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Multi-Component Environmental Gas Sensing using Dual-Wavelength Quantum Cascade Lasers

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The sensitive and selective observation of air pollutants and greenhouse gases is of great importance for our understanding of their sources and sinks. Measurements at various spatial and temporal scales are, for example, required for air pollution modelling and validation of emission inventories. Infrared laser absorption spectroscopy is frequently the method of choice, offering outstanding performance and reliability. Most often, however, this technology is used in as “one-species-one instrument” solution because of the narrow spectral coverage of DFB-lasers. This can be overcome by combining novel dual-wavelength continuous wave (cw) Quantum Cascade Lasers (QCLs), providing unique solutions in compact laser absorption spectrometers for environmental monitoring of multiple species in a single instrument.

In this work, multiple dual-wavelength cw DFB-QCLs [1-3] are combined into a single compact laser absorption spectrometer to measure up to nine different compounds. Three different configurations of dual-wavelength QCLs were developed and applied to gas sensing: Twin DFB QCLs, Neighbor DFB QCLs and Vernier-tuning devices. The lasers are driven time-multiplexed in intermittent cw mode [4] sharing a single detector. The transmission spectra of each QCL section are recorded by an FPGA-based data acquisition and pre-processing system with a sampling rate of 125 MS/s and 14 bit resolution. The spectra are averaged in real-time and then transferred to a small computer for spectral analysis. Atmospheric measurements of the greenhouse gases CO_2, N_2O and CH_4, and the pollutants CO, NO, NO_2, O_3, SO_2 and NH_3 in a single optical setup are presented. Furthermore, the instrument performance and comparison to standard air-quality monitoring instrumentation are discussed. The results demonstrate that spectrometers using dual-wavelength QCLs can serve as an all-in-one solution for environmental monitoring stations. They significantly reduce the footprint and cost by replacing several instruments, while delivering direct, selective, and precise measurements of all target molecules.

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