A compact mid-infrared dual-gas CH_4/C_2H_6 sensor using a single interband cascade laser and custom electronics

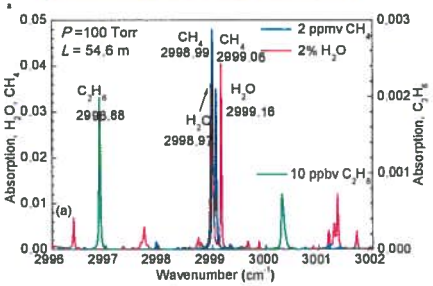
Weilin Ye, Chunguang Li, Chuantao Zheng, Nancy P. Sanchez, Aleksander K. Gluszek, Arkadiusz J. Hudzikowski, Lei Dong, Robert J. Griffin, and Frank K. Tittel

Introduction

CH_4 — A key contributor to the greenhouse effect
A safety hazard in natural gas industries

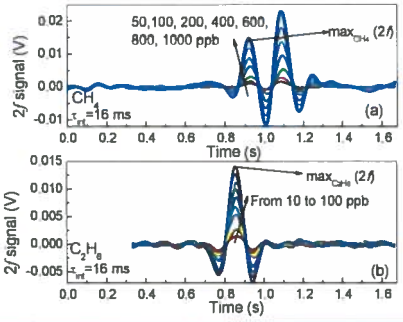
C_2H_6 — The second-largest component of natural gas in the chemical industry

Absorption Spectra



HITRAN based absorption spectra of C_2H_6 (10 ppbv), CH_4 (2 ppmv) and H_2O (2%) in a narrow spectral range from 2996 cm^{-1} to 3002 cm^{-1} at a pressure of 100 Torr and an absorption length of 54.6 m.

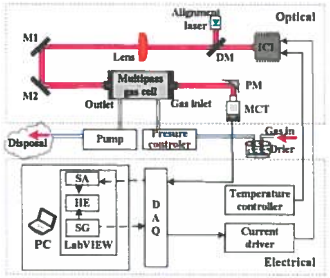
Second Harmonic Signal

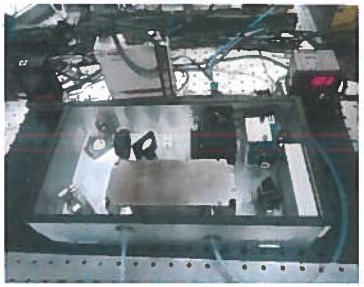


(a) Recorded 2*f* signals of seven different CH_4 concentration levels from 50-1000 ppbv.

(b) Recorded 2*f* signals of ten different C_2H_6 concentration levels from 10-100 ppbv.

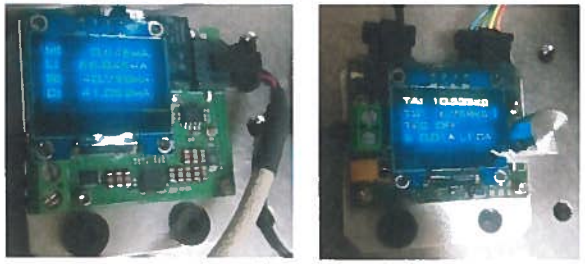
Sensor Architecture





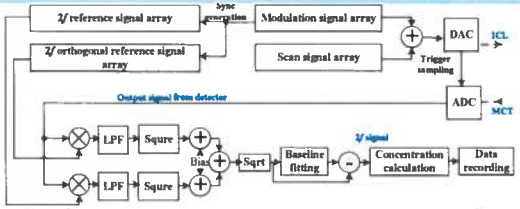
Left: Schematic of the dual-gas CH_4/C_2H_6 sensor based on a single CW, TEC ICL. Right: Photo of optical core.

Custom Electronics



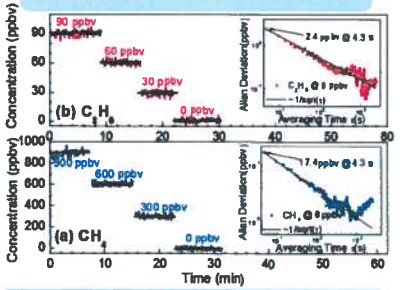
Left: Laser current driver, Right: Temperature controller

LabVIEW-based Data Processing System



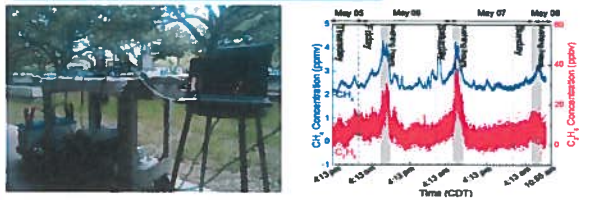
Function diagram of the LabVIEW-based laptop platform, which performs signal generation, signal acquisition and harmonic extraction.

Measurement Results



Measurement results of concentration levels of (a) four CH_4 samples and (b) four C_2H_6 samples. The insets exhibit the Allan deviation plots obtained for 0 ppmv CH_4 and 0 ppbv C_2H_6 samples for ~ 40 min, respectively.

Outdoor Measurements



Left: Single CW ICL based dual-gas CH_4 / C_2H_6 sensor system installed on a laboratory cart. Right: Measurement results of simultaneous CH_4 and C_2H_6 monitoring in the atmosphere for a time duration ~ 67 hours on the Rice University campus.

Summary

A continuous-wave (CW) interband cascade laser (ICL) based mid-infrared sensor system was demonstrated for simultaneous detection of atmospheric CH_4 and C_2H_6. An Allan deviation analysis yielded detection sensitivities of 17.4 ppbv for CH_4 and 2.4 ppbv for C_2H_6 for an averaging time of 4.3 s. The demonstrated dual-gas sensor architecture shows the merits of simultaneous CH_4 and C_2H_6 detection with a single sensor of significantly reduced size and cost without influencing the mid-infrared sensor detection sensitivity, selectivity and reliability.

Acknowledgement

National Science Foundation (NSF) (ERC MIRTHE award); USA Robert Welch Foundation (C-0586), NSF Phase II SBIR (IIP-1230427DE DE); DOE ARPA-E awards (DE-0000545, DE-0000547); National Natural Science Foundation of China (NSFC) (61307124, 61575113, 61275213); Changchun Municipal Science and Technology Bureau (14KG022); High School Outstanding Young Teacher Training Program of Guangdong Province (YQ2015071); China Scholarship Council (201506175025, 201508440112).

Rice Laser Science Group
Department of Electrical and Computer Engineering
Rice University, 6100 Main Street, Houston, TX 77005, USA

RICE LASER SCIENCE GROUP
Sensing the world around us.