

Evaluation of an Interferometric Sensor for In-Space Detection of Gas Leaks

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Space mission planning often involves long-term storage of volatile liquids or high-pressure gases. These may include cryogenic fuels and oxidizers, high-pressure gases, and life-support-critical consumables. The risk associated with the storage of fluids and gases in space systems has long been an issue and the ability to retain these fluids is often tied to mission success. A leak in the storage or distribution system can cause many different problems, including a simple, but mission endangering, loss of inventory or, in severe cases, unbalanced thrust loads on a flight vehicle. Cryogenic propellants are especially difficult to store, especially over a long duration. The propellant can boil off and be lost through the insulating walls of the tank or simple thermal cycling of the fittings, valves, and propellant feed lines may unseat seals allowing the fluid to escape.

Current NASA missions call for long-duration in-space storage of propellants, oxidizers, and life support supplies. Leaks of a scale detectable through a pressure drop in the storage tank are often catastrophic and have long been the focus of ground-based mitigation efforts where redundant systems are often employed. However, there is presently no technology available for detecting and monitoring low-level, but still mission-endangering, gas leaks in space. Standard in-space gas detection methods either have a very limited pressure range over which they operate effectively or are limited to certain gases. Mass spectrometer systems are able to perform the detection tasks, but their size, mass and use of high voltage, which could potentially lead to an arc that ignites a combustible propellant, severely limit their usefulness in a space system.

In this paper, we present results from testing of the light-based interferometric gas monitoring and leak detection sensor shown in Fig. 1. The output of the sensor is an interference fringe pattern that is a function of the gas density, and commensurate index of refraction, in the sample region. Changes in the density of gas cause the interference fringes to move across a photodiode detector, providing a temporal history of the leak. The sensor is fiber coupled and constructed from solid optics, allowing for placement almost anywhere on the spacecraft. It is also advantageous in that it consumes very little power and does not introduce an ignition source. Data are presented demonstrating the capability of the sensor to measure density variations in different gas species. In addition, the transient response of the sensor in vacuum is demonstrated. These data extend and improve upon the results previously presented by the authors in Ref. [1].

References

- ¹J. Sinko, V. Korman, A. Hendrickson, and K.A. Polzin, "An interferometric sensor for detection of gas leaks in a vacuum environment," *4th Liquid Propulsion Subcommittee Meeting of the JANNAF Interagency Propulsion Committee*, Orlando, FL, Dec. 2008. JANNAF Paper #135.

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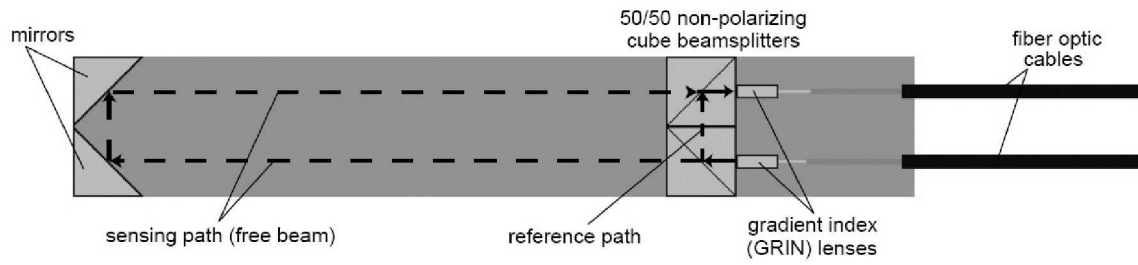
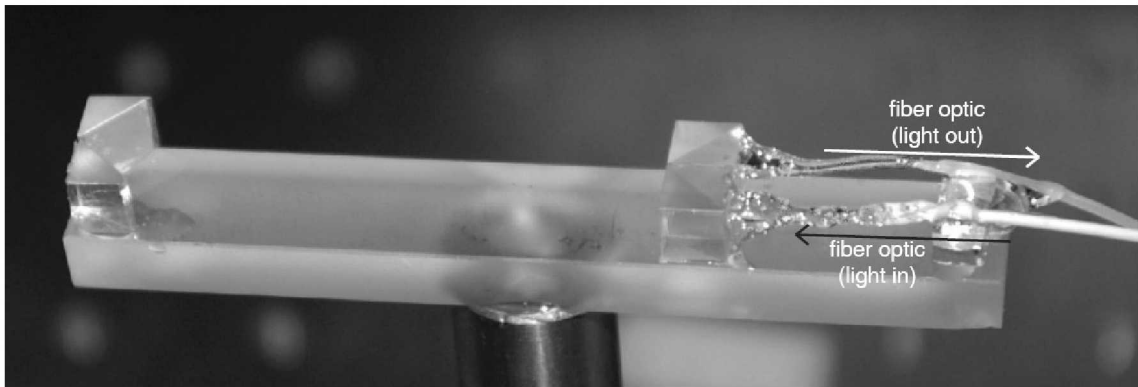


Figure 1. Photograph (top) and schematic (bottom) of a fiber-coupled gas detection sensor.