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Long-path atmospheric measurements using dual frequency comb spectroscopy

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Dual frequency comb spectroscopy (DCS) is a rapidly evolving technique that provides a high-resolution, broadband spectrometer with no instrument lineshape and near perfect frequency calibration. It relies on a laser frequency comb, whose output is composed of hundreds of thousands of perfectly spaced, discrete wavelength elements or comb teeth, which act as a massively parallel set of single frequency lasers with highly stable, well-known frequencies. A second frequency comb with slightly offset comb teeth is used to rapidly read out the spectrum with high resolution. We have developed a fieldable DCS system operating in the 1.6 μm spectral region for greenhouse gas measurements across 0.2-12 km open paths. In a recent measurement intercomparison, we have found that the instrument has concentration accuracy of better than 1 ppm CO_2 and 20 ppb CH_4. The measured CO_2 precision over a 2-km path is 0.85 ppm in 32 seconds, improving to 0.17 ppm in 1024 seconds. For CH_4, the precision is 9.1 ppb in 32 seconds, improving to 1.17 ppb in 1024 seconds. We have used this system for regional carbon monitoring across the city of Boulder, CO. We have also demonstrated spatial scanning (via a retroreflector mounted on a small quadcopter) for emission-rate quantification. In addition, we have extended the system operation to 2 μm and have demonstrated a system operating from 3 to 5 μm. This type of broadband open path dual-comb spectrometer will enable detection of an ever-wider range of molecules and isotopes. In this talk, I will discuss the status of open-path dual-comb spectroscopy and its future potential.