GENTNER – a miniaturised laser instrument for planetary in-situ analysis

Elmar K. Jessberger
Isabelle Rauschenbach
Institut für Planetologie
Westfälische Wilhelms-Universität Münster

Sergey G. Pavlov
Heinz-Wilhelm Hübers
Institute for Planetary Research
German Aerospace Center (DLR) - Berlin

Hartmut Henkel
Sabine Klinkner
von Hoerner & Sulger GmbH
Schwetzingen, Germany

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft
Institut für Planetologie Westfälische Wilhelms-Universität Münster
vH&S von Hoerner & Sulger GmbH

Outline

- Planetary instruments for in-situ chemical analysis
- Laser-induced plasma spectroscopy: principle, instrumentation, features
- GENTNER proposal of the LIBS instrument for the Europa lander mission
- State-of-the-art of the instrument

Space-qualified instruments for in-situ chemical analysis

α-particle X-ray Spectrometer

MINERALOGY determines the abundance of all rock-forming elements except hydrogen

Cornell University

Moessbauer Spectrometer

MINERALOGY determines the composition and abundance of Fe-bearing minerals

Both well developed

- space exploration heritage
- physics and interpretation clear

However, both have stringent limitations

- **4 – 8 hours for one spectrum**
- **4 cm diameter area analysis „point“**
- **„limited“ exobiologic relevance**

- **THEREFORE: A New Experiment is Needed...**

NEW GENERATION = optical

LIBS

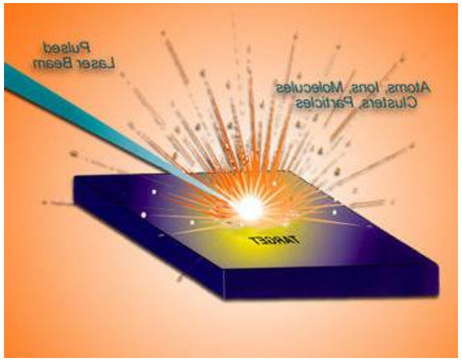
Laser **I**nduced **B**reakdown **S**pectrometry

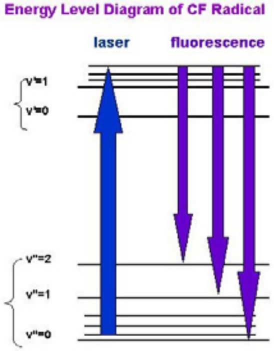
Laser **I**nduced **P**lasma **S**pectrometry

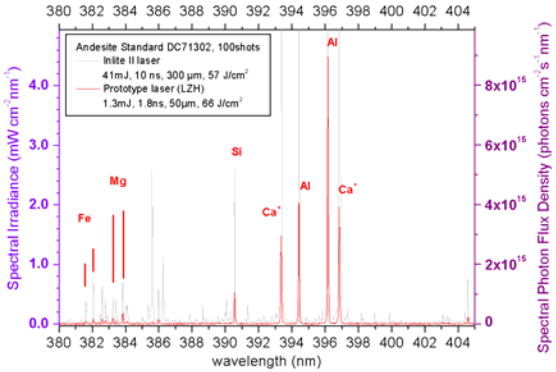
Analysis the emission of atomic lines from the plasma that is generated by a laser shot during photo-ablation

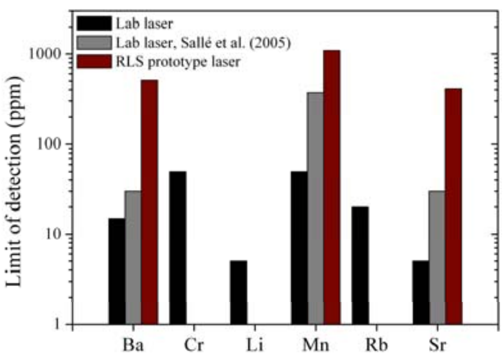
for

chemical analysis



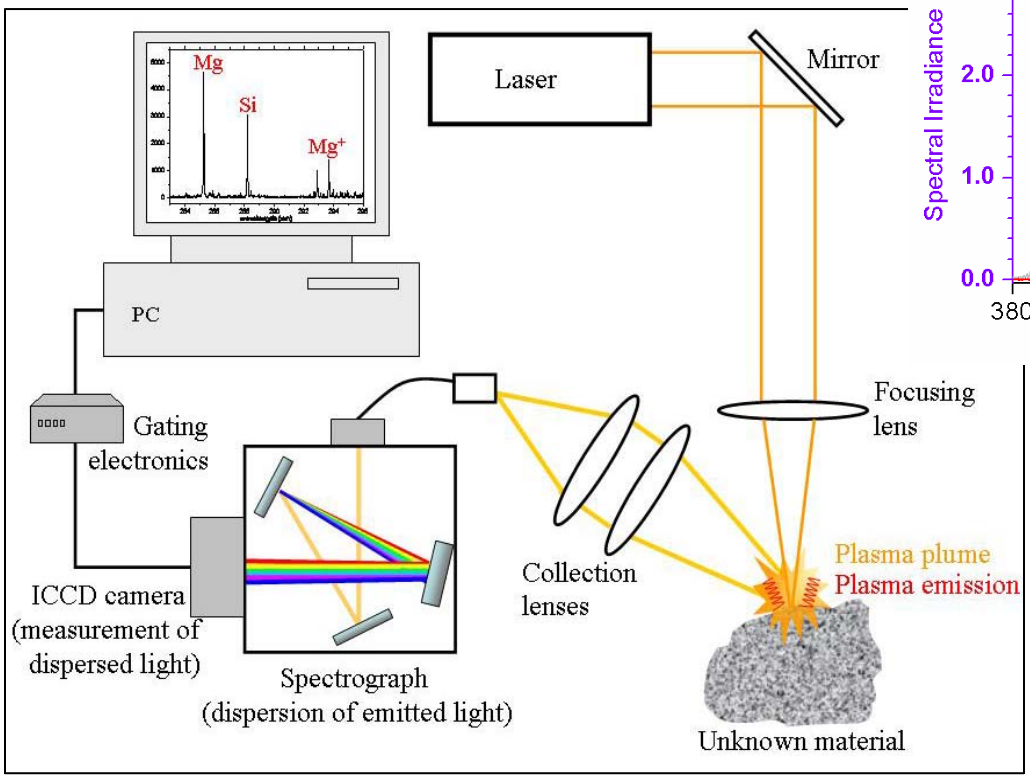


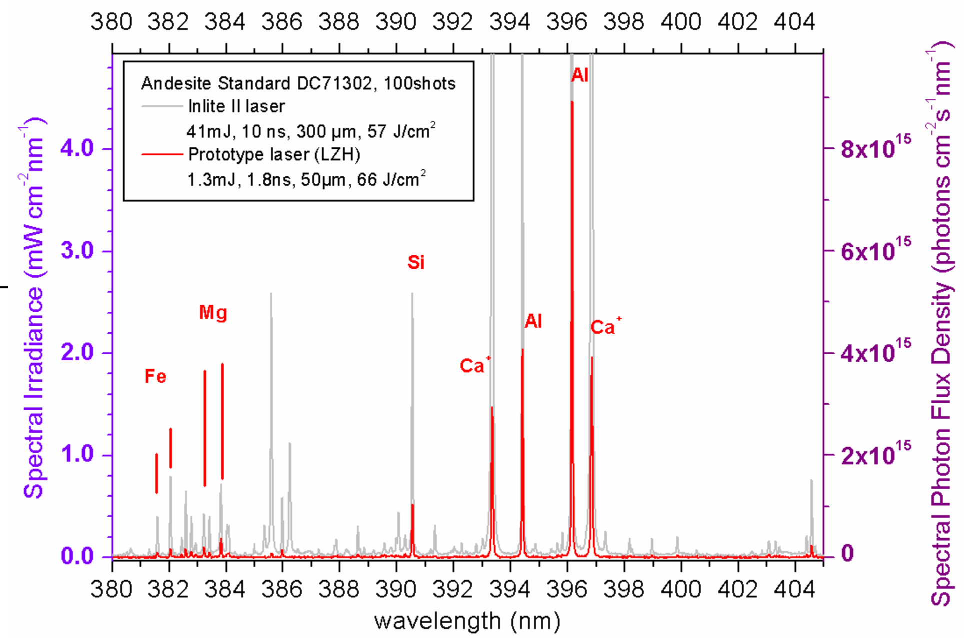




Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft
DLR
Institut für Planetologie
Westfälische Wilhelms-Universität Münster
vH&S
von Hoerner & Sulger GmbH

Laser-Induced Breakdown Spectroscopy (LIBS): Principle





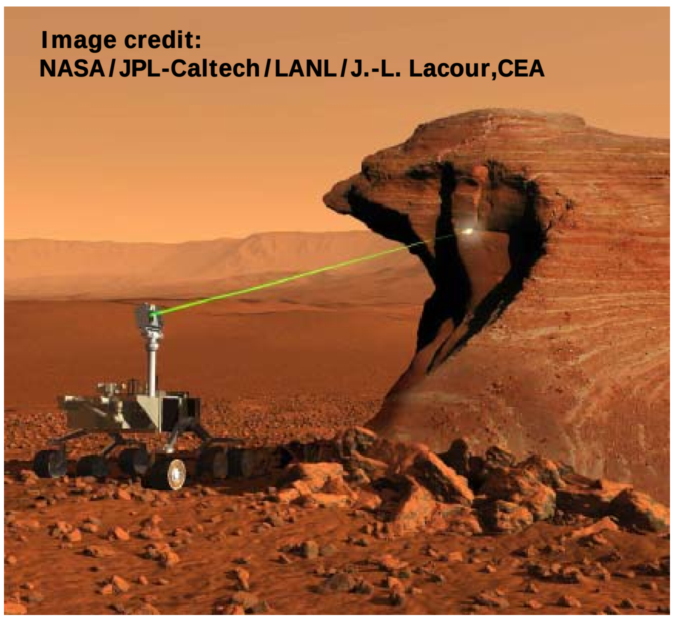
Laser-Induced Breakdown Spectroscopy (LIBS): Advantages

- Entirely optical technique, requires only optical contact to a sample
- Real time analysis (ultimate limit: spectrum per single laser shot)
- Minimal or no sample preparation (self-cleaning, penetrating)
- Multi-elemental characterization (no fundamental limit)
- No consumables or hazardous waste
- High spatial and depth resolution (profiling)
- Measurements on small sample (ablated mass ~ 1µg)
- Standoff remote analysis (up to a few meters)
- Suitable for combination with other optical spectrometers (e.g. Raman)

Future Missions Employing LIBS(/Raman) Instruments

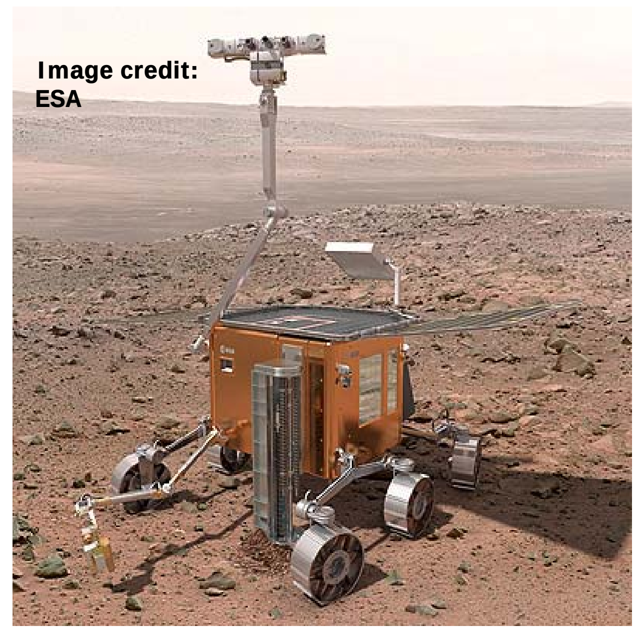
Laser-Induced Remote Sensing for Chemistry and Micro-Imaging (ChemCam)

NASA 2011



The Raman/Laser-Induced Breakdown Spectroscopy (Raman/LIBS) instrument

ESA 2013



GENTNER

LIBS/Raman

1. LIBS Instrument

⇒ quantitative elemental analysis

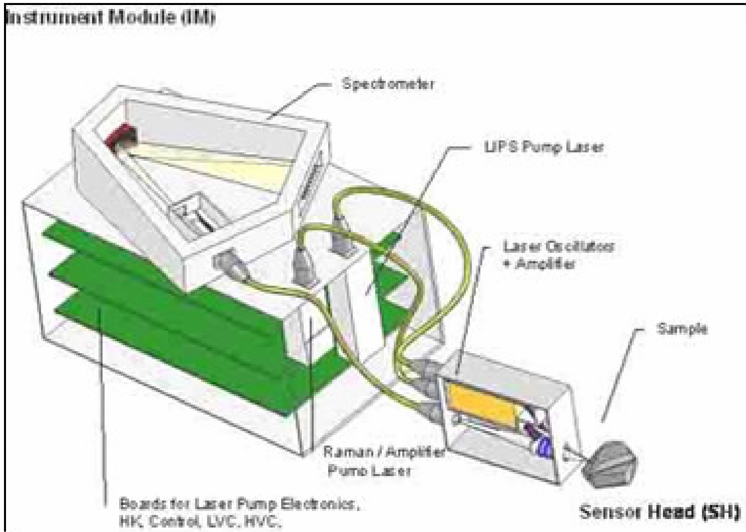
to 100 ppm within 1 minute of > 50 µm area
with 10 µm information depth

cf. APXS:
- 4 – 8 hours for one spectrum
- 4 cm diameter area analysis „point“

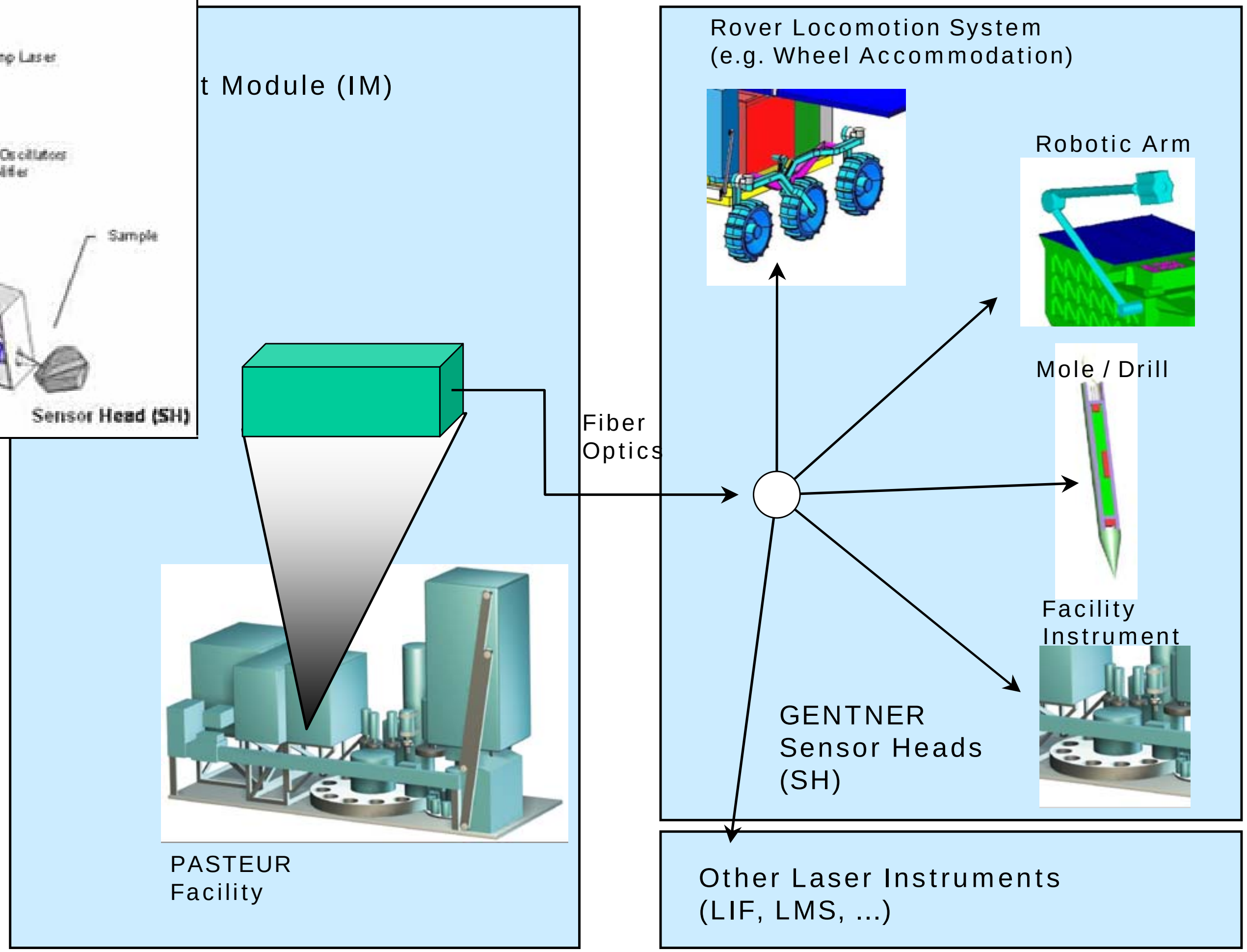
2. Possible combination LIBS with pulsed Raman

⇒ mineralogical & molecular information

Original Gentner Project



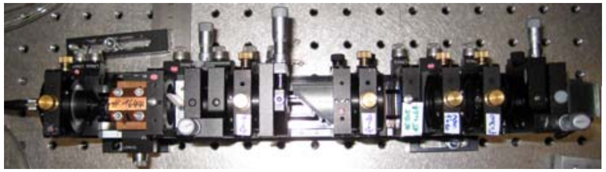
initial estimate: ≈ 1 kg

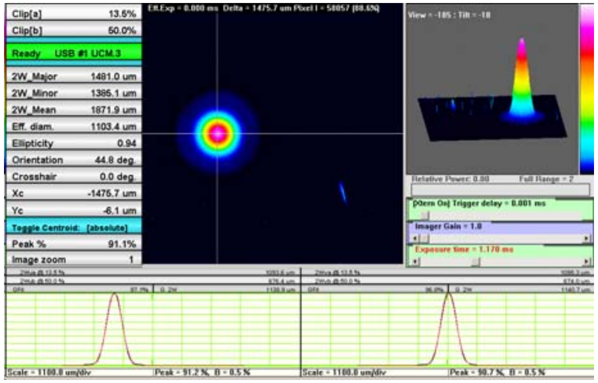


LIBS Instrument: State-of-the-art

Laser Prototype

Pulsenergy: 2.90 ± 0.05 mJ
t_{delay}: 180 ± 5 µs
t_{FWHM}: 2.0 ns
M^2_x u. M^2_y: < 2
$\varnothing_{spot} = 47$ µm $(1/e^2)$
z (from the last lens) = 260 mm

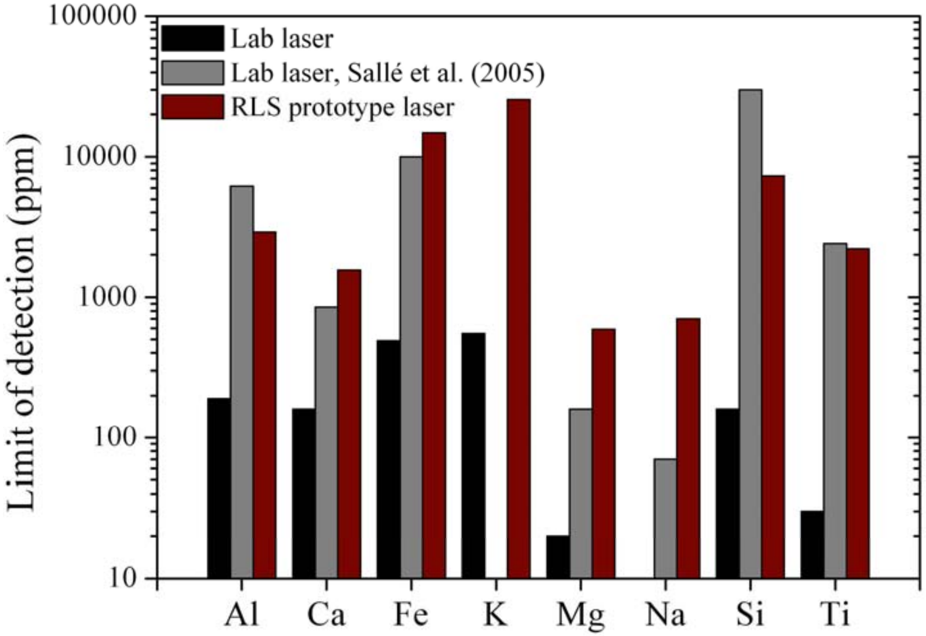


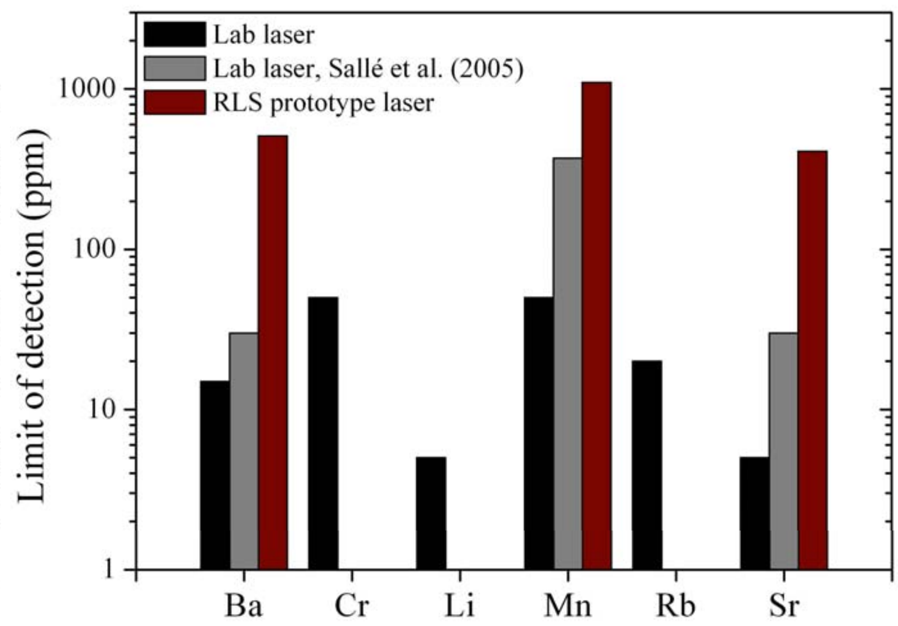


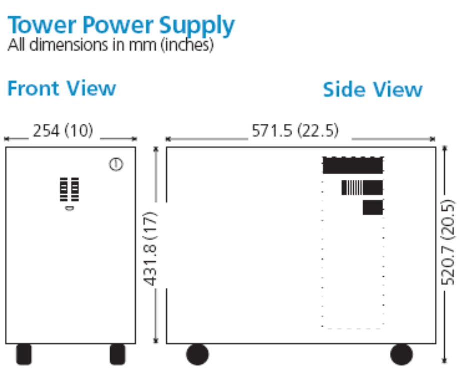
Spectrometer Prototype

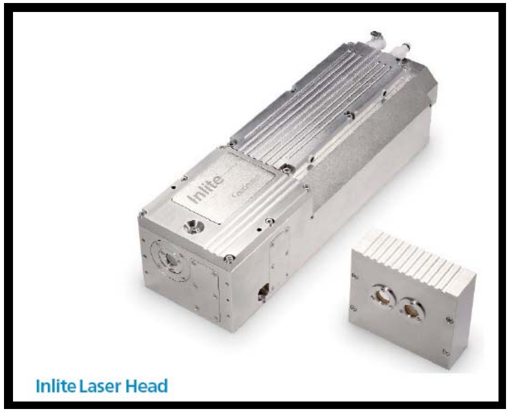
Research and Tests at Martian conditions

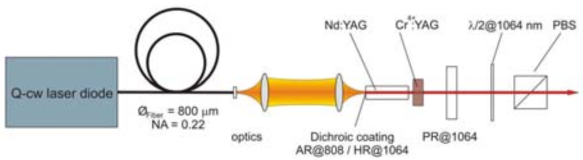
Martian conditions: Limits of Detection

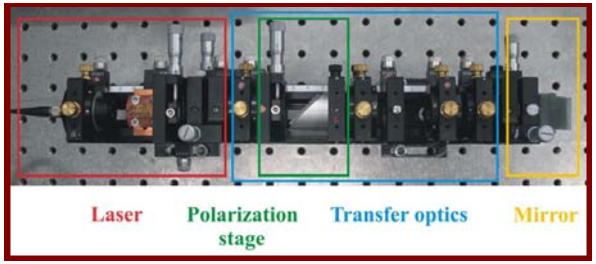




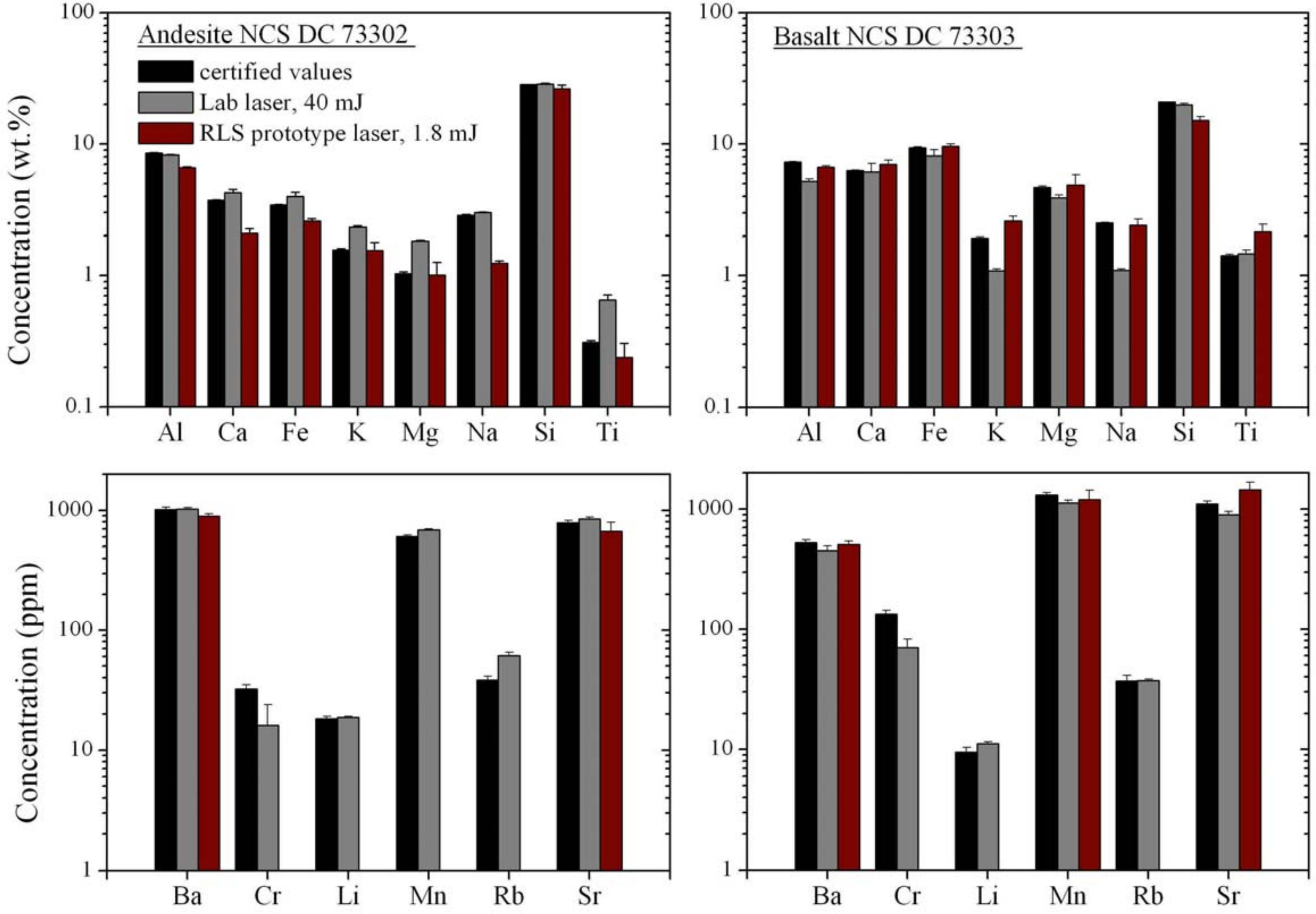








Martian conditions: Precision

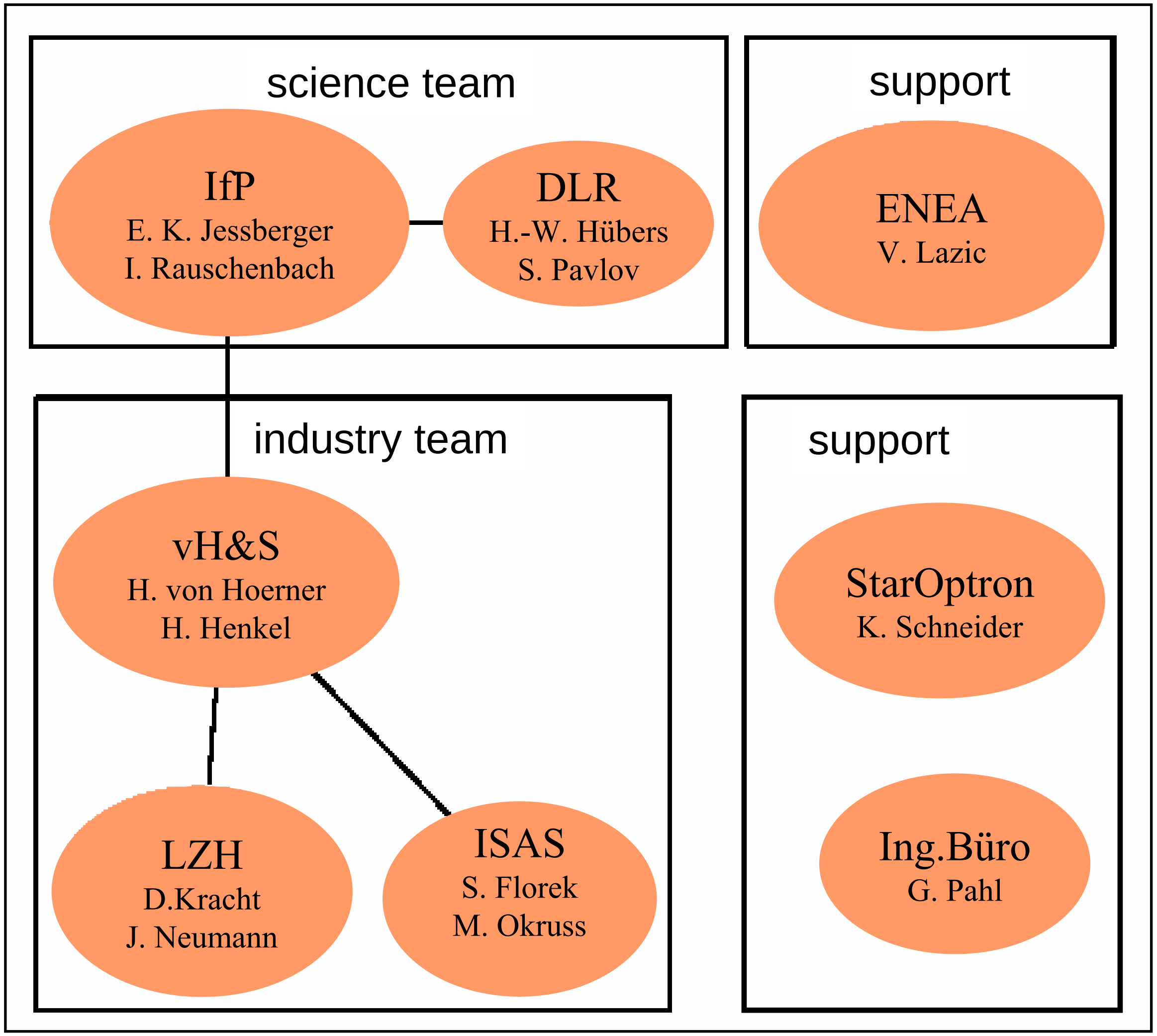


Advantages of LIBS: in comparison

- Fast analysis (seconds)
- High lateral resolution (≥ 50 µm)
- Simultaneous detection of major, minor and trace elements
- Sensitivity down to 100 ppm
- No sample preparation needed
- Independent from sample properties
  - ice, dust or rocks
- Capability of depth profiling up to 2 mm
- Can be combined with other methods like Raman spectroscopy for mineral identification

	LIBS (Laser prototype, 216 g, Martian cond.)	APXS (Alpha-Particle-X-ray Spektrometer)
Field of measurement	50 µm spot diameter	2.5 cm spot diameter
Duration of analysis	≤ 1 min	Major elements: 15–30 min Minor elements: up to 4 h
Depth of information	Equal for all elements: 100 shots ≈ 100 µm 1 000 shots ≈ 1 mm	Na ≈ 2 µm Fe ≈ 25–50 µm
Sample preparation	None, dust is removed by plasma shock wave	None, but dust layer can dominate spectra in cases
Detection area	H to Pb	Na to Br
Detection limits	Ba, Sr, Mg, Na: 400–700 ppm Al, Ca, Ti, Mn: 0.1–0.3 wt.% Fe, K, Si: 1–2 wt.%	Cl ≈ 500 ppm Ni ≈ 100 ppm Br ≈ 20 ppm

GENTNER science group and industry team



Summary

- LIBS is suitable and advance optical technique for in-situ chemical analysis of solid matter
- LIBS can operate along or in combination with other instruments, e.g. Raman spectrometer
- GENTNER proposal of the LIBS instrument for the Europa lander mission has a solid background, based on the developed partnership of science and industry teams having experience in planetary missions
- State-of-the-art: Running development and tests of the prototype parts of the instrument for the ESA Exo-Mars mission, LIBS database on planetary analogues at planetary conditions