NICE-OHMS – A Frequency Modulated Cavity Enhanced Spectroscopic Technique for Detection of Gases down to the 10^{-12} cm^{-1} $Hz^{-1/2}$ Range

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Noise-Immune Cavity-Enhanced Optical Heterodyne Molecular Spectroscopy (NICE-OHMS) is a laser-based spectroscopic technique originally developed for high precision frequency standard applications at JILA in Boulder, CO, USA, with unique properties. By combining an external cavity for increased interaction length with the sample with frequency modulation for reduced influence of noise, the technique achieves an extraordinary high sensitivity. In addition, by choosing the modulation frequency equal to the free-spectral range of the cavity, the technique obtains an immunity to laser frequency noise, which implies that detection can be made as if the cavity would not be there. Finally, both Doppler-broadened and Doppler-free signals can be measured in either absorption or dispersion mode of detection. In its first realization, based on a well stabilized solid state laser, an impressive absorption sensitivity of 10^{-14} cm^{-1} was demonstrated for molecular species detection.[1] This is several orders of magnitude better than any other optical detection technique can achieve, which gives NICE-OHMS a large potential for sensitive trace gas analysis.

However, the technique has, for a long time, been considered too complex to be used for practical trace gas analysis. To make the technique more applicable to trace gas detection, our research group has challenged this and is developing the NICE-OHMS technique further, with the main aim of reducing the complexity of the instrumentation while keeping as much as possible of the high sensitivity.[2] The systems developed so far are based upon narrowband fiber lasers, as well as a narrowband DFB laser, and have, whenever possible, utilized fiber-coupled components for a more compact realization. Using C_2H_2 as the pilot species, we have scrutinized the dependence of the technique on a variety of parameters for optimum sensitivity, selectivity, and thereby its applicability. Using a cavity with a finesse of 5700, we have presently demonstrated an absorption sensitivity of 5.6×10^{-12} cm^{-1} $Hz^{-1/2}$, or $\Delta I / I$ of 7.2×10^{-11} over 10 sec, which allows detection of low ppt concentrations of acetylene in atmospheric samples.[3] The talk will provide a short description of the basic features of the technique and some of the most important results.

[1] J. Ye, L. S. Ma, and J. Hall, *"Ultrasensitive detection in atomic and molecular physics: demonstration in molecular overtone spectroscopy"*, J. Opt. Soc. Am. B **15**, 6-15 (1998).

[2] A. Foltynowicz, F. M. Schmidt, W. Ma, and O. Axner, "*NICE-OHMS: Current status and future potential"*, Appl. Phys. B **92,** 313-326 (2008).

[3] P. Ehlers, I. Silander, J. Wang, and O. Axner, "*Fiber-laser based NICE-OHMS instrumentation for Doppler broadened detection in the 10^{-12} cm^{-1} $Hz^{-1/2}$ range"*, To appear in JOSA B (2012).