Development of Open-Path Cavity Ring-Down Spectroscopy Sensors for Methane and Ammonia

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We present the development of open-path cavity ring-down spectroscopy (CRDS) for the measurement of atmospheric methane and ammonia in the mid-infrared (MIR). In comparison to more common closed-path instruments, open-path CRDS sensors have the potential for lower mass (<5kg) and power (<50W), enabling more remote deployments and use on small unmanned aerial systems (sUAS). Such sensors are useful for studies of emissions from oil and gas extraction, and agricultural operations. An initial proof of principle open-path methane CRDS sensor has been developed at 1.73µm to investigate sensitivity, effects of mirror reflectivity degradation and aerosol particles. A simple purge system, utilizing a small HEPA filter and diaphragm pump (<50 g) was developed to maintain mirror reflectivity. Mirror reflectivity (R>0.99995) was preserved over long duration testing (>100 hrs) in the laboratory, outside and in the presence of high aerosol concentrations. Aerosol particles in the cavity contribute to quasi-constant background absorption (particles <1 µm) as well as fluctuations (varying presence of particles >1µm). A software filtering technique, which bins points by frequency and time, was implemented to mitigate the particle induced fluctuations. Binning absorption measurements in a small frequency range, outliers due to aerosols are removed and the spectral signal preserved. Using these approaches, a noise equivalent sensitivity of ~3 x 10^{-10} cm^{-1} (in 1 s) has been demonstrated, within a factor of ~3 of closed-path measurements. Comparisons were made against a commercial closed-path CRDS instrument (Picarro 2203) during a controlled release of methane in a warehouse, partially open to the outdoors, with good agreement. Ongoing efforts to develop open-path CRDS sensors utilizing strong fundamental vibration bands in the MIR will also be discussed, specifically an ammonia sensor at 10.3 µm (with a quantum cascade laser) and methane sensor at 3.65 µm (using an interband cascade laser).