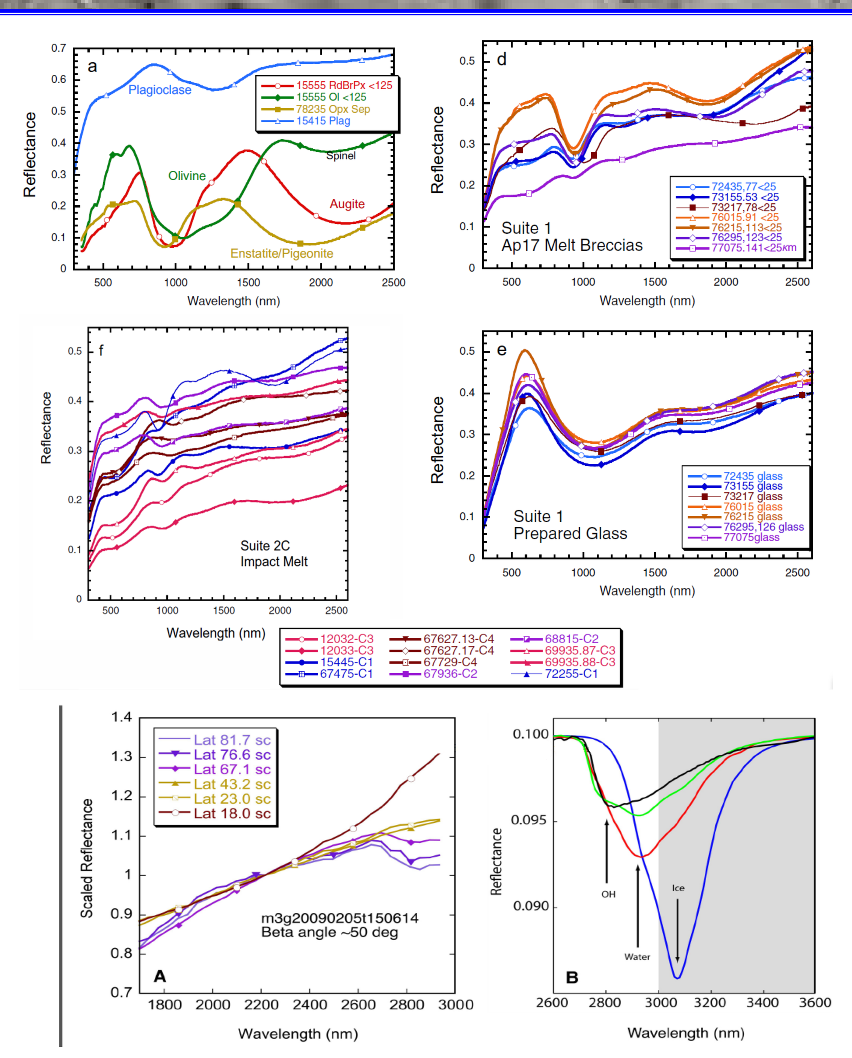
Spectrum measurement cycle

- ❑5000 spectrum points totally
- ❑Up to 8 separately tuned spectrum measurement intervals
- ❑Photocurrent integration time: 1.5 – 32 msec
- ❑Detector and AOTF temperatures monitoring

Background

LIS is designed based on technical solutions of AOTF spectrometers developed by IKI team or with participation of IKI.

In SPICAM IR spectrometer on board of Mars Express mission the technology of an acousto-optic tunable filter (AOTF) has been first applied in planetary research allowing unprecedented mass reduction [6]. SPICAV IR have been successfully working onboard of Venus Express since 2006 [7]. On the International Space Station cosmonauts worked with the RUSALKA AOTF echelle-spectrometer from 2009 to 2012 [8].



Science goals

From Tompkins et al., 2010

Most of lunar spectra demonstrate a prevalence of "dry"materials: plagioclases, olivine, pyroxenes, different kind of glasses and etc [10]

❑ LIS spectral range 1.15-3.3 µm is optimal for H_2O/OH mineral detection.

❑ One of most acceptable band for LIS studies is ~3 µm.

❑ The spectral resolution of LIS (better than 25 cm^{-1}) makes possible to detect H_2O/OH at the uppermost thin layer of Moon.

From Pieters et al., 2009

Status of development

At present the laboratory prototype of the instrument is passing mechanical, thermal and electrical tests. (fig.7) The optical scheme and the AOTF parameters are to be verified, and modified if necessary.

Instrument's group is open for comments, proposals on operational scenario and data treatment.

Instrument was proposed to ExoMars 2018 mission as Infrared Spectrometer for ExoMars (ISEM). It was proposed to install it on the rover's mast.

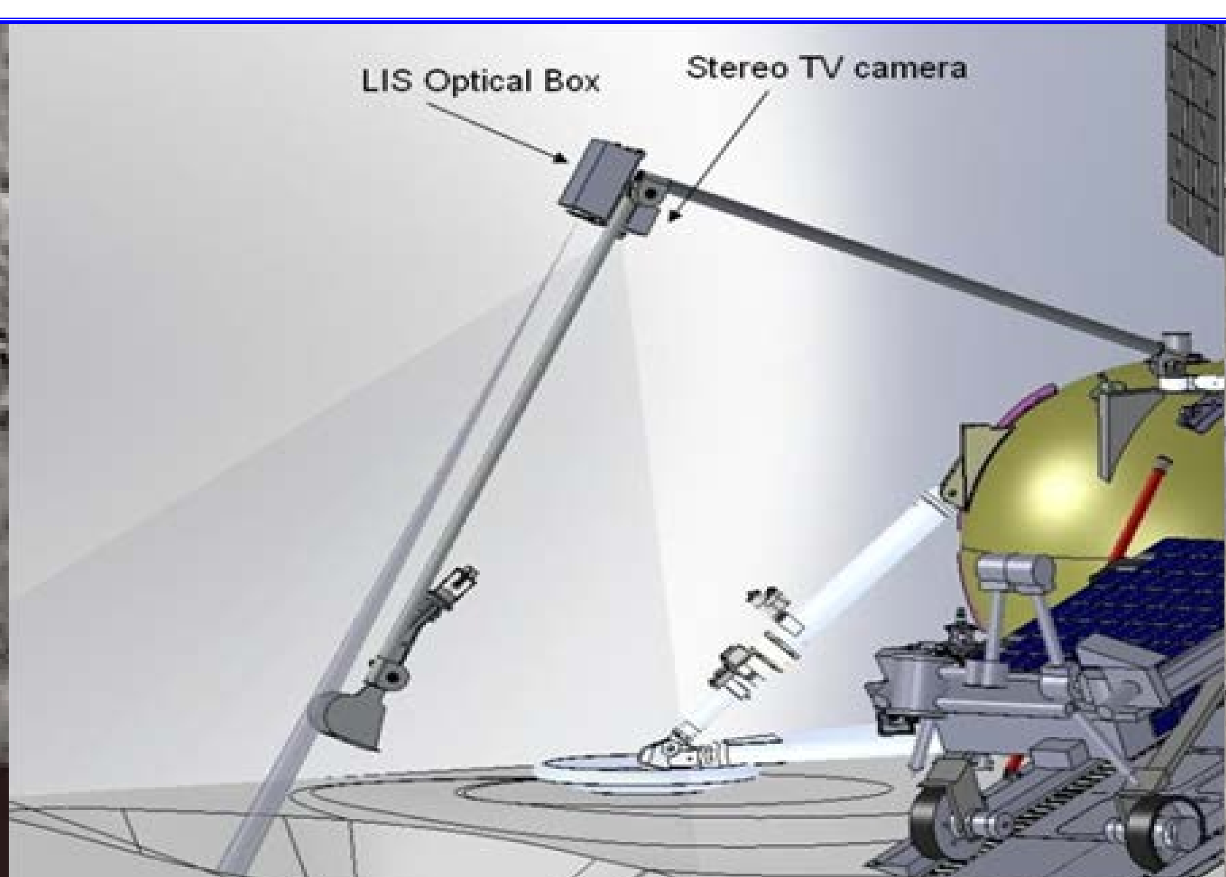


Fig.5 LIS optical box and stereo TV camera mounted on mechanical arm. ©NPO Lavochkin

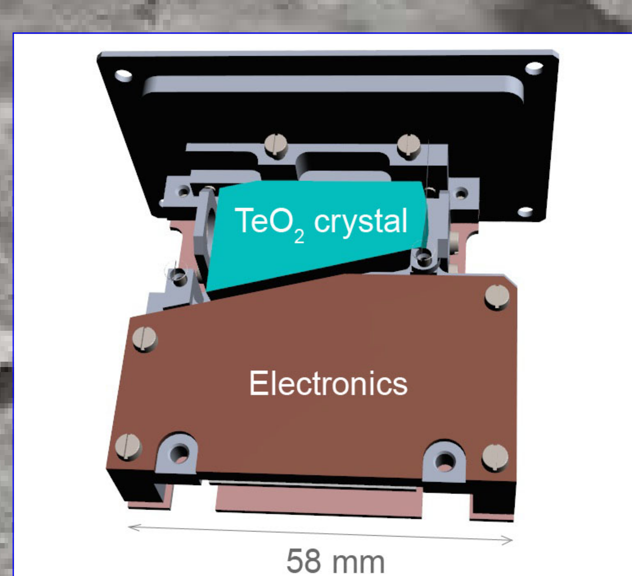


Fig.6 Acousto-optical tunable filter

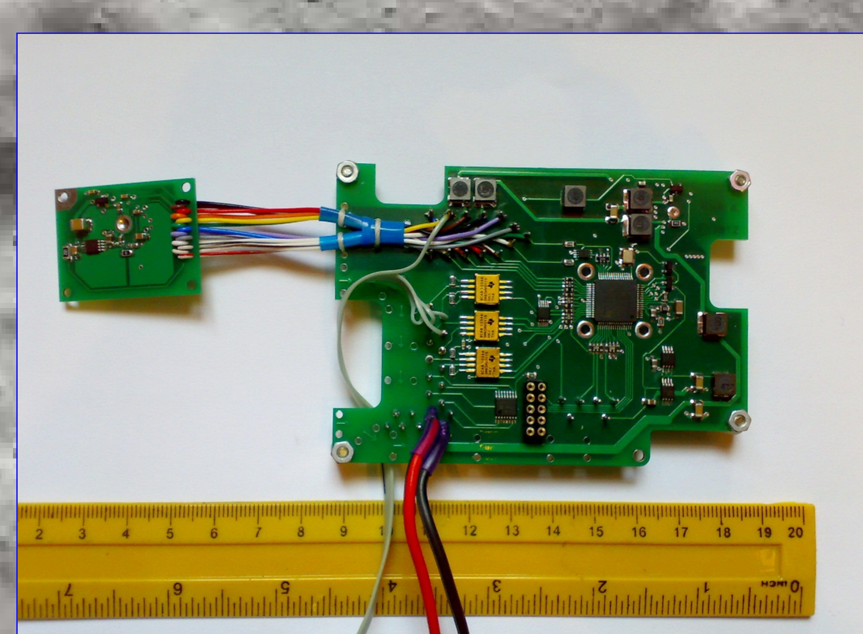


Fig. 7 Laboratory prototype electronics

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