Phase I Project Summary

Firm: MetroLaser, Inc.
Contract Number: NNX11CI24P
Project Title: Differential Diode Laser Sensor for High-Purity Oxygen

Identification and Significance of Innovation: (Limit 200 words or 2,000 characters whichever is less)

Portable robust sensors are needed for verifying the purity of oxygen in space operations. Presently, oxygen purity is verified by laboratory analysis on the ground using gas chromatography (GC), which requires bulky instrumentation that is generally not portable. Conventional compact oxygen sensors employ electro-chemical cells, ion conductivity, or oxygen adsorption on metal oxide semiconductors, all of which require the gas sample to be brought into contact with the sensor. Over time, sensors involving contact with oxygen degrade due to corrosion or poisoning of the active medium, limiting the accuracy and sensor lifetime. In contrast, diode laser absorption techniques don't require contact with the sample and have the potential for long term stability. The innovation explored is a method for sensing the difference in oxygen concentration between a high purity reference cell and a cell filled with the sample gas. Differential absorption between the two cells is performed using an auto-balanced detector, enabling measurements of oxygen purity with high accuracy in a compact, stable, and robust package.

Technical Objectives and Work Plan: (Limit 200 words or 2,000 characters whichever is less)

The technical objectives of this feasibility study were to 1) determine the effects of impurity species on accuracy of concentration measurements, 2) define which parameters can cause the greatest errors, 3) determine the extent of coherence fringe effects caused by the cell windows, 4) determine the lowest differential absorbance level that can be measured, 5) determine what level of long term drift may be expected, 6) demonstrate linearity of the differential signal with oxygen concentration of the range of 99.0 to 99.7 percent, and 7) define the requirements for a prototype design.

To meet these objectives, MetroLaser divided the Phase I effort into seven major tasks:

Task 1. Kick-off Meeting
Task 2. Spectroscopic Modeling
Task 3. Verification of O_2 Spectroscopy
Task 4. Construct Breadboard
Task 5. Conduct Experiment
Task 6. Design Feasibility Study
Task 7. Reporting

Technical Accomplishments: (Limit 200 words or 2,000 characters whichever is less)

A sensor concept for measuring oxygen purity with high accuracy in a compact rugged package that is adaptable to use in space use was investigated. A dual cell system was constructed that incorporated a device for maintaining equal pressure between the two cells. The beam from a diode laser was split into two parts, with one beam passing through the sample cell and the other passing through the reference cell. An auto-balanced detection system was used to produce an output signal that is proportional to the difference in intensities of the two beams. Feasibility was demonstrated by conducting differential absorption measurements in the dual cell system with continuous flows of pure oxygen mixtures, and by conducting static measurements in room air. It was possible to equate the results obtained in room air to results that would be obtained in a dual cell system with high purity oxygen in the sample and reference cells. The equivalent of 0.05 percent accuracy in oxygen concentration was demonstrated in a 20-cm path with a measurement time of 10 s.

NASA Application(s): (Limit 100 words or 1,000 characters whichever is less)

The primary NASA application of this sensor is verification of the purity of oxygen produced in orbit by equipment on board the International Space Station. Oxygen used for extra-vehicular activity (EVA), emergency medical, and contingency oxygen for metabolic consumption. The most critical application is EVA, which requires an oxygen purity of 99.5 percent or better. There is currently no method of purity verification to this level while in orbit. In addition, the sensor may find use in land-based NASA activities such as monitoring of oxygen at air separation plants and testing of oxygen purity at remote locations.

Non-NASA Commercial Application(s): (Limit 200 words or 2,000 characters whichever is less)

A compact portable high-purity sensor for oxygen would be useful to users of oxygen for verifying purity without having to bring a sample to the laboratory. Pure oxygen is used to enhance combustion, increasing yield and reducing NOx emissions, in a growing number of industries including glass, steel, and petrochemical manufacturing. The proposed sensor may provide a means of verifying purity with a compact and reasonably priced instrument to help ensure optimum plant performance. The sensor technique can also be adapted to other gases that have near infrared absorption lines. Future versions of the sensor could find use in verifying purity of ammonia for use in selective catalytic reduction of NOx, or purity of hydrogen fluoride for use in semiconductor manufacturing

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