Dual-resonant mode T-type cell-based photoacoustic spectroscopy for simultaneous trace gas detection

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Multi-component gas on-line detection is a topic of considerable interest in recent years because of its importance in numerous applications [1]. Miniaturization, multi-wavelength excitation and multi-frequency detection are the recent development trends of photoacoustic spectroscopy (PAS). Therefore, a dual-frequency T-type resonator-based PAS sensor system by using a frequency division multiplexing (FDM) technique was demonstrated for the simultaneous detection of C_2H_2 and CH_4. Instead of multi-resonator PAS scheme [2], utilizing two resonant modes of a single T-type photoacoustic cell (PAC) with multi-wavelength excitation enables dual-gas simultaneous measurement, which can decrease the bulk and energy loss.

In general, conventional cylindrical longitudinal resonant H-type PAC has large amplitude difference operating in the two resonant modes, which is not capable of the simultaneous detection using two frequencies. The novel T-type resonator can compensate the amplitude difference by flexibly adjusting the sizes of the vertically distributed absorption and resonance cylinders. This T-type resonant PAC has advantages of fast response time, periodic pressure amplification, background noise suppression, high PAC constant, low resonance frequency and multicomponent capability [3].

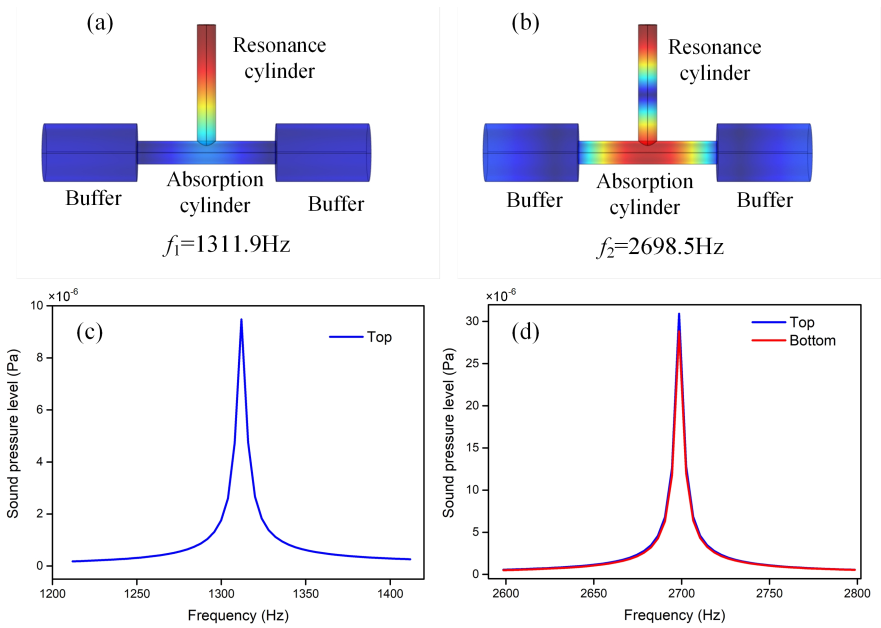

Fig. 1. The resonance modes of T-type photoacoustic cell by finite element simulation. **(a)(b)** The fundamental and overtone modes of T-resonator. **(c)(d)** The pressure levels with frequencies at antinodes.

As shown in Fig. 1, the different modes of identical T-type PAC and pressure levels at antinodes are presented by finite element method simulation (COMSOL Multiphysics ® v5.4). By adding two buffers at both ends of the absorption cavity, the standing wave antinodes of overtone mode will be located at the central bottom of the T-type PAC. The size of two identical cylindrical buffers was 40mm long and 25mm inner diameter, and the absorption cylinder was 60mm long and 10mm inner diameter. The length and inner diameter of the resonance cylinder were 50mm and 8mm, respectively. The fundamental and overtone modes can be exploited to detect gas molecules at two different modulation frequencies. Using microphones located at the top and bottom of the PAC to detect the photoacoustic signals can reduce the transmission loss of acoustic energy, and improve the utilization efficiency of the sound waves. In contrast to the multi-resonator, this T-type PAC is more flexible, miniaturized and effective without the guide tubes.

A schematic of the sensor setup is shown in Fig. 2. Two DFB lasers operating at 1532nm (NEL) and 1653nm (NEL) were used as excitation sources with different frequency current modulation for matching the two resonant modes for C_2H_2 and CH_4 measurement, respectively. Two electret microphones placed at the top and bottom of PAC were used to detect the acoustic waves generated by gas molecules with different frequency mode excitation. The second harmonic photoacoustic signals were demodulated by lock-in amplifiers. Thus, the PA spectra and concentration responses of dual sample gases can be retrieved. The performance of this PA system could be further improved by optimization of its configuration, the parameters of the T-resonator, and higher optical powers.

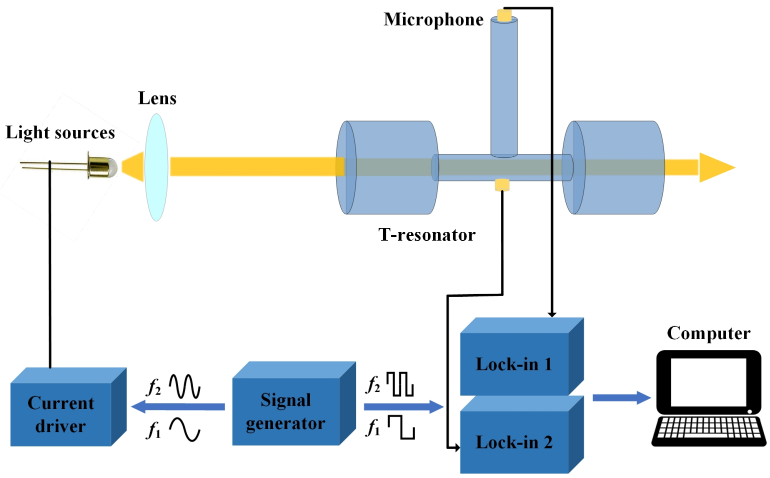

Fig. 2. A schematic of T-resonator-based dual-gas photoacoustic system.

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