Nonlinear Interferometry for Mid-Infrared Gas Sensing

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We report on the development and experimental demonstration of a gas sensing technique based on nonlinear interferometry, which enables spectroscopic measurements in the mid-infrared (mid-IR) range through the detection of visible photons. This approach harnesses the phenomenon of induced coherence between photon pairs generated via spontaneous parametric down-conversion (SPDC) in nonlinear crystals [1-3]. When two nonlinear crystals are placed within an interferometric configuration, visible signal photons originating from different crystals can interfere, while their entangled counterparts (idler photons) probe the sample in the mid-IR region.

The interference pattern of the visible photons encodes information about the absorption and refractive index of the medium interacting with the undetected mid-IR photons. We implemented this method using lithium niobate ($LiNbO_3$) and silver thiogallate ($AgGaS_2$) crystals [4,5], covering an idler wavelength range of 4 to 6.5 μm and 7 to 9 μm, respectively. Gas mixtures containing CO_2 and N_2O were introduced into a vacuum chamber placed in the idler beam path. Changes in fringe visibility and phase shifts in the visible interference pattern allowed us to extract spectroscopic signatures corresponding to known mid-IR absorption features of the target gases, particularly around 4.3 and 4.5 μm.

The results demonstrate strong agreement with HITRAN reference [6] data and validate the feasibility of using this technique for gas detection without the need for cryogenically cooled or inefficient IR detectors. This method offers a new pathway for compact, sensitive, and cost-effective mid-IR spectroscopy, with promising applications in atmospheric monitoring, industrial emissions control, and environmental sensing.

References

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