PROJECT Phobos-Grunt Past end future OF LASER TOF MASS-REFLECTRON LASMA

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In 1970 year the Active Experiments in magnetosphere of Earth were started.

In 1975 this type of experiments were continued for study of small body Solar system.

On this stage of activity the new tape of instruments were required.
The important information about past end evolution of space body's must be contenting in the «stone record» or in the substance of this objects.

Multifactor analysis of different instruments sown, the most optimal device for this task is laser ionization TOF mass-spectrometer with reflector.
Such type of instrument:
- doesn’t require complex sample preparation,
- can simultaneously detect all elements from H to U with equal-probable yields,
- configuration allows to make layer by layer analysis of the sample surface in depth of 1 mm without refocusing of the objective,
- allows to move the laser spot on the surface at the diameter of 6 mm,
- less than $10^{-4}$ sec is required to register a spectrum.
The plasma torch generated under the influence of the laser radiation.
Influence of the laser (A), operating in a Q-switch mode. Laser beam, focused on the target in a spot with diameter $d=2r_0$ with power density of $W>10^9$ W/sm$^2$, forms hot kernel (2) occupying a zone I (Bykovsky and Nevolin, 1985). At the adiabatic scattering of hot dense plasma as well as in case of impact influence, is formed plasma torch with zones II and III. Processes of torch formation by impact and laser influences are similar. Unlike impact, during laser influence the process of crater formation is weaker in several hundreds times.
In the frame of Phobos project a new ideology was proposed and unique on-board instruments LIMA-D and DION were created, capable to define volume chemical and fine surface composition of the regolith by TOF mass spectrometry and secondary ions registration techniques, from the board of flying apparatus at the distance of up to 100 m.
The scheme of the LIMA–D experiment – laser probing of the Phobos surface:

1–laser for the ion source;
2–focusing objective;
3–range finder;
4–servometer;
5–reflectron with the ion detector;
6–unit of data processing;
7–control unit.
Scientific ideology of new generation instrument – foil TOF MR for the measurements of the heavy component of Solar wind ions was proposed. With the use of this instrument, known in scientific literature as MTOF, an isotopic composition of Fe and other heavy ions was measured for the first time.

The instrument successfully worked on SOHO, ACE and WIND space apparatuses and have patents in Russia, USA, France, Germany and Austria.
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A scheme of the laser TOF MS:
1—vacuum chamber,
2—interchangeable carriage with sample,
3—detector,
4—TV camera,
5—reflector,
6—laser,
7—focusing lenses,
8—neutral filter,
9—radiation power meter,
10—target illuminator,
11—microscope,
12—motorized vacuum valve,
13—carriage adjusting system,
14—monitor.
Instrument is designed for the analysis of elemental and isotope compositions of space body’s regolites. It is completely axial symmetry mass reflectron created in Space Research Institute RAS. For operation on Mars surface a vacuum pumping and sample loading systems are required.
Laser source with a focusing system concentrates energy into spot diameter of 50 microns on the target surface and makes one shot in 1–10 sec. Ions emitted as a result of Q-switch laser irradiation are reflected in the field of the electrostatic reflector and directed to the detector where they form narrow mass peaks. The amount of ions in mass peaks is proportional to the concentration of ionized materials in a sample. High reproducibility of data is provided through axis symmetrical configuration.
Main analytical characteristics of the instrument

- Mass range: from 1 to 250 a.m.u.
- Mass resolution: nominal 200, maximum 600
- Relative sensitivity in weight % depending on matrix and element weights changes in the limits:
  - In one shot (for 10 - 200 a.m.u.) (50-1000) x10^{-7} %
  - In mode of spectra accumulation (3 min.) (2-50) x 10^{-7} %
- Absolute sensitivity: 5x10^{-16} - 10^{-14} g.
- Instrumental error: 1%
- Accuracy of isotope ratio detection (Ag and Cu): 1%
- Spectra replication: 95%
- Dimension of analytical part of the instrument with components, represented in the scheme: 200x100x50mm
- Weigh: ~2.5 kg
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<td>Definition of type, class, group and subgroup of Phobos regolith substance within the</td>
<td>Mass spectrometric (MS) measurements of ratios of basic elements that are a part of regolith composition: C, O, Mg, Al, Si, Ca, Fe. This data allows to</td>
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<td>limits of the common classification of the meteorites.</td>
<td>conduct classification of the substance.</td>
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<td>2</td>
<td>Definition of mineralogical structure of the regolith substance averaged along the</td>
<td>Conducting of standard less quantitative analysis of basic elements composition. Spectra are compared to spectra of the minerals from the library of</td>
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<td>spectra.</td>
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<td>3</td>
<td>Researches of A, B, C class anomalies of stable isotopes.</td>
<td>Measurements of isotope composition of regolith matrix elements after their averaging allow to define the anomalies of stable isotopes exceeding ~1 %</td>
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<td>Researches of the local superficial and volume heterogeneities of the regolith,</td>
<td>Fine movement of a beam, with step of ~100–200 microns along the surface and of ~1–3 a micron in the depth of regolith will allow to reveal these</td>
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<td>definition of their characteristic sizes.</td>
<td>heterogeneities. It is important that the device configuration allows carrying out the lay–by–lay analysis without restriction of depth.</td>
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<td>5</td>
<td>Definition of agglomeration temperature.</td>
<td>Direct quantitative MS measurements of Pb, Bi, Tl, Zn, and Cd micro-impurities sizes will allow to define this value.</td>
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<td>Quantitative measurements of bound H₂O presence and its volume distribution.</td>
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<td>Searches for surplus of the carbon in thin surface regolith layer providing abnormally</td>
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<td>low albedo of Phobos.</td>
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<td>8</td>
<td>Researches of the unstable isotopes formed under the influence of space radiation.</td>
<td>MS measurements of small components; the mass resolution allows to fix these isotopes and to conduct a quantitative estimation of their concentrations.</td>
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37. SATELLITES OF MARS: GEOLOGIC HISTORY

![Graph showing Geometric Albedo vs. Wavelength for Phobos and Deimos.](image)

- ▲ Mariner 9 Spectrometry
- ◇ Mariner 9 Star Tracker
- ○ Viking Lander Imaging
- ○ Ground-based Polarimetry
- ■ Ground-based Colorimetry

Wavelength, nm

Geometric Albedo
Solar radiation influence

UV-radiation

$\phi \sim +6 \text{ V}$

secondary electrons

$E \sim 5-6 \text{ eV.}$
Solar wind influence

$H^+ \quad E \approx 1 \text{ keV}$

$C^- \quad E \approx 5 \text{ eV.}$

$\varphi \approx +6 \text{V}$
Typical spectrum obtained in control measurement of the sample with unknown composition and origin. Processing of spectra allowed to make a correct conclusion that the sample has meteoritic origin and represents coal chondritis C3.
Laser source provides pulse energy of 15mJ at the impact time up to 5-7 ns and normally operates at -50 - +50°C temperature range. Total weight of the power supply is 150g.
Compact high-sensitive on-board time-of-flight (TOF) mass reflectrons (MR) are developed for the measurements of ion composition of the laser plasma. TOF MRs are included in scientific equipment of Phobos-Grunt project.

Model of laser TOF MR LASMA for Phobos-Grunt project
Laser mass spectrometer LASMA designed for analytical tasks in the field of ecology, metallurgy, geology and medicine
Tentative draft of measuring MS complex with the sample processing system

1. Container for the ice sample melting, with ultra-sonic generator
2. Filter for the extraction of biomass from the ice sample
3. Rotating sample unit
4. Laser TOF MS
5. Evaporator
6. Gas TOF MS
7. Electron gun
8. Window for the external ions
Preliminary experiments with yeast sample on the TOF MS LASMA

Mass spectrum of yeast sample obtain at single laser shot.
Percent concentration of matrix elements in the yeast sample. Black: experimental data; red: averaged concentration according to reference data.
The presented material demonstrate that the LASMA device is the instrument of the new generation, intended not only for the decision of actual problems of a modern science.

It also is very perspective instrument for space researches in the future.