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Cavity enhanced direct frequency comb spectroscopy

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Cavity enhanced direct frequency comb spectroscopy (DFCS) combines the broad bandwidth and precision frequency capabilities of the frequency comb with the high sensitivity to optical loss of a high finesse optical cavity. Precise control of an optical frequency comb allows the individual comb components to be coherently coupled to corresponding resonance modes of the high finesse optical cavity. By constructing the cavity from broad bandwidth, low dispersion reflectors, large spectral bandwidths ranging from 15% to 40% of the center optical frequency can be efficiently coupled. The long cavity lifetime dramatically enhances the effective interaction between the light field and intracavity matter, making it a very sensitive approach for measurement of optical losses. The light transmitted from the cavity is spectrally resolved with a virtually-imaged phased-array spectrometer to recover the optical loss information with resolutions ranging from a gigahertz to several kilohertz.

Recent experiments conducted in our laboratory have demonstrated the use of cavity enhanced DFCS for trace detection of molecular components within a host gas and the mapping of the quantum state distribution of cold molecules in a supersonic beam. In both cases, the wide bandwidth and ultrasensitive nature of the femtosecond enhancement cavity enable real time detection of multiple molecular species in a massively parallel fashion, greatly reducing the time required for molecule and state identification. We will present a brief overview of the properties of femtosecond enhancement cavities that make them suitable for these types of experiments and discuss the underlying physics of the coupling between a femtosecond comb and an external optical cavity. We will then discuss the detailed experimental implementation of the cavity-enhanced DFCS, with corresponding results illustrating the capabilities of our current systems. Finally, we will discuss our visions for future scientific explorations using these unique techniques.