MINIATURE TUNABLE LASER SPECTROMETERS FOR QUANTIFYING ATMOSPHERIC TRACE GASES, WATER RESOURCES, EARTH BACK-CONTAMINATION, AND IN SITU RESOURCE UTILIZATION

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Introduction: Tunable laser spectrometers offer a wide diversity of capability for highly sensitive measurement of atmospheric gases or those evolved (pyrolysis heating, laser ablation, etc.) from solid samples. Because it is based on IR laser absorption of individual rotational lines within a vibrational band, the method is very sensitive (parts-per-billion to parts-per-trillion), direct, non-invasive, easy to calibrate and unambiguous in its species identification and isotope ratio determinations without interference.

Although mass spectrometers have strength in wide survey capability and uniqueness in noble gas detection and noble gas isotope ratios, they are not well suited to low abundance H_2O and confuse H_2O, NH_3, and CH_4 when present in similar abundances. TLS is the preferred detection method for a variety of gases including H_2O, CH_4, N_2O, CO, CO_2, NO, NO_2, HNO_3, O_2, O_3, HCl, HF, and for stable isotopes in C, H, and O.

Laser sources are now available at room temperature with several to tens of milliwatts cw output power spanning a wide wavelength range. Detectors are simple, and miniature all-solid-state spectrometers are already being developed. Three detection methods (direct absorption, second-harmonic, and cavity ringdown) will be employed as appropriate.

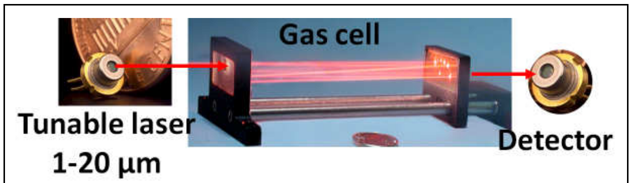

Figure 1. Schematic of an all-solid-state TLS with open-path cell

Tunable laser spectroscopy can be applied in a variety of simple configurations: closed mutipass cell (Herriott cell or cavity ringdown cell), open cradle cell, or direct to target ranging using topographically-scattered and return laser light. Hand-held portable systems are also feasible for many specific applications.

The Mars Exploration Program Advisory Group (MEPAG) and Small Bodies Advisory Group (SBAG) recently identified several strategic knowledge gaps that have to be bridged prior to sending humans to the Martian system (Mars and its moons Deimos and Phobos). To achieve the goal of humans to the surfaces of these three bodies, TLS offers significant contribution to several key strategic knowledge gaps listed in Table 1.

Strategic Knowledge Gap for Humans to Surface	**Significant potential contribution from a TLS**
Lower atmosphere	Measure local sources of trace gases such as H_2O, CH_4, NH_3, etc. and relate to atmospheric properties that drive wind modeling and chemical interactions with ascent vehicles, ground systems, and human explorers.
Back contamination to Earth	(i) Pyrolyze selected rock samples (pieces) and convert organic carbon to CO_2- detect CO_2 amount and delta-13C isotope ratio as biogenic indicator (ii) monitor capsule gases and gas production (e.g. H_2S, CH_4)
Dust effects	Monitor trace levels of inert gas (e.g. isotopic CO_2, N_2O, O_2) added to critical pressurized systems (including respiratory) to warn against seal loss or deterioration from dust entrainment.
Water resources	Accurately measure water abundances across a wide dynamic range from low atmospheric water (ppm) to wt% of liquid water in permafrost and subsurface sources.
Atmospheric ISRU	Quantify a large variety of composition targets from atmospheric gases and those evolved from surface pyrolysis and ablation of rocks and minerals.
Technology: sustain humans on the surface	Provide medical diagnostics of external and human air supplies, with emphasis on pollutants such as CO, hydrocarbons, combustibles, CO_2 isotope ratios for breath

	and vital organ diagnostics, ammonia in urine, etc.
Phobos/ Deimos surface science	Quantify a large variety of composition targets from atmospheric gases and those evolved from surface pyrolysis and ablation of rocks and minerals.

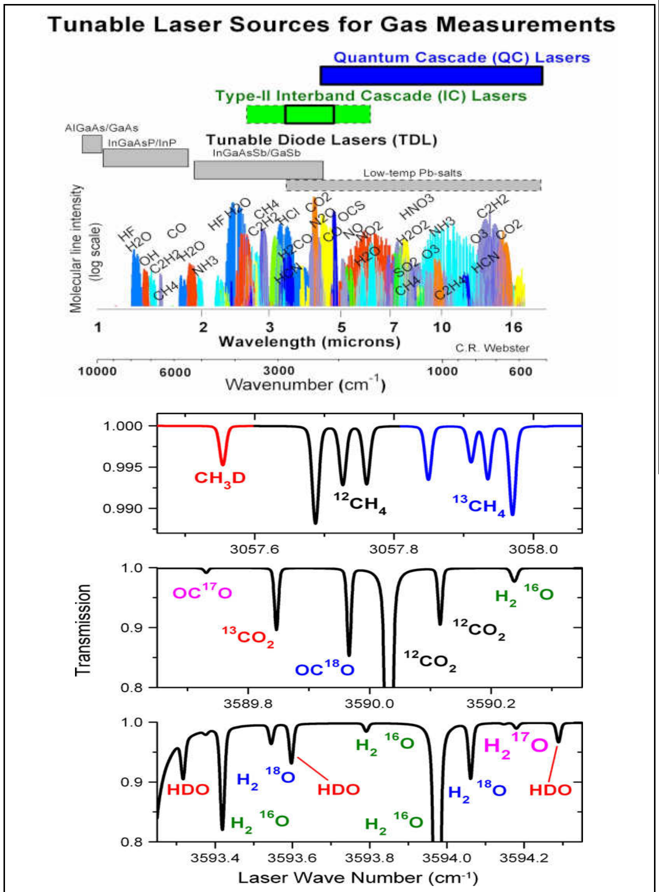

Figure 2. Spectral regions of target molecules and the three specific regions targeted by TLS-SAM-MSL using a two-channel configuration.

it requires sample preparation and long measurement times.

One important advancement in TLS instrumentation is the use of digital control, detection and on-board processing techniques developed by Flesch et al. (2010) that we will embody into our spectrometers to provide agility, configurability, robustness, reduced mass and power, and increased sensitivity.

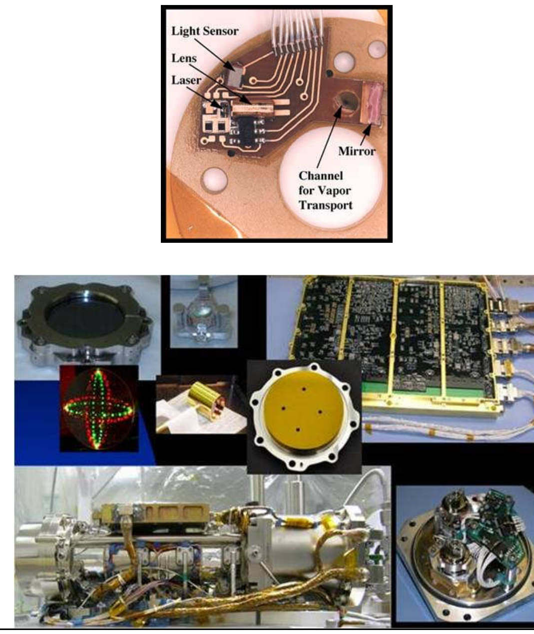

Figure 3. Top: TLS-on-circuit-board approach of JPL's DS-2 probe. **Bottom:** TLS flight hardware as delivered for SAM-MSL, currently on its way to Mars.

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References:

[1] "Determining the Local Abundance of Martian Methane and Its' $^{13}C/^{12}C$ and D/H Isotopic Ratios for Comparison with Related Gas and Soil Analysis on the 2011 Mars Science Laboratory (MSL) Mission", C.R. Webster and P.R. Mahaffy, *Planetary and Space Science*, 59, 271-283 (2011).

[2]. G. Flesch and D. Keymeulen, "Adaptive Tunable Laser Spectrometers" In 2010 IEEE aerospace, Big Sky, MT, March 2010.