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A miniaturised laser-ablation mass spectrometer for in-situ chemical analysis of planetary solids

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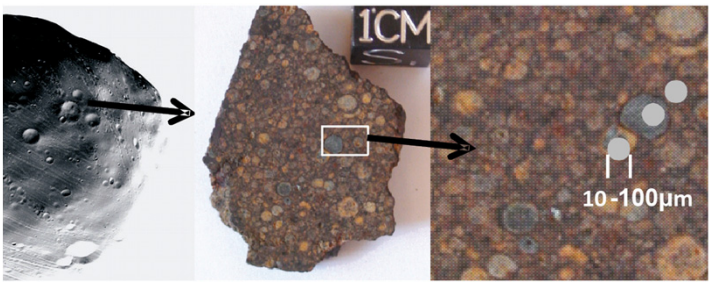
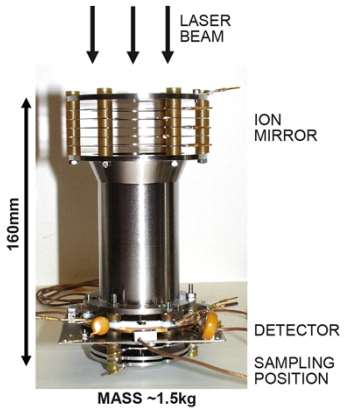
OBJECTIVE & GOALS

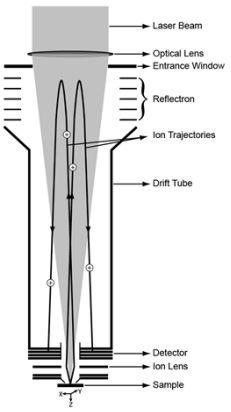
- In-situ analysis of the elemental and isotopic composition
- High lateral and vertical resolution
- In-situ radi-isotope chronology
- Chemical mapping of heterogeneous surfaces
- Preselection of samples for sample return missions
- Investigations on individual mineral grains, e.g., regolith, soils, rocks, etc.



INSTRUMENTATION & PRINCIPLES

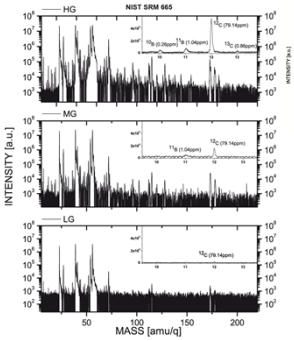
MINIATURISED REFLECTRON TIME-OF-FLIGHT MASS SPECTROMETER WITH LASER-ABLATION ION SOURCE



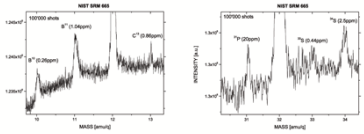


INSTRUMENTAL PERFORMANCE

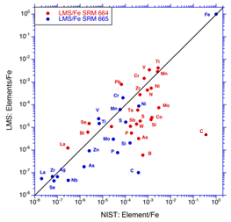
DYNAMIC RANGE AND SENSITIVITY



- Dynamic range of the system enhanced by using HG (high gain) and LG (low gain) measurement procedure.
- Dynamic range of at least 8 orders of magnitude.



- Measurement sensitivity of both metallic and non-metallic elements and their isotopes down to few tens of ppb.

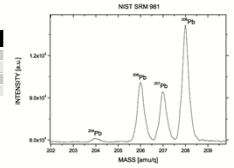


- Quantitative measurements can be achieved by using standard samples.

ISOTOPE MEASUREMENTS

LEAD STANDARD SAMPLE (NIST SRM 981)

NIST data			LMS data			
Mass [amu]	Isotopic Abundance [%]		Mass [amu]	Isotopic Abundance [%]	Abs. Accuracy [%]	Rel. Accuracy [%]
204	1.4255 ± 0.0012		204	1.4352 ± 0.0033	0.0097	0.68
206	24.1442 ± 0.0057		206	24.1092 ± 0.0308	0.0350	0.15
207	22.0833 ± 0.0027		207	22.0959 ± 0.0289	0.0126	0.06
208	52.347 ± 0.0086		208	52.3597 ± 0.0743	0.0127	0.02



Reference: NIST; Abs. Accuracy = abs(Ref. data – LMS data)

Rel. Accuracy = abs((Ref. Data – LMS data) / Ref. data)

GALENA SAMPLES FROM DIFFERENT LOCATIONS

Sample: Kengere, Congo:				Sample: Kilo Moto, Congo:				Sample: Ambatofangehana, Madagascar			
Mass [amu]	Isotopic Abundance [%]	Abs. Accuracy [%]	Rel. Accuracy [%]	Mass [amu]	Isotopic Abundance [%]	Abs. Accuracy [%]	Rel. Accuracy [%]	Mass [amu]	Isotopic Abundance [%]	Abs. Accuracy [%]	Rel. Accuracy [%]
204	1.3763 ± 0.0019	0.0056	0.41	204	1.4947 ± 0.0019	0.0060	0.40	204	1.4154 ± 0.0018	0.0001	0.01
206	24.969 ± 0.035	0.099	0.40	206	23.192 ± 0.023	0.025	0.11	206	24.435 ± 0.031	0.056	0.23
207	21.571 ± 0.030	0.040	0.19	207	22.921 ± 0.025	0.118	0.52	207	22.257 ± 0.031	0.036	0.16
208	52.083 ± 0.076	0.054	0.10	208	52.392 ± 0.059	0.100	0.19	208	51.892 ± 0.064	0.020	0.04

Reference: TIMS measurements

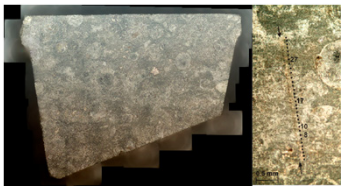
ALLENDE METEORITE

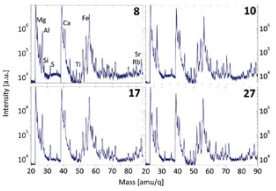
Mass [amu]	Isotopic Abundance [%]	Rel. Accuracy [%]	Mass [amu]	Isotopic Abundance [%]	Rel. Accuracy [%]	Mass [amu]	Isotopic Abundance [%]	Rel. Accuracy [%]
^{24}Mg	79.15 ± 0.12	0.2	^{28}Si	94.92 ± 0.82	0.1	^{52}Cr	83.73 ± 0.31	0.1
^{25}Mg	9.91 ± 0.02	0.9	^{29}Si	4.32 ± 0.50	1.6	^{53}Cr	9.56 ± 0.24	0.6
^{26}Mg	10.94 ± 0.02	0.6						

Reference: I. N. Tolstikhin and J. D. Kramers, 2008; H. Y. McSween and G. R. Huss, 2010

→ ISOTOPE MEASUREMENTS WITH PER MILL TO SUB PER MILL UNCERTAINTIES!

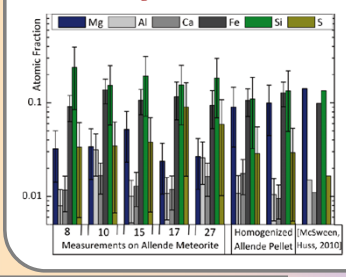
ALLENDE - SURFACE RASTERING



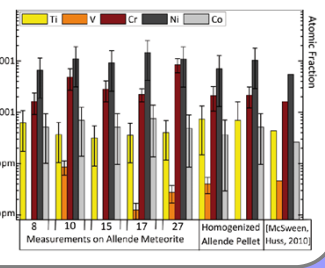


Highly sensitive chemical mapping (elemental and isotopic) with high spatial resolution (lateral and vertical).

Rock-forming elements



Metals



CONCLUSIONS & OUTLOOK

- High mass resolution of up to m/Δm ~ 900 – 1000 and high dynamic range of at least 10^8
- Detection limit of metallic and non-metallic elements as low as few tens of ppb
- ‰ -accuracy of isotope measurements - radio-isotope chronology, alteration, surface processes, etc.
- Further improvement in detection sensitivity, accuracy and precision by application of short-pulse laser sources, e.g., fs-laser
- Instrument calibration with a range of minerals and rocks, e.g., lunar simulants, etc.

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