

Highly-sensitive detection in mid-IR using Solid-state Laser Intracavity Photothermal Sensor (SLIPS)

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We present a unique, miniature double-beam gas sensor configuration where various gaseous compound concentrations with parts-per-billion by volume (ppbv) level detection are selectively measured, utilizing the photothermal (PT) effect. The PT spectroscopy needs an auxiliary laser beam to excite gas molecules that are locally heated due to the absorption effect. This phenomenon induces minuscule changes in the gas refractive index (RI), which are typically measured from 10^{-5} to 10^{-9} . Here, the PT-induced RI changes are detected in a specially formed air-gap section inside the monolithic diode-pumped solid-state laser (DPSSL) resonator ($2 \times 2 \times 14 \text{ mm}^3$) operating at 1064 nm [1]. Variations in gas RI modulate the optical path length of the *probe beam*, which results in its significant optical frequency shift. Note that the *reference beam* does not interact with excited gas molecules (Fig.1), which allows applying a heterodyne detection technique supported by wavelength modulation spectroscopy (WMS) to increase the signal-to-noise ratio (SNR) of the sensor.

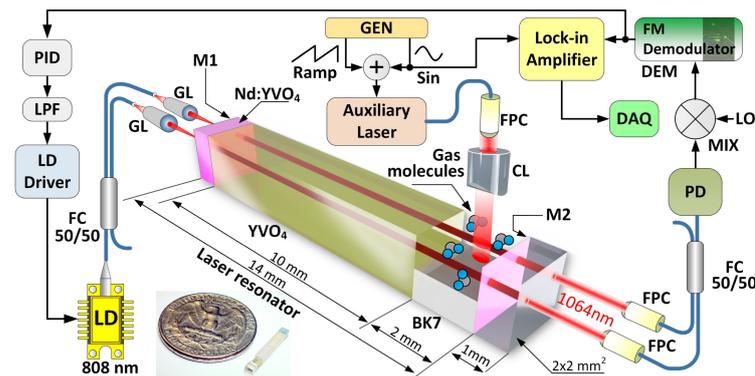


Fig. 1. The experimental setup of the SLIPS; LD – 808 nm pump laser diode, FC- fiber coupler, GEN – function generator, DAQ – data acquisition card, DEM – FM demodulator, MIX – RF mixer, CL – cylindrical lens, LO – local oscillator, PD – photodiode, FPC – fiber pigtailed collimator, GL – GRIN lens, M1 and M2 – laser resonator dielectric mirrors, LPF – low pass filter.

The SLIPS encodes the gas concentration level into frequency variation providing a baseline-free measurement at ppbv sensitivity and thousands of SNR values. Moreover, a single inexpensive near-IR detector realizes the spectroscopic signal readout. Hence, the other detectors are not needed even for measurements of gaseous compounds at mid-IR or far-IR ranges.

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[1] G. Dudzik, K. Krzempek, K.M. Abramski and G.Wysocki, *Sensors and Actuators B: Chemical* **328**, 129072 (2021).