H_2S photoacoustic detection with an integrated THz gas sensor for food quality control

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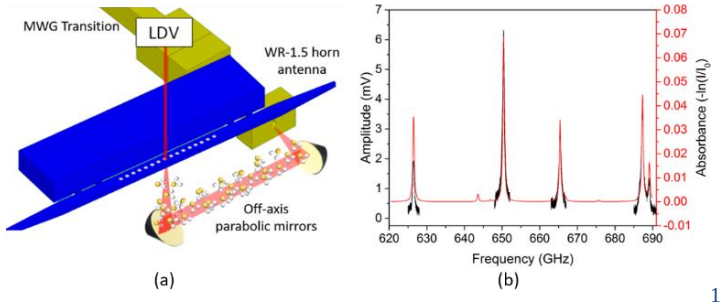
H_2S gas is a toxic molecule emitted by the bacterial growth in food and as such is a great indicator of food spoilage. Monitoring its concentrations to control food quality has been the subject of much research[1], [2]. For instance, in fresh beef meat conserved at 25 °C for 48 hours, the H_2S concentration evolves from 480 ppb to 7.16 ppm [2]. The detection of small H_2S concentrations at sub-ppm levels is necessary to ensure the safety of food consumption. In addition to being an excellent food spoilage indicator, the H_2S gas molecule presents high-intensity absorption peaks in the THz region. THz photoacoustic spectroscopy is a great tool for the detection of such molecules. In [3] we proposed the design of an integrated THz PA gas sensor for monitoring food spoilage. It is based on the confinement of the THz light in a PhC cavity with high Q factors [4] to increase the light-molecules interaction. Gas molecules absorbing the THz modulated light produce sound waves that are enhanced inside an acoustical cylinder which is at the same time the etched hole of the PhC THz cavity and then detected by a Poly-Si microphone covering the bottom of the cylinder. Here we present the detection of H_2S molecules by focusing the THz beam on the Poly-Si membrane and without considering the enhancement inside the THz cavity. A schematic of the experimental setup is presented in figure 1(a). A VDI electronic source is used to generate a THz signal in the 620-690 GHz frequency range with a power varying between 0.4 and 1.1 mW at the horn antenna output. The amplitude of the THz signal is modulated at the mechanical resonance frequency of the membrane (36.5 kHz) with a 100% duty cycle. A laser Doppler vibrometer (MSA-500 Polytec) is used to detect the mechanical displacement of the Poly-Si membrane. The THz emission frequency is controlled and swept using a Labview interface, collecting the LDV data through a lock-in amplifier. Figure 1(b) shows a great agreement between the measured and simulated absorption lines for an H_2S gas concentration of 2% at a pressure of 100 mbar. The PA signal is measured with a 16 ms of lock-in integration time while the THz source emission frequency is swept around 5 different absorption peaks of the H_2S. The simulated spectrum was obtained from Spectraplot based on the HITRAN database by using the same experimental parameters and a 10 cm long gas cell. The minimum detection limit (MDL) describes the sensitivity of the sensor and is defined as the lowest detected concentration with an SNR=1. We observe a MDL of 100 ppm of H_2S at 10 mbar. Higher sensitivity with an MDL of 10's of ppb is expected by coupling the poly-Si membrane to the PhC THz high Q cavity (Q =10000 [4]). This is a first step towards a fully integrated THz PA gas sensor with a sensitivity in the order of 10's ppb.

Figure



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(a) A schematic of the PA experimental setup. (b) The measured PA signal of a 2% concentration of H_2S at a pressure of 100 mbar (black line) and the simulated

References:

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