LMS INSTRUMENT: PRESENT STATE AND PERSPECTIVES FOR ELEMENT AND ISOTOPE ANALYSIS PLANETARY MATERIALS M. Tulej[1], A. Riedo[1], M. Neuland[1] and P. Wurz[1], [1]Physics Institute, Space Research and Planetary Sciences, Sidlerstrasse 5, 3012 Bern, Switzerland;
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Introduction: Laser ablation/ionisation mass spectrometry (LIMS) is important analytical technique for the quantitative and sensitive measurements of chemical composition of solid materials. Miniaturisation of the LIMS instrument was accomplished more than one decade ago [1]. With the progress in laser technology, electronics and material sciences current LIMS systems show increasingly high sensitivity, the quantitative performance and can be easy coupled with other instrumention for conducting complementary investigations.

We will demonstrate current performance figures of a miniature laser ablation/ionisation mass analyser (LMS) which was developed initially in Bern a lander on the BepiColombo mission to Mercury [2]. Current LMS supports increasingly high dynamic range (10^8) and sensitivity for the detection of all elements (isotopes) with the concentrations down to ppb level. The instrument also can be applied for investigation of organic molecules (laser desorption mode) which can be deposited in the solid material surfaces. Mass resolution of up to m/Δm=800 (at ^{56}Fe) and 1500 are achieved at laser ablation and laser desoption modes, respectively). Current performance figures are similar to typical instruments used in the analytical laboratories.

Performance features of the LMS: Figure 1 displays the mass spectrometer body. In current application a fs-laser system based on a fiber technology is applied [3, 4] and is proved to be essential for conducting standard-free quantitative compositional analysis [4]. A measurement procedure for accurate and precise element and isotope analysis is developed and allows highly sensitive and quantitative element and isotope analysis [3]. The frequently applied in the laser ablation/ionisation mass spectrometry relative sensitivity factors become close to one [4] and the accuracy and precision of the determination of isotope ratio is the function of the isotope concentration (see Fig. 2). The isotope compositional studies illustrate the capabilities of LMS for in situ dating and analysis of isotope anomalies with relevance to bio-relevant processes. The elemental analysis forms the basis for the investigation of modal mineralogy and details of formation processes by analysis of main and trace elements respectively. The quantitative isotope analysis is silent feature of the LMS instrument. The accuracy of the isotope analysis is sufficiently high to measure isotope fractionation effects (Fig. 2). In particular, the light element isotope fractionation effects (C, S, O) can be useful for investigations of bio-markers and the measuremnts of Pb isotope composition – for determination of crystalisation ages, respectively.

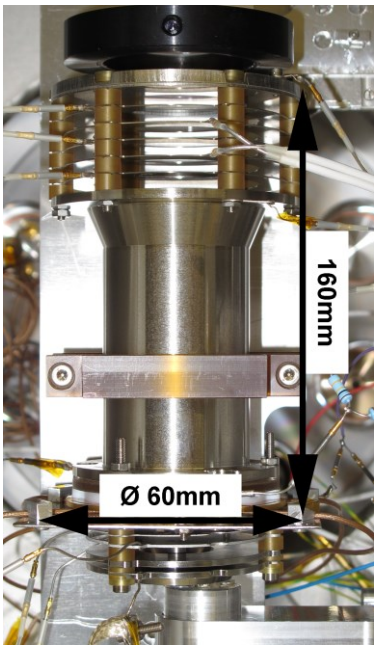

Fig 1 – LMS instrument body.

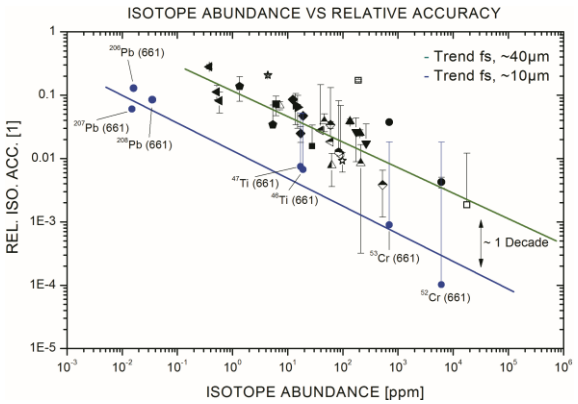

Fig 2 – The accuracy of isotope composition measurements as the function of the isotope concentration. Due to increase of the instrumental sensitivity, the current accuracy is increased in comparison to that determined previously [2].

We will discuss capabilities of the system for delivering the chemical imaging and vertical profiling analysis of the solid surfaces. This analyses can be per-

formed in situ planetary surface and yield contex information of grain-sized planetary samples. The introduction to the design of the instrument with to imaging/profiling capabilities is given in the next section.

CAMAM suite: Figure 3 shows displays a details of the CAMAM instrument suite. A compact instrument design was prepared for the MarcoPolo-R mission. The instrument can be used either on asteroidal surface or directly on the spacecraft for in situ measurements of asteroidal materials. The CAMAM analytical suite is an ensemble of four hardware systems: (1) the laser mass spectrometer (LMS), (2) a miniature microscope camera system (MCS), (3) a sample collecting and introduction system (SCIS), and (4) an electronic box (E-Box). The four systems can be assembled and tested individually at subsystem level.

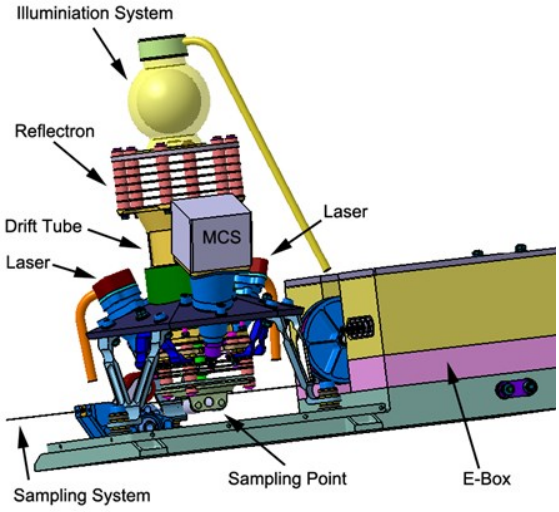

Fig 3 - : Left: Schematic of the CAMAM instrument suite. A miniature LIMS system and a microscope-camera system (MCS) are aligned to allow for complementary measurements from the same sampling point. A sample is delivered to the sampling point by a sample introduction system; here a particle trap mechanism is shown. The electronics is placed in the E-box.

Once all the four verified subsystems are tested, they can be easily integrated into the complete CAMAM instrument suite. The results of the studies conducted on several mineralogical samples by both the MCS and LMS instruments will be presented to emphasize the potential of this approach for delivering physical and chemical information. Figure 4 shows a photograph of sample are with the laser crater spots across. Complementary surface analysis has the potential for in depth investigations of its chemical and physical properties. In particular, it helps to understand details of heterogeneous details of the surface. The specifications of the CAMAM system are summarised in Table 1.

Quantity	***Value***
Dimension [*x*, *y*, *z* ; mm x mm x mm]	310 x 227 x 272
Basic Mass [kg]	4.0
Margin [%]	20.0
Nominal mass including margin [kg]	4.8
Standby power of analytical suite [W]	6.6
Peak Power [W]	17.7
Average Power [W]	9.9
Margin average power [%]	20.0
Average power incl. margin [W]	11.9

Table 1-Specifications of the CAMAM instrument.

Summary: The performance figures of the current miniature LMS instrument are comparable to that of instruments used in analytical laboratory. While applied to investigate planetary solids, it will have the potential for delivering sensitive and quantitative analysis of element and isotope composition of planetary solids. Context analyses of solids down to the micrometre-sized grains can be conducted with high spatial (lateral, vertical) resolution and yield context characterisation. LMS analysis can deliver mineralogy of individual grains and the investigation of altered and unaltered surface composition as well as molecules embedeed in the solid surfaces. High accuracy isotope measurements are very promising for delivering data suitable for dating and investigation of light isotope fractionation effects. A coupling of LMS with a miniature microscope-camera offers additional complementary characterisation of the sample. In the present investigations we demonstrate their performance and capabilities to deliver morphological, mineralogical and chemical information of rock or regolith/soil samples.

References: [1] Brinckerhoff W.B., Managadze G.G., McEntire R.W. , Cheng A.F., and Green, W.J. (2000), Rev. Sci. Instrum. 71, 536-545. [2] Rohner U., Whitby J. and Wurz P. (2003) Meas. Sci. Techol., 14, 2159-2164. [3] Riedo A., Bieler A. Neuland, M. Tulej M. and Wurz P. (2013), J. Mass. Spectrom., 48, 1 – 15. [3] Riedo A., Neuland M., Meyer S., Tulej M. and Wurz P. (2013) J. Anal. At. Spectrom., 28, 1256 – 1269. [4] Riedo A., Meyer S., Heredia B., Neuland M., Bieler A., Tulej M., Leya I., Iakovleva M., Mezger K. and Wurz P. (2013) PSS, 87, 1-13.