

A MINIATURE MASS SPECTROMETER MODULE. J. A. Whitby¹, U. Rohner¹, R. Schultz², J. Romstedt² and P. Wurz¹, ¹Physikalisches Institut, Universität Bern, Sidlerstrasse 5, CH-3012 Bern Switzerland. ²ESA/ESTEC, Science Payload and Advanced Concepts Office, Noordwijk, The Netherlands. email: James.Whitby@phim.unibe.ch.

Introduction: We describe here the most recent version of our miniature mass analyzer [1,2], suitable for deployment on board a planetary rover with very limited resources. Although we call the instrument LMS (Laser Mass Spectrometer) and have designed and tested it with a laser ablation ion source for the analysis of solids, the mass analyzer is a versatile instrument that could be used with other ion-sources, and for the measurement of fluids as well as solids. We will describe the potential use of such a miniature mass spectrometer in conjunction with chemically selective separation techniques such as gas-chromatography. Similar approaches have been proposed elsewhere [3].

The original version of the instrument, LMS 1.0, was intended for deployment on a stationary lander and was a simple time-of-flight mass analyzer using a linear reflectron with a total design mass of 0.5 kg. Subsequent versions have been intended for deployment as part of a suite of geochemical instruments either on a mobile rover or by a robotic arm. The instrument described here, LMS 3.2, is a 'flight-like' prototype intended to demonstrate 'proof-of-principle' and to allow us to experiment with various laser sources and to begin a calibration program. By 'flight-like' we mean that the mass, volume and power requirements of all components are compliant with foreseen requirements (e.g. for the Geochemical Instrumentation Package Facility under study by the European Space Agency), but that they have not necessarily been flight-qualified.

Instrument: Our current instrument (LMS 3.2) has a design mass (including electronics and laser-ablation ion source) of 0.28 kg, and will fit into a volume $7 \times 4 \times 3$ cm³ and operate on a power of just 3 W. Increasing prototype version numbers reflect increasing integration of 'flight-like' electronics, and improved optical designs for the ablation laser system.

Ions are produced using a passively Q-switched diode pumped microchip laser (from Northrop Grumman Space Technology - Synoptics) focused to a ~ 10 μ m spot on the target using two lens elements. The irradiance of the sub-nanosecond laser pulse on the surface is in excess of 10^9 W cm⁻², sufficient to create and heat a plasma above the surface. Positive ions from the rapidly expanding plasma are introduced through an aperture into the time-of-flight mass analyzer, which incorporates an electrostatic analyzer and a reflectron in

order to obtain sufficient mass-resolution and transmission. (Laser ablation typically results in a spread of ion-velocities greater than that from an electron impact ion source).

The detector is a small microchannel plate with a fast rise-time which has been used in an analogue mode but would also be suitable for pulse counting. The mass spectrometer system can be operated either with laboratory power supplies *ex vacuo* or purpose built miniature assemblies on printed circuit boards with the same footprint as the mass analyzer shown in Fig. 1. Although we have performed some design studies, we do not yet have a functional prototype for an suitable analogue-digital converter and buffer for signal acquisition. In the laboratory we make use of either a fast digital oscilloscope (20 Gs/s but limited trigger rate) or a plug-in card (only 2 Gs/s but can trigger at the 7 kHz free-running repetition rate of the laser) as appropriate.

Mass resolution (using laboratory electronics) is better than $m/\Delta m = 180$ (FWHM) and we expect to obtain a dynamic range of between five and six orders of magnitude by summing many spectra together.

Applications: The instrument was originally designed in the context of the Mercury Surface Element that was to have been part of the European BepiColombo mission to Mercury. The focus of the design was upon using geochemical measurements of elemental composition to infer the mineralogy of regolith samples or rocks. The use of a laser ablation ion source allows a high spatial resolution, comparable to the regolith grain size expected on Mercury, and a degree of depth-profiling, allowing compensation for the micro-impact produced glassy surfaces expected on grains with long regolith residence times. A knowledge of the chemical and mineralogical composition of Mercury's surface, together with models of crustal formation, would allow inferences to be made about both planetary accretion/formation and subsequent evolution. These quantities are of great interest on many other bodies, and we believe that LMS could be used with very little modification on other bodies with a negligible atmosphere. (Use on e.g. Mars would require some sort of vacuum pump).

The ability of the mass spectrometer to measure isotopes opens up the possibility of obtaining information about the timing and extent of events such as

planetary differentiation or crust formation. Unfortunately, most of the geochemically interesting systems either require very high precision (and mass resolution) or sensitivity, although we are studying some candidate systems where the elements concerned might be expected to be enriched in some mineral hosts.

Molecular species: The miniature mass analyzer could also be used as a detector in conjunction with chemically selective sample preparation (pyrolysis, gas chromatography) to measure molecular species. With an appropriate ion-source, for example carbon isotopes in CO₂ gas (perhaps from pyrolysis of martian soils) could be measured. A time-of-flight mass analyzer has no intrinsic high mass cut-off, and so more complex molecules such as poly-cyclic aromatic hydrocarbons could be detected given suitable ionization techniques. We are exploring the use of LMS as a detector with both gas chromatographic and gas-phase ion mobility separation systems. The use of a miniature robust mass spectrometer together with a robust chemically selective interface such as those used in Membrane Inlet Mass Spectrometry might allow the deployment of LMS in a planetary atmosphere or ocean (e.g. inside a drill string penetrating an ice covered sea).

References: [1] Rohner U., Whitby J. A. and Wurz P. (2003) *Meas. Sci. Tech.*, 14 , 2159–2164. [2] Rohner U., Whitby J. A., Wurz P. and Barabash S. *submitted to Rev. Sci. Instrum.* [3] Badman E. R. and Cooks R. G. (2000) *J. Mass. Spectrom.*, 35, 659-671.

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