Development of a Portable Photoacoustic Sensor for Short-Chain Hydrocarbon Isotopologues

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In recent years, photoacoustic spectroscopy (PAS) has evolved from a research subject into a powerful measurement technique with broad applications [1-3]. We leverage the latest developments in laser spectroscopy to archive environmental monitoring, industrial process control, and gas sensing applications to expand on state-of-the-art PAS applications.

This work presents the development of a portable PAS-based sensor for detecting short-chain hydrocarbon isotopologues [4-5]. The system employs Distributed-Feedback Interband-Cascade Lasers (DFB-ICL), enabling ultra-high-resolution spectroscopy in the mid-infrared range with continuous wavelength tuning. It is robust enough for mobile integration and eliminates the need for external mechanical modulation.

Developing a portable PAS sensor presents several technical challenges: (1) Ensuring compatibility between the selected DFB-ICL and target gases, as theoretical absorption spectra may not perfectly match actual molecular behavior. (2) Managing potential incompatibilities between electronic components, digital signal processing limitations, and microphone sensitivity constraints due to the compact measurement cell design. Additional challenges include (3) laser control and signal processing software stability, as well as (4) long-term sensor reliability. Issues such as electromagnetic interference, mechanical stress, and calibration uncertainties could hinder performance, while cross-sensitivity with other atmospheric molecules may affect detection accuracy. We present a systematic evaluation of these risks and propose mitigation strategies to advance PAS technology for real-world applications.

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