Multiple Gas Detection by Cavity-enhanced Raman Spectroscopy with Sub-ppm Sensitivity

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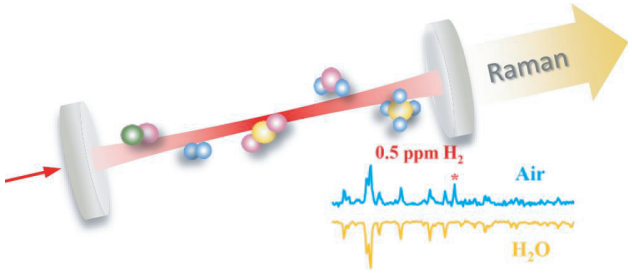
Abstract— Rapid detection of multi-component gases at trace levels (below ppm) finds broad applications across various fields. Raman spectroscopy has remarkable potential in quick diagnosis of samples by simultaneously identifying different molecules; however, its practical application is often impeded by sensitivity limitations. Here we present a cavity-enhanced Raman spectroscopy (CERS) instrument for detecting trace gases. We employed precision laser frequency locking techniques to stabilize a narrow linewidth 532 nm laser with a power of several hundred milliwatts onto a high-finesse optical resonator. Consequently, we achieved kilowatt-level laser pumping inside the cavity. This allows for continuous, real-time, high-precision quantitative monitoring of diverse atmospheric constituents such as carbon dioxide, hydrogen, oxygen, nitrogen, and methane, spanning a dynamic range from 0.07 ppm to 1. We successfully applied this sensor to trace detection in various systems, such as environmental air, natural gas, and sulfur hexafluoride reference gases, confirming its capability for trace quantification of both organic and inorganic gas components. Our future endeavors will focus on developing CERS devices as reliable detection probes, enabling high-selectivity, high-sensitivity, low-cost, and miniaturized on-site measurement of multiple gases, which has substantial potential across scientific and industrial applications.



REFERENCES

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