Broadband Multi-species Trace Gas Detection by Up-Converting Mid-Infrared Supercontinuum Light into the Near-Infrared

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Recent advancement in compact, stable, and broadband mid-infrared supercontinuum (SC) sources has provided attractive scientific and industrial applications in metrology, sensing, and communications [1]. The wide spectral coverage in the so-called molecular fingerprint region is the main advantage of such SC sources, opening up new opportunities for efficient multi-species trace gas detection at short time scale. Presently, there is a lack of sensitive, low-cost, uncooled MIR photodetectors. The alternative approach involves up-converting mid-infrared light into the near-infrared region via non-linear conversion, leveraging the benefits of sensitive and cost-effective CCD detectors [2]. Here, we present the development of a multi-species trace gas sensor utilizing a mid-infrared SC source in combination with a multipass absorption cell and an up-conversion-based spectrometer. The customized SC source (NKT Photonics) has a total power of 450 mW covering the 1.5 – 4.2 μm spectral window. The astigmatic Herriott multipass cell (AMAC-76, Aerodyne Research) provides an effective optical pathlength of 76 meters improving the detection sensitivity. Details of the up-conversion-based spectrometer (NLIR) have been recently published. [3]. Note that in the present upconversion system the intracavity laser at 1064 nm is generated by pumping the Nd:YVO_4 gain medium at 808 nm instead of 880 nm. In order to enhance the long term stability for single species detection, the amplitude drift of the SC source is minimized by counterbalancing the SC intensity with a non-absorbing reference.

Multispecies broadband absorbance spectra have been obtained for, amongst others, mixtures of ethane and acetaldehyde at ppm levels in nitrogen as shown in Fig. 1 (a). A non-negative least squares global fitting method has been applied to extract the concentration of individual sub-component.

To check system linearity by different gas concentrations, the absorbance with various mixing ratios were measured at a pressure of 900 mar for 60 s. A linear fit of these measurements that agreed with the calculated ones is depicted in Fig. 1 (b) for ethane.

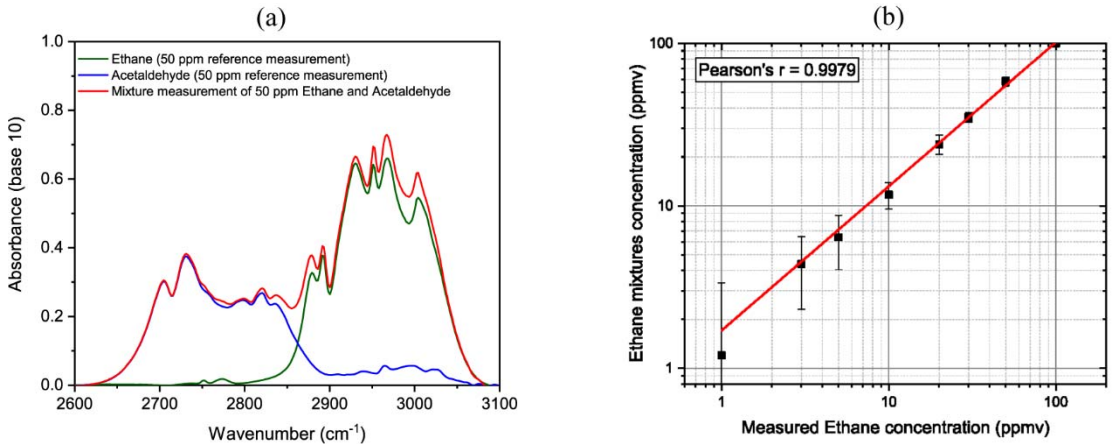

Fig. 1 (a) Measured absorbance (1 s data acquisition, 30 s averaging) for a mixture of 50 ppmv ethane and acetaldehyde with their reference measurements (b) Linearity for various applied ethane mixture concentrations versus the measured concentrations.

The sensor is capable of detecting sub-ppmv gas concentrations (e.g. ~300 ppbv ethane) in a wide range of spectrum (over 600 cm^{-1}) with a ~5 cm^{-1} spectral resolution. Broadening the spectrum to a wider range by using chirped crystals in the up-converter system and further experiments are under progress. More details and the results for the on-going experiments will be presented at the conference.

References

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