

A Light-Emitting Diode- (LED-) Based Absorption Sensor for Simultaneous Detection of Carbon Monoxide and Carbon Dioxide

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Abstract

A sensor was developed for simultaneous measurements of carbon monoxide (CO) and carbon dioxide (CO₂) fluctuations in internal combustion engine exhaust gases. This sensor utilizes low-cost and compact light-emitting diodes (LEDs) that emit in the 3–5 μm wavelength range. An affordable, fast response sensor that can measure these gases has a broad application that can lead to more efficient, fuel-flexible engines and regulation of harmful emissions. Light emission from LEDs is spectrally broader and more spatially divergent when compared to that of lasers, which presented many design challenges. Optical design studies addressed some of the non-ideal characteristics of the LED emissions. Measurements of CO and CO₂ were conducted using their fundamental absorption bands centered at 4.7 μm and 4.3 μm, respectively, while a 3.6 μm reference LED was used to account for scattering losses (due to soot, window deposits, etc.) common to the three measurement LEDs. Instrument validation and calibration was performed using a laboratory flow cell and bottled-gas mixtures. The sensor was able to detect CO₂ and CO concentration changes as small as 30 ppm and 400 ppm, respectively. Because of the many control and monitor species with infra-red absorption features, which can be measured using the strategy described, this work demonstrates proof of concept for a wider range of fast (250 Hz) and low-cost sensors for gas measurement and process monitoring.

Keywords

Absorption spectroscopy, carbon monoxide, CO, carbon dioxide, CO₂, light emitting diodes, LEDs, mid-infrared, MIR

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“...This sensor uses three LEDs to cover three different wavelength regions: a reference LED (I_0 in Beer’s law) centered near 3.6 μm, one near 4.2 μm for detecting CO₂, and one near 4.7 μm for detecting CO. ...Figure 1 shows the spectral absorption features of several important gases within the spectral range of mid-infrared (MIR) LEDs (LED from Ioffe Institute/MIRDOG, Russia)....”