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Benzene Monitoring Using Laser Difference Frequency Spectroscopy

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There is considerable interest in the detection of volatile organic compounds (VOCs) in the atmosphere because of their atmospheric reactivity. The need for identifying and quantifying VOCs has led to the development of measurement techniques such as chromatography coupled with mass spectrometry, Fourier transform spectroscopy, and laser spectroscopy. Laser absorption spectroscopy offers the advantage of highly selective detection and real-time measurement with detection sensitivities in the ppm to ppt range.

In this paper, the feasibility of benzene (C6H6) concentration measurement by using mid-infrared laser absorption spectroscopy is reported. The spectrometer is based on laser difference-frequency generation (DFG) by mixing of two Ti:Sapphire lasers in a GaSe nonlinear crystal. The laser has a repetition rate of 10 kHz and a maximum pulse energy of 1 mJ. Tunability of the laser is achieved by using a Q-switching mode with simultaneous generation in two wavelengths. The laser has been developed on the basis of the CW 3 kW CO2 laser. The laser can measure benzene in ambient air at a pressure of 1 atm.

A 10-liter glass flask was used for the preparation of benzene trace gas samples. The flask was filled with ambient air at a pressure of 1 atm and an accurately weighed sample of pure benzene gas was injected into the flask. The benzene gas mixture was then introduced into the absorption cell at a reduced pressure in the range of 1 to 10 mbar. Benzene absorption lines in the 2.18 micrometer range were selected for the concentration measurement. The signal-to-noise ratio of 20 was deduced from the spectrometric measurement, yielding a minimum detectable path-integrated concentration of 1 ppm.

References

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Rapidly Tunable 2.5 kW CO2 Laser Operating in Single-frequency and Two-wavelength Modes for Pollution Monitoring, Laser and Scientific Applications


The output of the experimental setup is reported. The laser has been developed with a maximum output power of 2.5 kW. Single-frequency operation is realized in the range of 10 kHz with peak pulse power of 100 kW. The laser is equipped with three accessory units to provide a variety of operation modes:

1. Single-frequency mode with a capability of measurement line tuning (about 70 lines in the CO2 band) with a maximum output power of 2.5 kW.
2. The mode with simultaneous two-wavelength laser output, with maximum total power of 2.5 kW.
3. The mode with rapid tuning of the generation line (with an accuracy of ±10⁻³, a maximum tune rate of 10⁻⁵ Hz/s).
4. The mode of rapid tuning of a two-wave simultaneous generation in neighboring spectral lines (in particular, in lines from different isotopes and bands, more than a thousand combinations with a peak power of 100 kW with a repetition rate of 10 kHz, with a maximum output power of 2.5 kW).
5. Repetition rate Q-switching mode with a peak pulse power of 100 kW and an average power of 2.5 kW.

It should be particularly emphasized that the two-wavelength injection is realized in single mode with a relative intensity of 10⁻¹ compared to the fundamental wave. It generates a substance of high power with a relative intensity of 10⁻¹ compared to the fundamental wave. It enables the performance of Q-switching with two wavelengths simultaneously, with a peak output power of 100 kW and an average power of 2.5 kW.

In the case of simultaneous generation of two wavelengths, the laser monitors two power levels with a relative intensity of 10⁻¹. Hence, the use of the laser is promising in the following areas:

1. Single-frequency generation mode makes it possible to use this laser as a radiation source for the laser Doppler velocimeter with high performance and reliability (in principle). The accuracy of determination of the object's velocity is 0.1 m/s in the case of frequency stabilization at the level 10⁻³.
2. Two-wavelength mode will make it possible to increase substantially the range of laser system for measuring the object's velocity and for improving the accuracy of determination of the object's velocity in the case of frequency stabilization at the level 10⁻⁴.
3. With rapid frequency tuning mode and a capability of measurement of the two wavelengths simultaneously, the laser can be used to detect the Doppler shift of two laser frequencies in the case of dual-wavelength measurement.