An open-path QCL-based sensor for fast-response and high-sensitivity measurements of atmospheric ammonia

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Abstract

The paper presents a high-precision, fast-response, and low-power open-path quantum cascade laser (QCL) based sensor for measuring atmospheric ammonia (NH3). The sensor has a detection limit (1σ) of 0.53 ppbv at a 10 Hz sampling rate, with power consumption as low as 50W. The performance of the sensor fully meets the technical requirements for the eddy covariance (EC) flux measurement of NH3. The EC measurement system based on the sensor has a lower detection limit of around 17 ng m-2 s-1. This NH3 sensor shows a wide range of environmental adaptability, being suitable for versatile deployment under different field conditions.

Keywords: open-path, ammonia flux, eddy covariance, QCL

1. Introduction

Fertilization and livestock are the two main anthropogenic sources of ammonia. Ammonia is easily diffused and deposited, so its concentration in the atmosphere varies widely. Meanwhile, ammonia gas has strong adsorption and viscosity. Conventional NH_3 sensors are subject to drawbacks, such as slow response time, limited precision, intensive maintenance, or high power consumption due to the use of the closed-path tube, optics, and vacuum pump.

We have developed an open-path QCL-based NH_3 sensor with optical mirrors exposed to the environment to detect the absorption spectrum of the NH_3 molecule. There is no delay due to sample adsorption. The signal response time can be as short as 0.1 s with a detection limit (1σ) of 0.53 ppbv.

2. Sensor Design and Performance

The sensor is based on second-harmonic (2f) wavelength modulated laser absorption spectroscopy technique (WM-LAS), which employs a distributed-feedback semiconductor QCL (DFB-QCL) and a thermoelectrically cooled mercury cadmium telluride (MCT) detector. An open-path Herriott cell configuration with a 0.5 m physical path and 46 m optical path-length is used for selective and sensitive detection of the mid-infrared absorption transition of NH_3 at 9.06 μm (Miller et al., 2014). The sensor has a precision (1σ noise level) of 0.53 ppbv and 0.15 ppbv at a sampling frequency of 10 Hz and 1 Hz, respectively. The sensor has a weight of ~7 kg and dimensions of 84 cm (length) and 20 cm (diameter). It can be powered by rechargeable lithium batteries, with a total power consumption of as low as 50 W.

3. Eddy Covariance Flux Measurement

With the good performance in terms of response time and precision, this sensor is an ideal tool for NH_3 flux measurements based on the eddy covariance (EC) technique (McDermitt et al., 2011). Fig. 1 shows an EC measuring system including the presented NH_3 sensor. Experiments on a rice paddy field showed that the lower detection limit of the EC system for NH_3 flux was around 17ng m^{-2} s^{-1}.

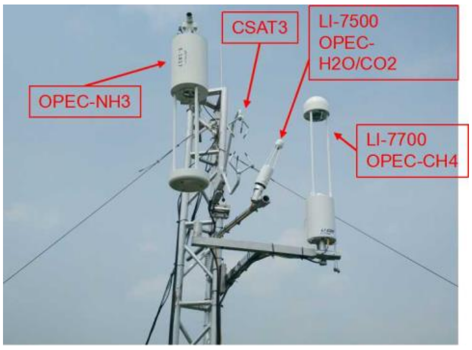

Fig. 1. An eddy covariance measuring system based on the presented NH_3 sensor (OPEC-NH3), a sonic anemometer (CSAT3), a CO_2/H_2O analyzer (LI-7500) and a CH_4 analyzer (LI-7700).

References

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