NOVEL LASER-BASED GAS SENSORS FOR TRACE GAS DETECTION IN A SPACECRAFT HABITAT

D. Leleux, R. Claps, F.V. Englisch, and F.K. Tittel
Department of Electrical and Computer Engineering, Rice University, Houston, TX, 77251-1892

INTRODUCTION
Ammonia vapor is one of the nitrification by-products produced by a tubular bioreactor being developed at the NASA Johnson Space Center for wastewater treatment during long duration space missions (Figure 1). In order to quantify this NH₃ vapor production, a portable diode laser-based gas sensor for NH₃ detection using overtone infrared absorption spectroscopy was developed, and a 2-week campaign to carry out concentration measurements was performed. This sensor is capable of NH₃ vapor concentration measurements at the parts-per-million (ppm) level in the bioreactors being developed by NASA-JSC for water recycling in the International Space Station. The use of all fiber-coupled optical components makes such a trace gas sensor rugged and alignment insensitive.

CURRENT STATUS OF RESEARCH
Methods
The basis of operation is laser overtone absorption spectroscopy of ammonia at ~ 1.53 microns. Overtone line strengths are typically 2 orders of magnitude weaker than those of fundamental bands; and thus, a multipass cell with an effective optical path length of 36 meters is used in conjunction with balanced detection to achieve adequate sensitivity (Figure 2). With a 5 mW probe beam, a sensitivity of less than $2.5 \times 10^{-4}$ is reported. The detection limit achieved is 1 ppm NH₃ with a signal-to-noise ratio of approximately 5 at a pressure of 100 Torr.

Figure 1 - Nitrification Process

Figure 2 - Sensor Configuration
Results
During the 2-week concentration measurement of NH\textsubscript{3}, we determined that it was also possible to perform simultaneous measurements of CO\textsubscript{2}. Carbon Dioxide is a by-product of the organic carbon removal process of the reactor (Figure 1). Measurements were also correlated to reactor events such as the periodic addition of acids to control the pH level of the solution. Sensor field performance was also assessed and compared to baseline measurements taken in the laboratory. Results from this campaign will be reported at the presentation.

Conclusion
This novel laser-based gas sensor shows potential for several applications involving both spacecraft habitats for long-duration missions and non-space applications. These include: (1) environmental monitoring in the International Space Station, (2) monitoring of NH\textsubscript{3} leaks in cooling pipes, as well as (3) the monitoring and control of nitrogen cycling in the nitrification bioreactor and, (4) monitoring of NH\textsubscript{3} slip in catalytic removal of NO\textsubscript{x} species in post-combustion processes.

FUTURE PLANS
A longer duration measurement campaign is planned for the near future in addition to comparison studies with other types of laser-based trace gas sensors such as a quantum-cascade laser operating at \(\sim\) 10 microns capable of accessing a strong ro-vibrational NH\textsubscript{3} transition.

INDEX TERMS
Ammonia, Nitrification, Trace Gas Sensor, Diode Laser-Based Absorption Sensors, Laser Spectroscopy, Bioreactor