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Multi-species trace gas analysis with dual-wavelength quantum cascade laser

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Simultaneous detection of multiple gas species using mid-IR laser spectroscopy is highly appealing for a large variety of applications ranging from air quality monitoring, medical breath analysis to industrial process control. However, state-of-the-art distributed-feedback (DFB) mid-IR lasers are usually tunable only within a narrow spectral range, which generally leads to one-laser-one-compound measurement strategy. Thus, multi-species detection involves several lasers and elaborate beam combining solutions [1]. This makes them bulky, costly, and highly sensitive to optical alignment, which limits their field deployment.

In this paper, we explore an alternative measurement concept based on a dual-wavelength quantum cascade laser (DW-QCL) [2]. Such a laser can emit at two spectrally distinct wavelengths using a succession of two DFB gratings with different periodicities and a common waveguide to produce one output beam. The laser design was optimized for NO_x measurements and correspondingly emits single-mode at 5.26 and 6.25 μm. Electrical separation of the respective laser sections makes it possible to address each wavelength independently. Thereby, it is possible to detect NO and NO_2 species with one laser using the same optical path, without any beam combining optics, i.e. in a compact and cost-efficient single-path optical setup.

Operated in a time-division multiplexed mode, the spectrometer reaches detection limits at 100 s averaging of 0.5 and 1.5 ppb for NO_2 and NO, respectively. The performance of the system was validated against the well-established chemiluminescence detection while measuring the NO_x emissions on an automotive test-bench, as well as monitoring the pollution at a suburban site.

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