Quantum Cascade Laser stabilization at Hz-level by use of a frequency comb and an optical link

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Ultra-high-resolution spectroscopy enables to test fundamental physics with molecules as for instance the non conservation of parity[1] or the stability of the electron-to-proton mass ratio[2]. However many of these tests rely on the availability of ultrastable and accurate laser sources emitting in the mid-infrared (IR) where molecules exhibit rovibrational transitions. It is thus very challenging to develop a frequency stabilization scheme in the mid-IR with performance similar to the visible and near-infrared domain.

For that purpose, we have built a frequency chain which enables to transfer coherently the stability and accuracy of an ultrastable laser emitting at 1.54 µm to the mid-IR spectral region (Fig. 1). This ultrastable signal is generated at LNE-SYRTE where its frequency is measured against a set of primary standards using an optical frequency comb. It is transferred from LNE-SYRTE to LPL through an optical link[3]. A second optical frequency comb is phase-locked to this signal and, using sum-frequency generation in a non-linear crystal, the mid-IR frequency is compared to a high-harmonic of the comb repetition rate.

With this set-up, we stabilized a CO_2 laser and obtained a relative frequency stability of a few 10^{-14}, at the state-of-the art[4]. We then extended this scheme to stabilize a Quantum Cascade Laser (QCL) emitting at 10 µm at an unprecedented Hz-level. We are now progressing towards high resolution spectroscopy of molecules of interest to test parity non-conservation.

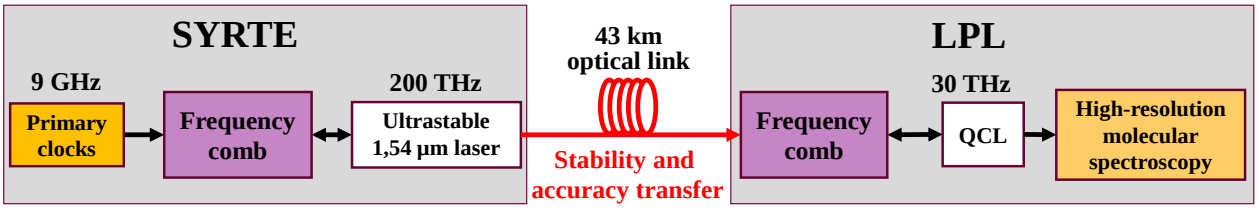

Fig. 1: Principle of the mid-IR frequency stabilization

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