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A novel wavelength-modulation spectroscopy gas sensor for methane detection

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We present a novel gas sensor based on wavelength modulation spectroscopy to measure methane concentrations in the farming and food industry. Methane is a highly impactful greenhouse gas, and its monitoring is essential for environmental surveillance, the development of low-emission breeding strategies, and the detection of leaks across production and processing stages. Moreover, captured biogas from wastewater treatment plants, primarily methane and carbon dioxide, can be repurposed as renewable natural gas, transforming emissions into a valuable energy resource. The proposed sensor uses a broadband 1685 nm super luminescent diode (SLD) coupled to an aperiodic Fiber Bragg Grating (FBG), whose reflectance spectrum mimics methane absorption features between 1630 nm and 1675 nm. A stacked piezoelectric actuator periodically modulates the FBG spectral response which is recovered by a circulator and routed to a 50:50 coupler. The signal is then split in two paths: one goes directly to a balanced photodetector, while the other passes through a methane sample before reaching the detector. The latter stage was implemented in two different ways: a multi-pass fibre-coupled 80 cm gas cell and a 450 cm free-space optics path. Methane was successfully detected at concentrations of 500 ppm, 200 ppm, 100 ppm, 50 ppm, 10 ppm, and 5 ppm in the fibre-coupled setup, and at 50,000 ppm, 5,000 ppm, 500 ppm, and atmospheric levels in the free-space setup. Specificity was confirmed by testing 50 ppm methane against 2.5% carbon dioxide, a potential interloping species. These results demonstrate that the proposed instrument is a compact, selective, and highly sensitive tool for methane characterisation. Future developments include the employment and simultaneous testing of different gas species, mitigation of atmospheric scintillation, environmental vibrations and jitter-induced coupling noise.

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