Quantum cascade laser emission width narrowing at the kHz level by means of optical feedback

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Quantum Cascade Lasers (QCL), in particular room-temperature distributed-feedback lasers, are becoming the usual sources for accessing the mid-IR molecular fingerprint spectral region. For advanced applications in precision spectroscopy a great effort is aimed at further improving their spectral purity performance. Indeed, although the intrinsic emission linewidth of a QCL can be as low as a few hundreds of hertz [1, 2], excess technical noise, such as the pump current noise, broadens the QCL emission linewidth by several orders of magnitude up to few megahertz for 1-ms observation times. For this reason, different electronic feedback techniques have been implemented to narrow the QCL linewidth down to the 10-kHz level, such as locking to the side of a molecular line [3], to an optical cavity [4], as well as phase locking QCLs to thulium frequency comb [5]. Even better results have been obtained using electronic feedback from a molecular sub-Doppler reference [6].

In this work, we demonstrate the kHz linewidth narrowing of a room-temperature distributed feedback QCL, tunable in the range from 8.56 to 8.63 μm. In particular, the QCL is frequency locked to a high-finesse V-shaped cavity by the optical feedback method [7-11]. This simple and robust technique allows us to narrow the 1-ms QCL linewidth from 3 MHz down to $\sim$2 kHz. A preliminary characterization of the frequency stability of the QCL source, performed by using a properly developed mid-IR optical frequency comb [12], demonstrated a relative frequency stability of 10^{-10} for an integration time of 100 ms.

The proposed QCL source will be a powerful tool for high-resolution molecular spectroscopy and optical frequency standard in the mid-IR spectral region. In particular, the QCL laser will be used for the absolute measurement of the line center frequency of a two-photon transition in a molecular beam of CHF_3, allowing for a determination of the possible variation of the electron to proton mass ratio at level of $10^{-15}\mathrm{yr}^{-1}$ [13].

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