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Area Source Emission Quantification Applying Multi-Beam Open Path Laser Dispersion Spectroscopy

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Quantifying emissions for area sources such as landfills, poultry farms and oil and gas facilities is important to establish effective mitigation policies. Furthermore detecting, localising and quantifying fugitive emissions with greater accuracy at shorter temporal scales supports emission reduction from industrial activities. At the shorter temporal scales, mobile point sensors or a stationary distributed networks of point sensors coupled with atmospheric models are widely used monitoring systems for emission quantification. However mobile monitoring solutions are not continuous which lead to misrepresentation of emission by not taking into account temporal and seasonal effects. Distributed networks require significant maintenance and can be costly to set up. We will present results from controlled release studies applying a recently developed technique for continuous monitoring using long range Mid-infrared open path instrument with robust collocated equipment. The instrument applied Laser Dispersion Spectroscopy (LDS), a new approach to tuneable diode laser spectroscopy delivering unique benefits for long open-path molecular sensing [1,2]. Contrary to standard absorption techniques that rely on measuring variations of transmitted light intensity to derive gas concentration, LDS-based instrument derives concentration from variation in refractive index induced by molecular resonance. This quantity is deduced from the phase variations of the detected light, which yields unique sensing benefits including immunity to transmitted intensity fluctuations, large and linear measurement dynamic range and improved molecular selectivity. As a result, LDS is particularly relevant to real world deployment for long open path sensing systems and “dirty” environments, where transmitted signals are bound to fluctuate.

The development of an LDS open-path sensor targeting atmospheric methane and with programmable fast scanning capability will be described. Early results from a Mid-IR open path Ammonia system will also be described. The principles underpinning the sensor will be presented as well as its field deployment during a campaign of controlled methane test releases. In the field, the instrument is coupled with an array of 7 retroreflectors and a 3D ultrasonic anemometer to measure methane concentrations over a wide area with beam angle and beam length diversities. The spatial scans are made at a high temporal resolution ($\sim$1s per spatial scan). A total of 17 calibrated gas releases were carried out from 2 x 2 m diffuse area sources on the ground to evaluate the instrument performance and demonstrate source mapping and quantification. The path averaged gas concentrations and uncertainties retrieved from the instrument were processed using LightSource™, a new proprietary mapping solution from Shell that maps multiple emission sources and estimates their respective mass release rates. LightSource employs a Gaussian plume atmospheric eddy dispersion forward model using Bayesian statistics and Markov chain to solve the inverse gas transport problem that best explains the retrieved concentrations given wind data.

The campaign demonstrated the high level of performance of the system for precision in concentration measurement ($\sim$20 ppbv in 100 ms over a 100 m single path), harsh weather conditions (fog, rain) and spatial scanning speed. The accurate mapping and quantification of methane sources of $\sim$1.2 kg/h was successfully demonstrated, even for sources outside the beam arrays, which is usually not achievable with tomographic, multi-instruments systems.