FM Spectroscopy of NH2 and NOx Chemistry

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Overview

The principle of frequency modulation (FM) spectroscopy is differential absorption detection of two closely spaced sidebands of the analysis laser beam. Passage through the shock tube equally influences both sidebands. Therefore FM detection should be insensitive to the typical shock tube related noise sources and potentially allow a considerable improvement in detection sensitivity compared to conventional laser absorption techniques.

Passing a narrow-linewidth laser beam with an optical frequency wL through an electro-optical crystal and modulating the refractive index of the crystal with an RF frequency wRF results in a phase-modulated laser beam with a central frequency wL and sidebands with the frequencies wL + wRF and wL - wRF . In the absence of any absorber, each of the two sidebands forms a beat signal with the central band. The two beat signals are displaced in phase by 180° and equal in amplitude so that they completely cancel and, ideally, no RF amplitude modulation is observed. When the phase-modulated beam propagates through an absorbing medium (NH2 radical in our case), differential absorption or phase shift between the two sidebands leads to imperfect cancellation of the two beat signals and to an amplitude modulation of the laser beam.

In the limit of small absorption, dispersion, and modulation index the signal detected at the modulation frequency is given by

$$I_{FM} = M \times I_0 \times [(d_+ - d_-) \cos q + (f_- - 2f_c + f_+) \sin q]$$

where M is the sideband modulation index; I0 is the intensity of the carrier beam; d+ and d- are the amplitude attenuations at the higher and lower sideband frequencies, respectively; f- , fc , and f+ are the optical phase shifts at the sideband and carrier frequencies, respectively; and q is the absolute phase between the reference and the beat signal at the mixer. If the phase q is aligned to q = 0° the signal becomes proportional to the differential absorption between the two sidebands only.

References

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