Detection of H_2S based on Off-Axis Integrated Cavity Output Spectroscopy

Weidong Chen[1], Anatoliy A. Kosterev[2], Frank K. Tittel[2], Daniel Boucher[1]
[1]Laboratoire de Physicochimie de l'Atmosphère, UMR CNRS 8101, Université du Littoral Côte d'Opale
189A, Av. Maurice Schumann, 59140 Dunkerque, France
[2]Rice Quantum Institute, MS 366, Rice University, 6100 Main St., Houston, TX 77005, USA

In the present work, we demonstrate the feasibility of hydrogen sulfide (H_2S) trace detection by means of off-axis integrated cavity output spectroscopy (OA-ICOS) using a DFB diode laser at ~ 1571.8 nm. A minimum detectable H_2S concentration of 700 ppb (signal-to-noise ratio, SNR=3) was achieved.

The OA-ICOS cavity consisted of two 1" diameter spherical mirrors (1 m radius of curvature) separated by a 0.5 m long quartz coated stainless tube. The mirrors reflectivity was ~ 99.995% at 1560 nm as specified by the manufacturer (Los Gates Research). Based on the measured cavity ring down time with on-axis alignment, the effective optical path length of the ICOS cavity was ~ 10.2 km. In the off-axis configuration (OA-ICOS), the measured effective absorption path length was ~ 700 m. Three alignment screws located on one of the two cavity mirror mounts are piezo actuator-driven, which allows modulation of the cavity length. A GaInAsP DFB laser diode operating in the near infrared around 1571.8 nm (~ 6362 cm^{-1}). The single mode diode laser was fiber pigtailed with a linewidth of <350 kHz and an output power of up to 63 mW. Frequency tuning of the diode laser is performed by scanning either the temperature (over 10 cm^{-1} with a tuning ratio of ~ 0.4 cm^{-1}/K) or the current (over more than 1 cm^{-1}). A switchable-gain InGaAs detector (PDA10CS, from Thorlabs) was used for detecting the radiation exiting the optical cavity.

The spectral data of H_2S from the Pacific Northwest National Laboratory (PNNL) database were used for the spectroscopic analysis in the present work. Figure 1(a) shows a H_2S FTIR spectrum acquired at 1 atm pressure from the PNNL database (bottom). A direct absorption spectrum of CO_2 from a reference cell in the same spectral region is depicted at the top of Fig 1(a) . The R20 CO_2 line of the $3\nu_1$ band at 6362.5038 cm^{-1} was used as a frequency reference and for a determination of the effective optical path length of the OA-ICOS cavity using a calibrated CO_2 concentration. A gas standard generator (KinTek Model 491 M) was used to provide a traceable calibration standard of H_2S. The H_2S concentrations range from 24 to 2.4 ppmv in a diluting gas (nitrogen). The ICOS cell pressure was maintained at 100 Torr with a pressure controller (MKS Instruments type 649). H_2S absorption spectra were collected by scanning the DFB laser current at 10 Hz over ~ 1 cm^{-1} at ~ 6362.6 cm^{-1}. Typically, 1000 spectral scans were averaged for each H_2S concentration measurement. Figure 1(b) shows an OA-ICOS spectrum of 2.437 ppmv H_2S. Based on the experimentally estimated SNR of the spectral signal, the corresponding minimum detectable concentration (MDC) was found to be 700 ppbv (SNR=3). Further improvement in detection sensitivity can be realized by use of OA-ICOS in combination with wavelength modulation [1,2].

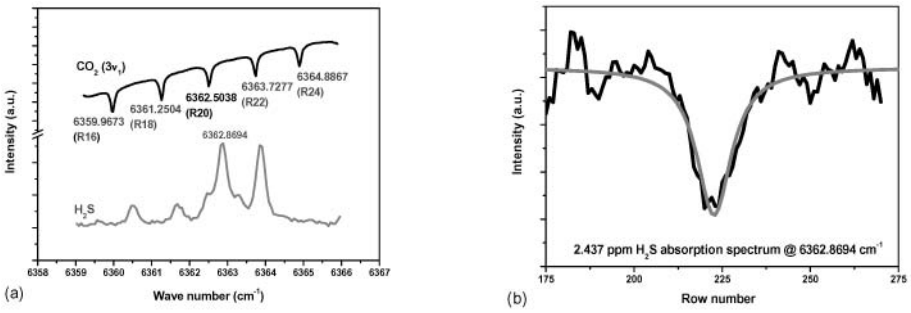

Fig. 1 H_2S spectra (a) : Spectrum from PNNL spectroscopic data base, compared with an absorption spectrum of CO_2 in a reference cell; (b) : OA-ICOS spectrum of H_2S as recorded in the present work.

References

[1] Y. Bakhirkin, A. Kosterev, R. Curl, F. Tittel, D. Yarekha, M. Giovannini, J. Faist, "Sub-ppbv nitric oxide concentration measurements using cw thermoelectrically cooled quantum cascade laser-based integrated cavity output spectroscopy", Appl. Phys. B **82,** 149-154 (2006)

[2] W. Zhao, X. Gao, W. Chen, W. Zhang, T. Huang, T. Wu, H. Cha, "Wavelength modulated off-axis integrated cavity output spectroscopy in the near infrared", Appl. Phys. B (2006), DOI:10.1007/s00340-006-2451-3