DEVELOPMENT OF A TELESCOPIC IMAGING SPECTROMETER FOR THE MOON.

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Introduction: ALIS (Akita Lunar Imaging Spectrometer) is a telescopic imaging spectrometer which we developed for Space Station Lunar Observatory project. A future purpose of this project is to establish the photometric model of the moon as a spectral radiance standard of space-borne imaging instruments by repeated observation of the moon with VIS/NIR (Visible and Near Infra-red light) from the International Space Station.

McEven [1] derived the visible photmetric functions for the entire moon by utilizing the images taken by SSI onboard Galileo. The improved version was applied to the photometric normalization of lunar images from Clementine UVVIS camera [2]. Robotic Lunar Observatory (ROLO) provides photometric models for 32 bands, including nine SWIR bands, that are position and phase dependent [3]. The primary advantage of ALIS, compared with these previous datasets, lies in the continuous wavelength coverage between 380 and 1700 nm (2400nm in the future).

A ground-based model of ALIS has been developed through a Phase-IA research of "Ground-based Research Announcement for Space Utilization" (PI: K. Saiki) promoted by Japan Space Forum. Within this near-term project, telescopic imaging spectrometers have been developed and examined through ground-based observation of the moon. The study of photometric characteristics of rocks and minerals has been started for getting a better photometric model of the lunar surface.

ALIS Features: ALIS (Fig.1) is generally located at Akita University. There is a plan to move it to a new observing location where we will obtain better observing conditions. ALIS has two spectrometers; Visible (VIS) one and Near Infrared (NIR) one. Each spectrometer is composed of an imaging sensor and a prism-grating-prism unit named “ImSpector” made by Specim corporation. These spectrometers take “1-line spatial resolution” x “wavelength resolution” image as one shot. Line images are assembled by scanning image on a slit of the spectrometer with rotating mirror (Fig.2). The mirror is also used to switch VIS-system and NIR-system. The design drawing of ALIS is shown in Fig.3.

Figure 1. Appearance of ALIS.

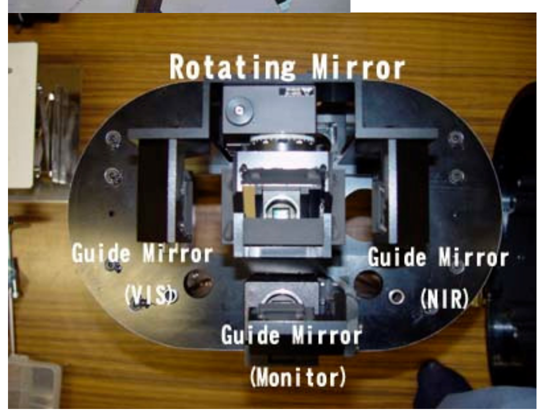


Figure 2. Photo of the interior of ALIS showing scanning and camera-switch system.

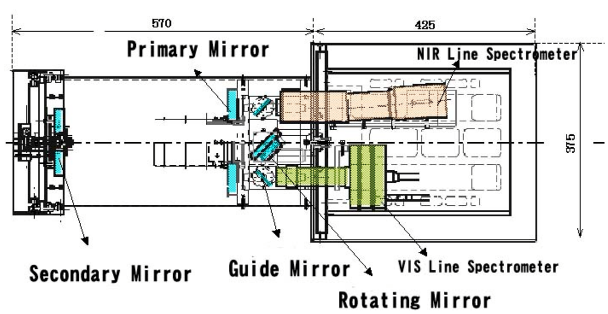


Figure 3. Design drawing of ALIS.

The specification of ALIS is as follows:

Specification of ALIS

Telescope Type:	Cassegrain
Aperture:	200mm
Focal Distance:	800mm
Spectrometer Type:	Prism-Grating-Prism
Image Scanning:	Mirror Rotation System
Spectrometer Range:	VIS: 380-1060nm
	NIR:1000-1700nm
Wavelength Resolution:	5nm (380-1060nm)
	9nm (1000nm-1700nm)
Sensor: VIS: Spectra Video SV512 (Pixel Vision)	
	512 x 512 pixels
NIR: SU320MS-1.7RT(Sensors Unlimited)	
	320 x 256 pixels

Microscopic Imaging Spectrometer Features: The visible imaging spectrometer of ALIS can be mounted on a microscope. For microscopic analysis, a sliding stage is used for scanning in place of rotating mirror. Results using this microscope will be presented at the next opportunity. The specification of our microscopic imaging spectrometer is as follows:

Specification of Microscope Imaging Spectrometer

Microscope:	BX51M-IR1 (Olympus)
Spectrometer Range:	380nm-1060nm
Wavelength Resolution:	5nm
Area:	512pixel x "number of lines (Max:256)"

Spatial resolution:

object lens	x1	x5
Scan direction	46.7µm/pixel	9.35µm/pixel
Line direction	23.4µm/pixel	4.67µm/pixel

Results: Jupiter and its four Galileo satellites were observed to check the performance of ALIS optics. Figure 4 is the monitor image of them. The monitor camera is used for adjusting focus and frames.

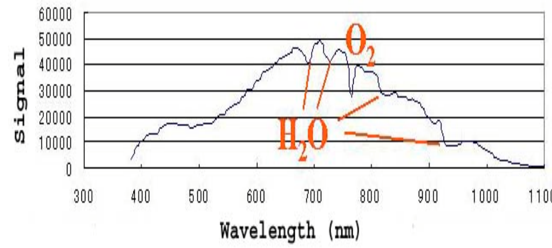
Figure 4. Image of Jupiter and its satellites taken by ALIS monitor camera.

Spatial resolution of ALIS-VIS is 6.188"/pixel and that of ALIS-NIR is 6.435"/pixels. ALIS-VIS is available for spectroscopy of these satellites and other stars by adjusting exposure time. ALIS-NIR has high dark current and it is not suitable for observation of dark stars.

Lunar data taken by ALIS-VIS is shown in Fig.5 and Fig.6. All pixels on the lunar image has spectral data such as figure 6. Prominent absorption bands are owing to H_2O and O_2 molecule in the air. Spectral analysis using ALIS-VIS data is presented at this conference [4].

Figure 5. Lunar image generated from 450nm intensity of ALIS data.

Figure 6. Raw spectrum of the center of Tycho.



Future Plans for the Radiometric Calibration: Even by the ground-based observation, ALIS will enable us to study the photmetric properties of the lunar surface after we complete the absolute radiometic calibration. Absolute spectra and their phase-angle dependence will be essential for investigations of the surface particulate structure and composition of the lunar soil. Furthermore, we plan to employ the ALIS data for the photometric normalization of Multi-band Imager and Spectral Profiler [5] onboard SELENE. Absolute radiometric calibration of ALIS will be conducted in two ways. One is the standard astronomical photometry of bright stars with well-known absolute irradiance, such as Vega. The effect of telluric extinctions can be accurately corrected, except for strong absorption of H_2O and O_2 (Fig.6), with several observations at the different air mass in a photometric night. Another method relies on the measurement with a 1-meter integrating sphere just before and/or after the lunar observations. This integrating sphere is routinely calibrated to the fixed-point blackbody sources at JAXA. ALIS can be set in front of the aperture owing to the portability. This method will give better results in the near-infrared wavelengths because the absolute radiance of the integration sphere is more accurate than the flux of standard stars [6].

References: [1] McEwen, A.S. (1996) *LPSXXVII,* 841-842. [2] McEwen, A.S. *et al.* (1998) *LPSXXIX,* 1466-1467. [3] Stone, T.C. and Kieffer, H.H. (2002) *Proc. SPIE,* 4814, 211-221. [4] Hirata, N. *et al.* (2004) *LPSXXXV*, this issue. [5] Matsunaga, T. *et al* .(2000) *Proc. SPIE*, 4151, 32-39. [6] Megessier, C. (1995) *Astronomy and Astrophysics*, 296, 771.