Abstract number: I12
Invited

Precision spectroscopy enabled by optical cavities and frequency combs

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Our laboratory leverages recent developments in optical cavities and optical frequency combs to perform highly precise and accurate measurements of atomic and molecular species as well as to perform physical metrology. These efforts span a wide variety of length scales from macroscale optical cavities near a meter in length to cavity optomechanical devices with lengths of only a few hundred micrometers.

On major effort in our group is to utilize novel cavity ring-down spectroscopy methods to produce high accuracy line shape parameters for atmospherically relevant species. Much of this work is done to enable retrievals of greenhouse gas concentrations from satellite and ground-based remote sensing platforms. Recently, we have demonstrated line intensity uncertainties below 0.1% for carbon dioxide[1] as well as transition frequency uncertainties near 200 Hz[2]. These measurements have been enabled by high finesse optical cavities, linkage to a self-referenced optical frequency comb, and electro-optic-modulator-based rapid scanning approaches[3].

Further, we have been developing devices and methods for the use of cavity optomechanical devices for high accuracy acceleration measurements. These devices contain few-hundred-micron-long Fabry-Pérot optical cavities in which one of the mirrors is suspended on a series of narrow beams. This allows for readily observable cavity length changes in the presence of external acceleration. We have demonstrated thermomechanically noise limited performance with sensitivities near 30 $ng/\sqrt{Hz}$[4]. Finally, we have developed electro-optic frequency comb approaches for rapid interrogation of the cavity displacement, allowing for dramatically improved dynamic range[5].

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