CAVITY-ENHANCED DUAL-COMB SPECTROSCOPY WITH QUANTUM CASCADE LASERS IN THE MOLECULAR FINGERPRINT REGION

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Optical frequency combs pose a promising approach to molecular spectroscopy and trace gas detection, offering the benefits of both broadband and high-resolution sources. When combined with enhancement cavities, extremely long effective pathlengths can be achieved in a benchtop system. Combining the benefits of enhancement cavities and combs can be technically challenging, and often requires multiple feed-back loops which preclude measurements in the field. There is also desire to push direct frequency comb spectroscopy into the mid-infrared where strong fundamental vibrational bands exist, which adds additional difficulty.

Here, we demonstrate cavity-enhanced dual-comb spectroscopy in the mid-infrared for the first time, covering 60 cm^{-1} centered at 9.4 μm using quantum cascade lasers (QCLs). The cavity length was set such that the repetition rate of the probing comb matched an integer multiple of the cavity's free spectral range. In order to avoid feedback from reflections off the cavity, a bow-tie geometry was used. The frequency comb that was transmitted from the cavity was heterodyned with a second QCL frequency comb and the signals were processed using a commercial dual-comb spectrometer. The high power-per-mode and heterodyne detection provided high signal-to-noise on the transmitted light, while the large difference in repetition rate between the combs allowed for high temporal resolution. The system was completely free running, allowing for robust and sensitivity measurements. A demonstration using trace methanol was performed to characterize the sensitivity of the system. The effective pathlength was increased to 285 m (cavity Finesse of 800), and the system reached a sensitivity of 2.7×10^{-8} cm^{-1} per spectral element.