

## Fabry–Perot-based phase demodulation of heterodyne light-induced thermoelastic spectroscopy

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CW-DFB (continuous-wave distributed feedback); FC (fibre collimator); PD (photodetector); QTF (quartz tuning fork); SMF (single-mode fibre). Credit: Ziting Lang, Shunda Qiao, and Yufei Ma



Trace gas sensors are used in different fields. Light-induced thermoelastic spectroscopy (LITES) has extremely high sensitivity and offers non-contact measurement, attracting extensive research attention. In general, the electrical signal amplitude increases linearly with an increase in laser power.

However, <u>thermal noise</u> caused by <u>laser irradiation</u> in <u>electrical signals</u> magnifies exponentially as the <u>laser power</u> increases, restricting the signal-to-<u>noise ratio</u> (SNR) and minimum detection limit (MDL) of a LITES sensor.

A potential solution is demodulating the vibration of the QTF in place of the <u>electrical signal</u>. Fabry–Perot (F–P) interferometers (FPI) are safe, remote, sensitive, anti-electromagnetic interference measurement devices for micro-vibration. For F–P micro-vibration sensors, the intensity demodulation method is typically used. Owing to ambient interference and disturbance of the laser wavelength, the signal becomes unstable.

In a new paper published in *Light: Advanced Manufacturing*, a team of scientists, led by Professor Yufei Ma from National Key Laboratory of Science and Technology on Tunable Laser, Department of Aerospace, Harbin Institute of Technology, China, and co-workers have developed a F–P-based phase demodulation of heterodyne LITES (H-LITES).





a, Using the phase demodulation method, the peak-to-peak values of H-LITES signal were generally consistent, with an average of 55.54° and a standard deviation of 0.64°. The phase demodulation method is immune to disturbances from the laser source, and can produce excellent detection performance even with a low-power probe laser. b, The peak-to-peak values remained constant at wavelengths from 1536 nm to 1555 nm. The phase demodulation method is approximately wavelength-independent, with the same sensitivity at any wavelength; it does not require the wavelength to be fixed at the Q-point, and is immune to laser wavelength disturbances. Q-point drifting due to ambient interference can be overcome using the phase demodulation method in the FPI. Credit: Ziting Lang, Shunda Qiao, and Yufei Ma





a, Using the intensity demodulation method, the peak-to-peak values of the H-LITES signals gradually decreased over time; the stability was poor. b, The peak-to-peak values of the H-LITES signals obtained using the phase demodulation method were consistent, demonstrating that FPI-based H-LITES with phase demodulation method had excellent system stability. Credit: Ziting Lang, Shunda Qiao, and Yufei Ma

The F–P cavity is comprised of an end-face of a single-mode fiber and a side of a prong of the QTF. When the QTF vibrates due to the effect of light-induced thermoelastic, the F–P cavity length varies; thus the phase changes. Because the vibration of the QTF is proportional to the gas concentration, the concentration can be inverted linearly by demodulating phase.

Compared to the H-LITES signal obtained directly from the electrical signal, the signal based on FPI had a greater SNR. The phase demodulation method can produce better detection performance, linear response, and long-term stability than the intensity demodulation method.



Using the phase demodulation method, the signal peak-to-peak values are independent from power and wavelength. The phase demodulation method is immune to interference from the laser source and wavelength, and can resolve the issue of Q-point drifting due to ambient interference.

**More information:** Ziting Lang et al, Fabry–Perot-based phase demodulation of heterodyne light-induced thermoelastic spectroscopy, *Light: Advanced Manufacturing* (2023). DOI: 10.37188/lam.2023.023

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