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Laser Based Absorption Sensor for Trace Gas Monitoring in a Spacecraft Environment

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Summary

Formaldehyde is a chemical widely used in many industrial manufacturing processes due to its high chemical reactivity and good thermal stability. Commonly used building materials like foams and numerous consumer paint and polymer products contain formaldehyde. Studies indicate that H_2CO can cause a variety of health effects ranging from irritation of eyes, nose, and throat to nausea and headaches at concentrations above 100 ppb. At 100 ppm it is dangerous to life and health.

In order to monitor the concentration and to locate emission sources, the development of an in situ, real-time, portable gas sensor capable of detecting formaldehyde of sub-ppm levels in air is of considerable interest. Specifically, we have demonstrated a portable laser based sensor for both enclosed volume monitoring of formaldehyde out gassing from materials to be used in the space station (such as melanine foam) and real time, formaldehyde monitoring of ambient spacecraft air. In addition, the high levels of ambient methane (>170 ppm) in a space station environment make formaldehyde spectral line selection critical and necessitates multiple line fitting in the data analysis.

The gas sensor described here uses difference frequency generation (DFG) in periodically poled $LiNbO_3$ (PPLN) of a single longitudinal mode (SLM) diode laser (816 nm) and a SLM Nd:YAG laser (1064 nm). Typically, 5 μw of mid-IR light is generated. The sensor layout is shown in

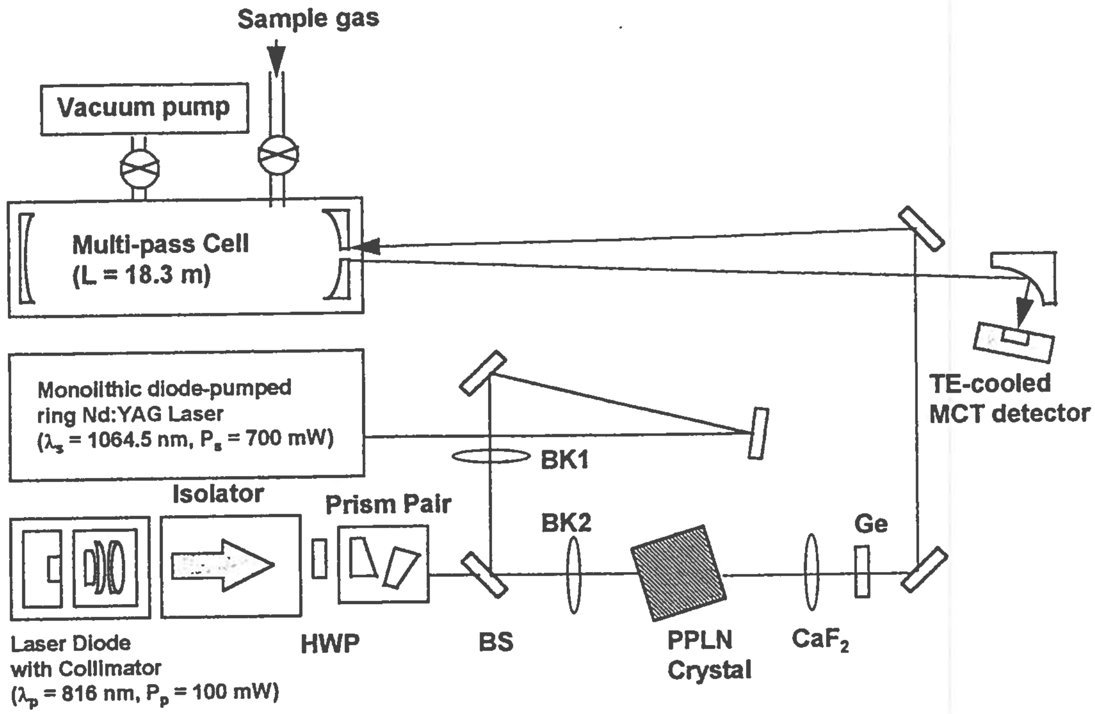

Fig 1: Diagram of the compact (30 cm x 61 cm) diode-pumped difference frequency spectrometer for formaldehyde detection.

fig-1, and is similar in design to that reported previously [1]. Absorption is measured in a 18 m, multi-pass cell. Data acquisition is performed by a laptop computer equipped with a PCMCIA A-D card. Control, data recording and analysis is carried out using Labview software.

Mid-infrared light is generated at 3.5 µm, (2831.5 cm^{-1} or 2861.7cm^{-1}), corresponding to formaldehyde lines relatively free of interfering species. The latter line was identified by Fried [2], however in the presence of a high ambient methane concentration a weak methane line is close by (~0.08 cm^{-1}) and must be taken into account. The spectral lines are resolved by conducting the absorption measurements at reduced pressure (60 torr), and simultaneously fitted to a Lorentzian lineshape as well as a weak third order polynomial to the baseline.

Calibration of the sensor was performed by using a standard 5.5 ppm (± 5 %) formaldehyde in nitrogen (Scott Specialty Gases). This calibration mixture was further diluted to 140 ppb by

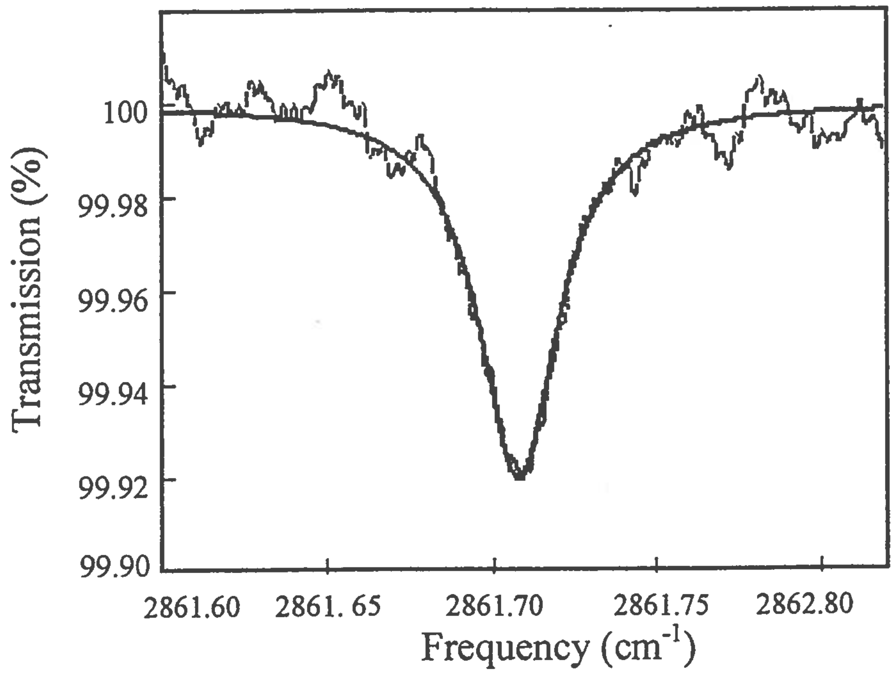

Fig. 2: A spectrum of 140 ppb formaldehyde in nitrogen at 100 Torr for an optical path length of 18 m. The solid line is a Lorentzian curve fitted to the data with a rms error of 7 ppb.

mixing nitrogen gas. The spectrum is shown in fig. 2 and corresponds to a concentration of 135 ± 15 ppb, in good agreement within the uncertainty of the calibration gas.

In conclusion, real time detection and measurement of formaldehyde at sub-ppm concentrations in air using diode pumped 3.5 μm DFG radiation in PPLN has been demonstrated. A minimum detectable concentration of < 30 ppb was obtained.

References

1. Thomas Toepfer, Konstantin, P. Petrov, Yasuharu Mine, Dieter Jundt, Robert F. Curl, Frank K. Tittel, Appl. Opt. Oct, 1997.

2. A. Fried, S. Sewell, B. Henry, B.P. West, T. Gilpin and J.R. Drummond, J. Geophys. Research 102, 6253 (1997).