

FOURIER-SPECTROMETER “AOST” FOR MARS AND PHOBOS INVESTIGATION IN “PHOBOS-SOIL” MISSION. A. V. Grigoriev¹, O. I. Korablev¹, F. Montmessin², B. E. Moshkin¹, D. V. Patsaev¹, V. S. Makarov¹, S. V. Maksimenko¹, G. Arnold³, L. V. Zasova¹, K. V. Grechnev¹, A. V. Shakun¹, A. A. Fedorova¹, A. I. Terentiev¹, A. P. Ekonomov¹, B. S. Mayorov¹, E. Palomba⁴, Yu. V. Nikolskiy¹, I. A. Maslov¹, R. O. Kuzmin¹ and G. Bellucci⁴. ¹Space Research Institute / RAS, 84/32 Profsoyuznaya str, 117997, Moscow, Russia. grim@im.iki.rssi.ru ²Service d'Aeronomie du CNRS / IPSL, Route des Gatines - BP 3, 91371 Verrieres Le Buisson, France. franck.montmessin@aero.jussieu.fr ³Institut fuer Planetologie / WWU, Wilhelm-Klemm-Str. 10, 48149, Muenster, Germany. gabriele.arnold@dlr.de ⁴Istituto di Fisica dello Spazio Interplanetario / INAF, Via del Fosso del Cavaliere, 100, 00133, Rome, Italy. ernesto.palomba@ifsi.rm.cnr.it

Introduction: The goal of “AOST” experiment is to investigate Mars and Phobos by means of IR remote sensing. The spectrometer operates while orbiting Mars and after landing to Phobos.

The spectral range is 2.5 – 25 micron, best spectral resolution – 0.6 cm⁻¹ (without apodization), field of view – 2.3 deg. AOST has its own two-axis pointing system and can measure direct Sun light. One interferogram acquisition varies from 5 to 50 sec.

For nadir observations of Mars from so-called “Observation Orbit” (535 km above Phobos orbit) the diameter of FOV footprint is 250 km.

For observations of Phobos from so-called “Quasi-Synchronous Orbit” (“QSO”, distance to Phobos is about 50 km) the same parameter is about 2 km.

Smearing (blurring) due to orbital movement is always less than 10% of the FOV.

An overview of AOST mounted to the spacecraft is shown in Fig. 1.

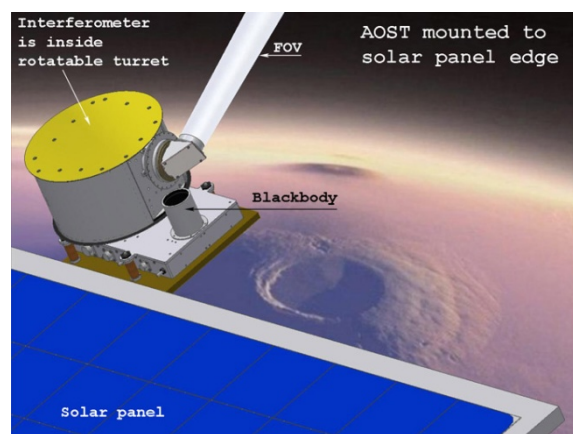


Fig.1. AOST is located at the far edge of the spacecraft solar panel. The MLI is not shown. The Sun illuminates solar panel and the heating-radiator of AOST.

Scientific objectives: AOST will study Martian atmosphere, Martian surface and Phobos surface. All these objects will be observed directly, from different orbits. For the atmosphere also “Sun occultation” methodic will be used. Phobos surface, in addition, will be observed after landing.

AOST scientific objectives include:

- By “Sun occultation” methodic:

- Methane and formaldehyde detection. For CH₄ band at 3018 cm⁻¹ the detection limit is about 1 ppb
- Getting information about vertical distribution of aerosols
- Direct observations of Mars will allow to:
 - measure diurnal and seasonal variations of the following atmosphere parameters:
 - ✓ temperature profile up to height about 60 km
 - ✓ abundance of water vapor and other minor constituents
 - ✓ abundance of aerosols
 - ✓ non-LTE atmospheric emissions
 - study spatial distribution of different minerals
 - discriminate surface regions with chemically bound and adsorbed water
 - diurnal (incl. surface frosts) and seasonal variations
- Direct observations of Phobos will allow to:
 - Make global mineralogical mapping (from QSO)
 - Search for surface variations at centimeter scale (after landing)
 - Determine thermal parameters of Phobos regolith.

Some parameters of different observation modes are shown in the table.

Observation mode	Spectral resolution	Angular resolution	Interferogram duration
Sun occultation	0.6 cm ⁻¹	Sun' disk (0.35 deg)	5 sec
Atmosphere	1.2 cm ⁻¹	2.3 deg	50 sec
Soil	6 cm ⁻¹	2.3 deg	50 sec

Technical details: AOST is a Fourier-spectrometer based on “double-pendulum” type interferometer with 1-inch retroreflectors. The beamsplitter/compensator pair is made of KBr. IR radiation comes through the Instrument inlet, passes the interferometer and enters Cassegrain-type telescope. The latter collects energy to the active area of special pyro-electric detector. The field lens is made of KRS-5. A special additional filter in front of detector blocks radiation with wavelengths less than 2.5 micron.

The reference channel implements DFB laser diode (which emits at 1.35 micron) and two InGaAs

photodiodes. The exact value of reference wavelength provides that methane band (3018 cm^{-1}) is not contaminated by aliasing of other gases bands.

The two-sided interferogram is packed to save data volume and is transmitted to Earth for processing.

The Instrument consists of two big parts, connected to each other: so-called “Turret” and so-called “Base”. The latter is mounted to the spacecraft structure. The Turret is able to rotate with respect to Base by some 200 deg. The additional flat mirror at the Turret inlet can rotate by 360 deg. So, AOST can cover the full sphere, be pointed to any direction, including the built-in blackbody (a part of the Base) for in-flight calibration.

The Turret houses the interferometer and a part of electronics, based on Actel FPGA. A special flexible cable connects the Turret and the Base. The latter has the second FPGA, of the same type, with the same processor implemented. Both processors (the Turret one and the Base one) can communicate with each other. The Base electronics also includes 2-megabyte mass-memory and MIL-STD-1553 controller for communication with spacecraft systems.

AOST is mounted to the far edge of spacecraft solar panel through special thermo-vibro-insulating stubs. The Instrument is thermally separated from the spacecraft and itself, automatically provides the desirable thermal regime. AOST is covered with its own MLI, except two radiators: one for acquiring solar heat, the other for cooling, if needed. The active area of the cooling radiator may be automatically adjusted in flight.

All details of AOST construction themselves strongly emit IR radiation in the working spectral range ($2.5 - 25\text{ micron}$). To kill this emission completely the whole Instrument must be cooled to liquid helium temperatures, which is absolutely impossible in a mission to Mars. Instead, the temperature of AOST interferometer must be stabilized during measurements with accuracy 0.1 K or better. The exact temperature value is not very important, it just must be known and be stable during measurements. That is why the interferometer is thermally separated (as much as possible) from other Turret details. This results in huge thermal inertia of the interferometer subsystem and provides almost constant temperature during measurements.

AOST mass is 4 kg, power consumption – 10 W.

Detecting methane: During one Sun occultation (sunset) AOST will acquire about 20 spectra. The first one will be taken when Sun projection is well outside the atmosphere, it will be

the reference spectrum. The closer Sun comes to the limb – the bigger path light goes inside the atmosphere. Spectral bands associated with atmosphere gases will show progressive deepening from spectrum to spectrum.

This method is self-calibrated: dividing by the first (reference) spectrum excludes contribution of those bands which are present in the spectrum of the Sun itself. The latter bands will not show the said deepening. AOST observes the whole Sun disk, so variations of Sun spectrum along its disk are not important.

Fig. 2 shows results of computer simulation of expected spectra for region around main CH_4 band. Boresight to the center of the setting Sun disk passes in 10 km from limb. Methane abundance is 10 ppb, spectral resolution with apodization – 0.9 cm^{-1} . The methane band 3018 cm^{-1} is not contaminated with bands of other gases, including water vapor. For the specified conditions this band is only 4% deep, but the expected signal/noise ratio for this mode is much more than 100 even for one interferogram. Averaging will decrease the detection limit to 1 ppb or even less: we'll have several hundred of sunset/sunrise events before landing to Phobos and AOST can work during every event.

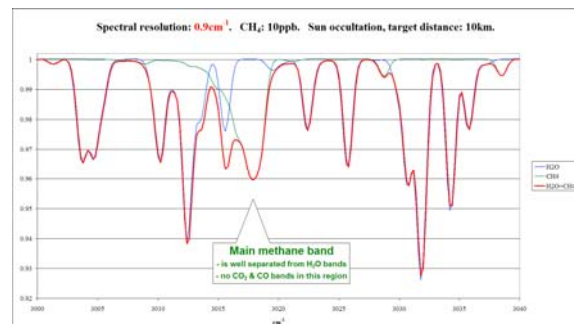


Fig. 2. Computed spectra of sunlight passed through martian atmosphere with 10 ppb of methane. The distance limb – boresight is 10 km. Spectral resolution with apodization is 0.9 cm^{-1} . Blue line – water vapor, green – methane, red – their sum.

In March 2008 AOST engineering model has passed all the required tests and was integrated with the spacecraft. The qualification model is being manufactured.

The set of AOST parameters is really unique (for a just 4-kg instrument!) and its modifications would be effectively used in future missions to Venus, Jupiter and other objects.