Applications of quantum cascade lasers (QCLs) in sensitive and reliable trace gas sensors require stable long-term operation, in particular with respect to their spectral properties. In this work, we present the results of an experimental study of the frequency stability of a QCL continuously assessed over a period of two months. In addition, we also investigated a possible change in the noise properties of the laser during the same period by regularly measuring its voltage flicker noise. Such study is important for the long-term operation of sensitive laser-based gas sensors as developed in IrSens-2.

Motivation

Spectroscopy setup for QCL stability and noise measurements

- N₂O absorption line in a sealed low-pressure gas cell used to accurately determine the QCL noise and central wavelength.
- Distributed feedback (DFB) QCL at λ = 7.96 µm (T = 21.4 °C and I = 600 mA), driven by a home-made low-noise controller.
- Stabilization to the transition centre by wavelength modulation spectroscopy applied by modulating the QCL current.
- The frequency drift of the free-running laser is assessed from the evolution of the DC current required to maintain the laser at the center of the absorption line.
- The current changes are converted into corresponding frequency changes using the laser current-tuning coefficient (Δν/ΔI = −0.39 GHz/mA).
- Regular check by scanning the laser through the resonance.
- Additional noise measurements regularly performed (2-3 times per day)
- Two months of continuous measurement

QCL frequency stability over time

- Blue line: data from the continuous stabilization to the N₂O transition. Red points: complementary data obtained from occasional current scans through the transition (see below)

Day 23: restart of the experiment due to a power failure
Day 19: an erroneous set current applied to the laser resulting in a large temperature change
Days 44-46: problem with the monitoring photodiode (laser not stabilized to the N₂O transition)

- Monotonous drift of the laser current of about 4.6 mA observed during a first period of slightly more than one month (days 0-32), corresponding to a frequency change of ~1.8 GHz.
- Drift comparable to the value of <2 GHz/month reported for NIR DFB laser diodes at 852 nm.
- Then, the change in the QCL current is strongly reduced and the optical frequency remains within a range of ~100 MHz during more than 20 days. The QCL voltage also becomes much more stable than in the first part of the experiment.
- No observable variation of the laser current-tuning coefficient Δν/ΔI throughout the experiment.
- Possible explanation: improvement of the laser contacts over time resulting from an annealing effect, which slightly reduces the voltage drop in the contacts and the associated laser heating.

Noise evolution over time

- The voltage noise across a QCL was shown to be a simple and powerful tool to investigate noise processes, as frequency noise (responsible for the laser linewidth) and voltage noise are highly correlated [1].
- Regular decrease of the voltage noise over time during the first 30 days.
- Good correspondence observed between the time where the noise starts to stabilize and the point where the QCL wavelength drift is reduced (at day ~30).
- A similar cause is believed to produce the two effects.


Conclusion and outlook

- The observed frequency drift is acceptable for gas sensing applications.
- Interest for similar studies during temperature cycling.