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A miniature laser-ablation time-of-flight mass spectrometer for sub-ppm analysis of planetary surfaces

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Time-of-flight mass spectrometers (TOF MS), based on pulsed laser sources are of considerable interest for landed missions to Mars, asteroids, comets, and planetary moons. The mass spectrometric analysis can provide both elemental and molecular composition of the material including the grain-scale and bulk major, minor, and trace composition with minimal sample manipulation and preparation. These informations are of particular interest because it can be used to investigate the origin and evolution of the solar system.
The performance of a laser ablation mass spectrometer (LMS) developed in our group will be demonstrated. The instrument is a small size reflectron-type time-of-flight mass spectrometer specifically developed for the application to space research [Rohner et al., 2003]. It has been carefully designed by taking into account the results achieved from detailed simulation of ion trajectories.
In present investigations mass analyzer has been coupled with 1064 nm output of Nd:YAG laser which is used for the ablation and ionization of NIST standard materials and natural samples. From the measurements of elemental and isotopic composition of the NIST samples the detection limits of ∼100 ppb could be determined. Although the method can be considered as a quasi-quantitative for the measurements of heavier elements (amu> 39), the quantitative detection of the lighter elements (e.g., C, P, S) is less accurate. The isotopic fractionation effects are found to be negligible and the error of their determination is generally smaller than 1 %. The measurements can be prepared with a high resolution (m/[U+F044]m) exceeding 800. Charged effects during the ablation process and other effects (e.g., space charge) are found to be negligible at the applied experimental conditions and measurements are highly reproducible. In studies of minerals and meteoritic materials, the elemental composition of major, minor and trace elements can be obtained together with their isotopic pattern proving that this approach can be powerful in the investigation of the composition of airless surfaces of asteroids, planets, and their moons on in situ and sample return missions.