# Combined broadband photo-acoustic and absorption spectroscopic techniques of measurement for $C_2H_2$ with supercontinuum laser


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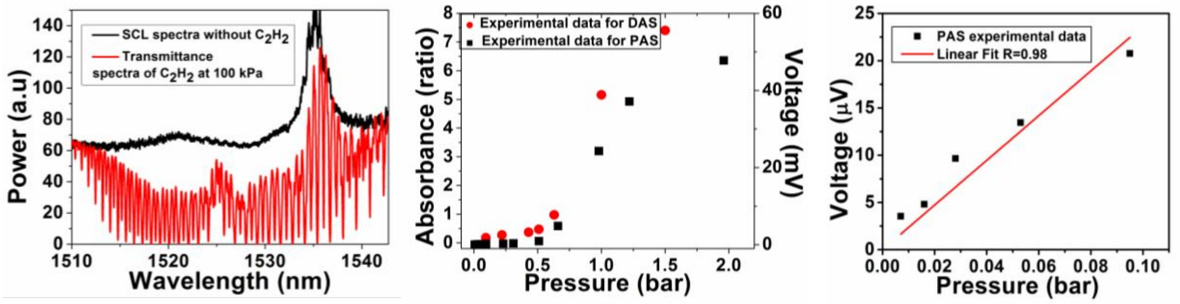
$C_2H_2$ is a colourless and highly flammable gas that becomes explosive when liquefied, compressed, heated, or mixed with oxygen. The development of compact optical sensors for acetylene is of interest for many applications like manufacturing plants and industrial process monitoring. There are a wide range of spectroscopic and non-spectroscopic techniques employed widely to detect trace gases. Photo-acoustic spectroscopy (PAS) is one very versatile and efficient technique to detect trace gases of the order of ppb levels [1, 2]. A broadband photoacoustic gas sensor with a supercontinuum laser (SCL) in the near infra red region has been proposed for monitoring the ($\nu_1+\nu_3$) vibrational combinational band. In the study, a supercontinuum laser (Leukos, SM-250-IR) with a wide bandwidth (900-2800 nm) was used. To match with the absorption lines of $C_2H_2$, a bandpass filter centered at 1525 nm and with a bandwidth of 50 nm (FWHM) was used. A cylindrical PA cell with an electret microphone (Ono sokki MI 1235 with a preamplifier MI 3111) was used for measuring the PA signal. The signal from the preamplifier was then fed to a lock-in amplifier (SR 7225) which was set at the modulating frequency of 1250 Hz to match the 1st longitudinal mode of the PA cell. The photo-acoustic spectroscopy technique was combined with the direct absorption spectroscopy technique. Direct absorption spectroscopy (DAS) measurements were performed by feeding the transmitted laser beam through the photo-acoustic cell to an optical spectrum analyzer (Yokogawa, AQ6370B) [3]. The broadband absorption of $C_2H_2$ was analyzed with a spectral resolution of 0.1 nm and effective data acquisition speed of 1 μs.




(a) (b) (c)

Fig. 1 (a) $C_2H_2$ transmittance spectra at 100 kPa (b) Experimental data for DAS and PAS showing saturation effects (c) Experimental data for PAS at lower pressures

Figure 1(a) shows the spectra obtained from the OSA with an optical path length of 250 mm. The spectral resolution of the system was kept at 0.1 nm. Since the absorption cross section of $C_2H_2$ is of the order $2.5\times10^{-20}$ $cm^2$/molecule, saturation is seen at 100 kPa. Figure 1(b) shows the comparison of absorbance varying as a function of pressure for both DAS and PAS. When the entire combinational band of acetylene lines are considered for generating the photoacoustic signal, at higher pressures $C_2H_2$ lines are saturating and a linear trend line is not observed. Figure 1(c) shows Absorbance varying as a function of pressure for PAS experiments at lower pressures. A linear trend line is observed. The q factor of the cell obtained from $Q = w_0/\Delta w$ was 63. The average output power of the SCL for the $C_2H_2$ band is 170 mW. The setup constant for the resonant cell was calculated as 1657 Pa cm/W. The microphone responsivity is 35 mV/Pa. Thus the minimum detectable limit of the PA setup for a noise equivalent signal was estimated at 10 ppbv. The minimum detectable limit for DAS with SNR as 3 dB was 100 ppmv at an absorption wavelength of 1532.8 nm. The estimation of gas concentration in a mixture of gases is challenging when the spectral band of multiple gases overlap in the same region. Nevertheless, the broadband PAS technique combined with the DAS is suited for such measurement applications.

## References


[1] F. Yehya, A.K. Chaudhary, "Time-resolved time-dependent photo-acoustic spectroscopy of $NO_2$ in a high frequency multi-resonant cavity," Appl. Phys. B **106**, 953-959 (2012).

[2] H. Yi, K. Liu, W. Chen, T. Tan, L. Wang, and X. Gao, "Application of a broadband blue laser diode to trace $NO_2$ detection using off-beam quartz-enhanced photoacoustic spectroscopy," Opt. Lett. **36**, 481-483 (2011).

[3] J. Hult, R. Watt, and C. Kaminski, "High bandwidth absorption spectroscopy with a dispersed supercontinuum source," Opt. Express **15**, 11385-11395 (2007).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