MINIATURIZED HOLLOW-WAVEGUIDE GAS CORRELATION RADIOMETER (GCR) FOR TRACE GAS DETECTION IN THE MARTIAN ATMOSPHERE. E. L. Wilson, E. M. Georgieva, and H. R. Melroy,

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Introduction: Gas correlation radiometry (GCR) has been shown to be a sensitive and versatile method for detecting trace gases in Earth's atmosphere [1, 2]. Here, we present a miniaturized and simplified version of this instrument capable of mapping multiple trace gases and identifying active regions on the Mars surface [3]. Reduction of the size and mass of the GCR instrument has been achieved by implementing a lightweight, 1 mm inner diameter hollow-core optical fiber (hollow waveguide) for the gas correlation cell. Based on a comparison with an Earth orbiting CO₂ gas correlation instrument, replacement of the 10 meter multipass cell with hollow waveguide of equivalent pathlength reduces the cell mass from ~150 kg to ~0.5 kg, and reduces the volume from 1.9 m x 1.3 m x 0.86 m to a small bundle of fiber coils approximately 1 meter in diameter by 0.05 m in height (mass and volume reductions of >99%) [4, 5]. This modular instrument technique can be expanded to include measurements of additional species of interest including nitrous oxide (N₂O), hydrogen sulfide (H₂S), methanol (CH₃OH), and sulfur dioxide (SO₂), as well as carbon dioxide (CO₂) for a simultaneous measure of mass balance.

Instrumental Design: The miniaturized GCR has been designed as a modular instrument with a single module for each trace gas measurement. The current configuration contains four stacked modules (Figure 1) for simultaneous measurements of methane (CH₄), formaldehyde (H₂CO), water vapor (H₂O), and deuterated water vapor (HDO). The modules are self-contained, and fundamentally identical; differing by the bandpass filter wavelength range and gas mixtures inside the hollow-waveguide absorption cells. Figure 2 shows the optical layout of a single module of the gas correlation radiometer.

Figure 1. Prototype GCR instrument showing 4 - stacked modules, each containing a channel to detect a different trace gas.

Figure 2. Optical layout of a single module of the gas correlation radiometer.
duplicate hollow core fibers both reduces etalon and fringing effects in the ratio, and removes interferences by absorption features at adjoining or overlapping wavelengths. Light in each channel is focused onto HgCdTe detectors. Signals are processed through lock-in amplifiers referenced to the frequency of the optical chopper. Data is handled and processed through custom Labview software.

Relevance and Capabilities: Identifying active regions in the Martian atmosphere is key to identifying future locations for lander and sample retrieval missions – and ultimately identifying whether these gases originate from geological sources such as gas seeps, active volcanism and serpentization reactions, or from the presence of extant life. Figure 3 identifies several pathways that may account for methane and formaldehyde production in the Martian atmosphere adapted from Atreya and Wong [6, 7]. Isotopic ratios of water vapor will offer insights into the history, age, and depth of water.

Expected capabilities of the four module instrument in a Mars orbit are summarized in the table in Figure 4. These assume one second of averaging and 3 km displacement along the satellite ground track.

Preliminary Results: The detection limit for formaldehyde in the lab is slightly better than 3 ppm. This corresponds to a 30 ppb sensitivity in the Martian atmosphere. A change of 0.04 torr of methane is equivalent to an approximate change of 0.5 ppm methane in the Martian atmosphere. These early lab results are shown in Figure 5.

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References:


