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Off-Axis Integrated Cavity Output Spectroscopy based H_2S Trace Detection in the Near-Infrared

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Demonstration of hydrogen sulfide (H_2S) trace gas detection by means of off-axis integrated cavity output spectroscopy (OA-ICOS) [1,2] using a DFB telecommunication laser will be reported. In this work, 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 steel tube. The mirrors reflectivity was ~99.995 % at 1560 nm as specified by the manufacturer (Los Gates Research). The experimentally determined effective optical path length was ~700 m. The diode laser source used was a continuous-wave GaInAsP DFB laser diode (JDS Uniphase) operating in the near infrared at ~1571.8 nm (6362 cm^{-1}). The single mode diode laser was fiber pigtailed with a maximum output power of 63 mW and linewidth of <350 kHz. Frequency turning of the diode laser can be carried out either by varying the temperature (over 10 cm^{-1} with a tuning rate of ~0.4 cm^{-1}/K) or scanning the injection current (over more than 1 cm^{-1}). An amplified, switchable-gain InGaAs detector (PDA10CS, Thorlabs) was used for the radiation detection after the optical cavity.

The R(20) CO_2 line of the $3\nu_1$ band at 6362.5038 cm^{-1} was used in this work for frequency reference and determination of the effective optical path length of the OA-ICOS cavity using a calibrated CO_2 concentration. A gas standard generator (KIN-TEK Model 491 M) provided a traceable calibration standard of H_2S. The H_2S concentrations ranged from 24 to 2.4 ppmv in the diluting gas (nitrogen). The ICOS cell pressure was maintained at 100 Torr by means of a pressure controller (MKS Instruments type 649). Absorption spectra of H_2S were acquired by scanning the DFB laser current at 10 Hz, corresponding to ~1 cm^{-1} frequency scans encompassing the 6362.85 cm^{-1} H_2S absorption line. Typically, 1000 spectral scans were averaged for each H_2S concentration measurement. Based on the experimentally estimated SNR of the OA-ICOS 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 [3,4].

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Ultra compact Herriott cell for optical gas sensor applications

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Multi reflection cells like the White or the Herriott type are used in gas spectroscopy in order to increase an absorption signal by stretching the optical path. We present a Herriott cell with a minimized volume implemented in a setup for oxygen measurement. The absorption of the oxygen line at 763.84 nm is measured by tuneable diode laser spectroscopy (TDLS). A fiber coupled Vertical Cavity Surface Emitting Laser (VCSEL) scans the narrow wavelength range around the P9P9 line of the P-branch of the oxygen A-band transition.

The Herriott cell type is suitable for minimizing the cell volume because it is made of two spherical mirrors in comparison to the White cell with three mirrors. The optimized cell (fig. 1) provides high sensitivity by a long optical path and fast detection of gas concentration changes because of the small sample volume which enables a fast gas exchange. The optical path length is longer than 5 m within an enclosed volume of 40 ml. The design with separated in and out coupling holes in the mirrors enables small hole diameters which determine the maximum numbers of reflections. The distance of around 100 mm between the mirrors determines the real numbers of reflections (55).

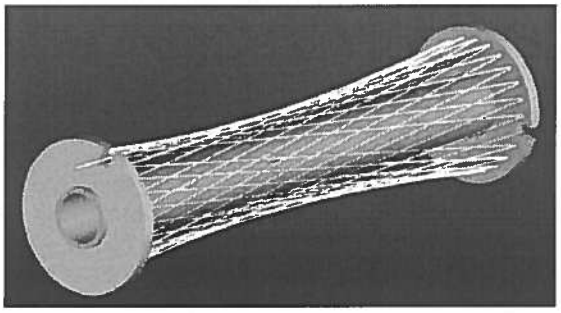

Fig. 1: Side view (left) of the optical pathway simulation of the Herriott cell. The path length is 5,5 m in 40 ml cylindric volume.

The fiber coupling of the gas cell enables gas concentration detection in highly inflammable environments because light source and control electronics are separated from the sample volume with its temperature and pressure terms and gas composite. This would be important if the oxygen concentration has to be controlled to avoid explosive gas composites by too high oxygen concentrations. The concentration measurement can be realized by TDLS at 763 nm cross sensitivity free.

The presented Herriott cell merges robustness, low cost, compactness and is used for high sensitivity applications.