NOISE IMMUNE CAVITY ENHANCED OPTICAL HETERODYNE VELOCITY MODULATION SPECTROSCOPY

BRIAN SILLER, ANDREW MILLS, MICHAEL PORAMBO, *Department of Chemistry, University of Illinois at Urbana-Champaign, Urbana, IL 61801*; BENJAMIN McCALL, *Departments of Chemistry and Astronomy, University of Illinois at Urbana-Champaign, Urbana, IL 61801*.

The technique of Cavity Enhanced Velocity Modulation Spectroscopy (CEVMS) has recently been developed[a b]. By demodulating the detector signal at twice the plasma modulation frequency ($2f$), the velocity-modulated ionic absorption signal can be extracted. Although the concentration-modulated excited neutral molecules are also observed at $2f$, the ion and neutral signals can be distinguished and separated with phase-sensitive demodulation.

The optical cavity provides two major benefits. It increases both the optical path length and the intracavity laser power by a factor of $2\times\text{Finesse}/\pi$. The multipass advantage allows for much longer path length than was previously possible with unidirectional multipass White cells. The power enhancement combined with perfectly overlapped counterpropagating beams within the cavity allows for sub-Doppler spectroscopy. Although CEVMS showed much potential, its sensitivity was ultimately limited by electronic noise from the plasma interfering with the cavity-locking electronics.

We have further improved upon CEVMS by combining it with Noise Immune Cavity Enhanced Optical Heterodyne Molecular Spectroscopy (NICE-OHMS). The laser is frequency modulated at precisely an integer multiple of the free spectral range of the optical cavity; this allows the heterodyne sidebands to be coupled into the optical cavity. Heterodyne detection of the cavity leak-out is immune to noise in the laser-cavity lock, and $2f$ demodulation further decreases electronic noise in the system and retains ion-neutral discrimination.

The additional level of modulation beyond ordinary CEVMS has the added advantage of enabling the observation of both absorption and dispersion signals simultaneously by using two RF mixers, each driving its own lock-in amplifier. In a single scan, four distinct signals can be obtained: absorption and dispersion for ions and excited neutrals. The technique has been demonstrated in the near-IR for N_2^+.

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[a] B. M. Siller, A. A. Mills and B. J. McCall, *Opt. Lett.* **35**, 1266-1268 (2010)

[b] A. A. Mills, B. M. Siller and B. J. McCall, *Chem. Phys. Lett.* **501**, 1-5 (2010)