# Multimode Laser-Driven CW-THz TDS for Ammonia Gas Sensing

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## 1. Introduction

Terahertz time-domain spectroscopy (THz-TDS) systems based on femtosecond (fs) pulsed lasers have shown great potential in nondestructive and non-contact inspection of semiconductor and biomedical materials [1]. Due to their time-domain measurement approach using mechanical delay scanning, THz-TDS systems can retrieve both amplitude and phase information, enabling their use in gas sensing applications [2]. However, the high cost and bulky nature of femtosecond lasers limit their suitability for practical, on-site, or commercial deployment. Therefore, a more cost-effective alternative is provided by continuous-wave multimode laser diode (cw-MLD) based TDS [3-4]. In this work, we demonstrate that a MLD-THz-TDS system can detect phase shifts caused by ammonia gas at parts-per-million (ppm) levels.

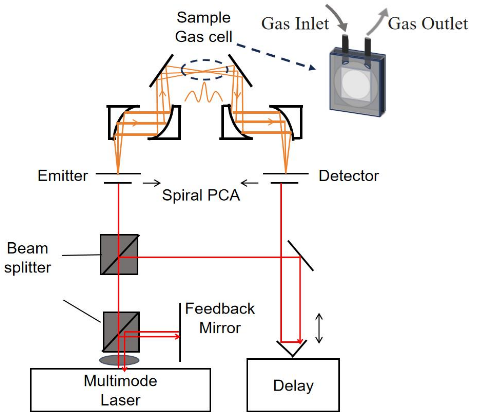


**Fig. 1.** Schematic diagram of the CW-MLD THz-TDS system and gas cell.

## 2. Experiment and Results

The MLD-THz-TDS system, as illustrated in Figure 1, employs commercially available multimode laser diodes (MLDs) with a center wavelength of approximately 660 nm. One part of the laser beam drives a photoconductive antenna (PCA) emitter to generate THz radiation, while the other part passes through a mechanical delay line and is directed to a PCA detector, where it overlaps with the received THz signal for coherent detection. The experimental system has a stability of approximately 7 fs for the time axis..

A gas cell is placed in the THz beam path, as shown in the setup. The cell is primarily constructed of metal, with both ends sealed using 3-mm thick PTFE windows to ensure low-loss THz transmission. Inside the cell, a piece of porous glass with 50 nm pores is used which can trap ammonia molecules. During the experiment, a mixture of ammonia and dry air is continuously introduced into the cell. As the porous glass traps the ammonia molecules, the detected THz time-domain signal begins to shift. By varying the flow rate of the gas, we not only detected the time shift caused by ammonia, but also demonstrated that the magnitude of this shift can be used to estimate the gas concentration.

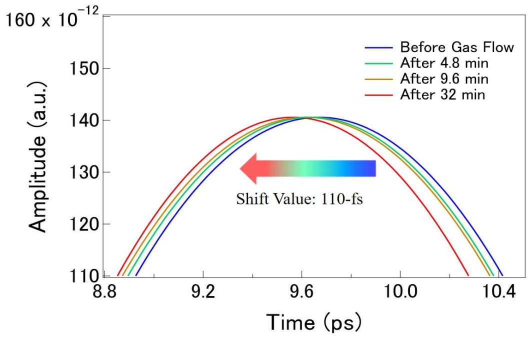


**Fig. 2.** Magnified view of the THz time-domain waveform peak. As ammonia gas was introduced into the cell at a fixed flow rate of 0.5 L/min (4.3 ppm concentration), the peak exhibited a clear time advancement, reaching a maximum shift of 110 fs.

As shown in Figure 2, controlling the flow of air containing 4.3 ppm ammonia with a flow rate of 0.5 L/min, the observed time shift reaches approximately 110 fs which is well above the system's timing uncertainty of 7 fs, clearly indicating a detectable ammonia-induced time shift.

## 3. Conclusions

In this study, we successfully demonstrated the use of a compact and cost-effective MLD-based THz-TDS system for gas sensing. Our system was able to detect a time shift of approximately 110-fs under a 4.3 ppm ammonia concentration. These results highlight the high sensitivity and stability of the MLD-TDS, paving the way for its application in real-time, low-cost gas sensing across various environmental and industrial scenarios.

## Acknowledgement

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## References

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