A HIGHLY MINIATURISED LASER ABLATION TIME–OF–FLIGHT MASS SPECTROMETER FOR PLANETARY EXPLORATION. Peter Wurz, Urs Rohner, and James A. Whitby, Physics Institute, University of Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland (email: peter.wurz@phim.unibe.ch).

Introduction: We report the development and testing of two highly miniaturised mass spectrometers intended to be deployed on an airless planetary surface to measure the elemental and isotopic composition of solids. We designed and built two instruments, a larger unit for use on a fixed landing spacecraft and a smaller unit intended for use in a small mobile platform roving on a planetary surface. Both instruments were designed and built with the intention for implementation in the Mercury Surface Element (MSE) of the proposed BepiColombo mission to the planet Mercury [1], either in the landing spacecraft itself or on the rover. Both mass spectrometers are time-of-flight instruments using ion mirrors to increase the ion path length and increase the mass resolution by time-focussing.

Laser Ion Source: The ion sources for these mass spectrometers utilise in both cases a laser induced plasma, which is directly coupled into the mass analyser. When using a time-of-flight spectrometer the use of a pulsed laser is obvious and we histogram many individual spectra to obtain a mass spectrum with high dynamic range. For example, by accumulating 10'000 spectra (which can be done in about 1 s with our system) a mass spectrum with a dynamic range exceeding six decades can be obtained in principle, and at least five decades in an real instrument. Laser ablation gives high spatial resolution and potentially depth resolution [2], and avoids the need for sample preparation [3]. Laser ablation and ionisation is a common method in the laboratory for mass spectroscopic analysis of surfaces [4]. Once a critical power density of approximately 10^9 W/cm^2 is exceeded during the laser pulse the ionisation of released surface material is more or less independent of the element, i.e., minimal inter-element fractionation in the ionisation process occurs [4, 5]. We use a commercial passively Q-switched Nd:YAG laser system, either with the fundamental wavelength of 1064 nm or the second harmonic at 532 nm. Once available, we will test operation with the higher harmonic wavelengths as well before we decide what to use in the flight application. Of course, with a suitable laser system our mass spectrometers can be operated as laser desorption instruments for chemical analysis of the surface and possibly even as MALDI system given that the sample preparation can be realised with robotic means.

Lander Instrument: The instrument for the landing spacecraft is a simple time-of-flight instrument using a grid-less reflectron as ion mirror. The ions removed from the target surface are accelerated into the mass spectrometer through a small hole and focussed through a narrow tunnel in the centre of the detector toward the reflectron. The ions pass the time-of-flight tube and are reflected by the ion mirror back onto the MCP detector. Mass resolution is typically $m/\Delta m$ = 600 FWHM. The resolution can be adjusted ion-optically; a higher mass resolution can be set at the expense of ion-optical transmission and vice-versa. The total dimension of the instrument, as displayed in Figure 1, is 120 mm x Ø60 mm. The flight instrument will be somewhat taller since the laser electronics will be accommodated in a compartment above the ion mirror. The anticipated weight of the flight unit would be about 500 g including all electronics [6].

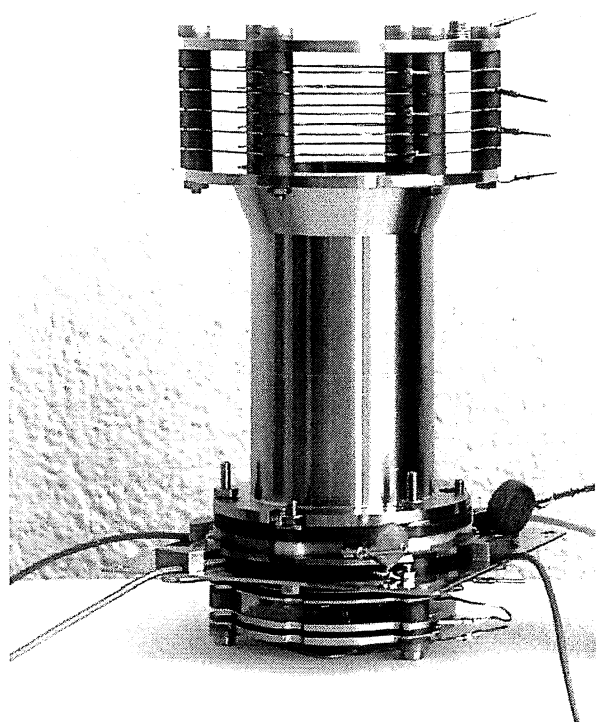

Figure 1: LMS Prototype for the landing spacecraft [6]: Topmost is the reflectron built from a set of potential rings, in the centre is the actual flight tube with the MCP detector below; further down are the ion optical elements for collecting and focussing the ions removed from the investigated surface.

Rover Instrument: The instrument for the rover is also of the time-of-flight type, but using a novel combination of an electrostatic analyser and grid-less reflectron [7]. The time-of-flight path is folded two times to make it sufficiently long for decent mass analysis. The prototype instrument, as shown in Figure 2, has a demonstrated mass resolution $m/\Delta m$ in excess of 180 (FWHM) and a predicted dynamic range of better than five orders of magnitude. The ion-optical system itself has a mass resolution of 400, as seen from single shot spectra, which is in good agreement with the ion-optical design. As with all time-of-flight instruments, covering a large mass range is not a problem here and elements from hydrogen up uranium have been detected with this instrument. When aiming for the detection chemical compounds of higher mass we have to improve the mass resolution during routine operations to the single-shot value, which is about the theoretical limit of an instrument of that size. We estimate that a flight instrument would have a mass of 280 g (including laser and all electronics) and a total volume of $7 \times 4 \times 3$ cm^3 including all electronics. For full operation only 3 W power will be needed making use of local energy storage to accommodate the short-term power needs of the laser system.

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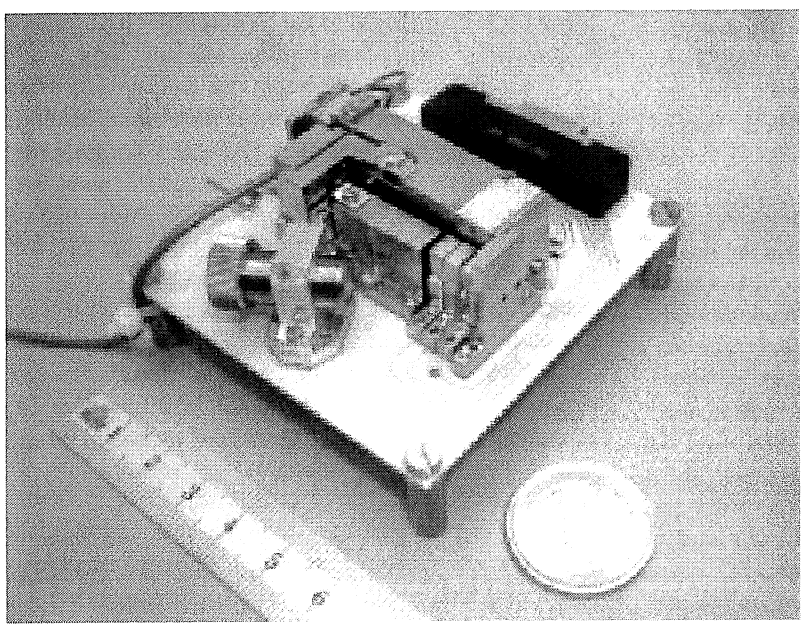

Figure 2: LMS prototype for the planetary rover [7]. In the foreground is the lens holder for focusing the laser radiation onto the sample. The sample will be placed in front of the spectrometer, at the small hole. The ruler is in cm.