MID-INFRARED SATURATION SPECTROSCOPY FOR VIBRATIONAL FREQUENCY MEASURMENTS AT THE SUB-KHZ LEVEL

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Molecular systems, owing to their numerous degrees of freedom, offer promising perspectives for improving tests of fundamental physics and precision measurements in general[1,2,3,4,5]. In our group at Laboratoire de Physique des Laser, using an optical frequency comb, a 10 μm quantum cascade laser (QCL) is stabilized at the sub-Hz level to an ultra-stable near infrared reference signal operated at the French metrology institute. This signal is calibrated there to some of the best atomic clocks and transferred through a noise-compensated 26-km long fiber cable of the REFIMEVE infrastructure[6]. This results in a record relative frequency uncertainty of 10^{-14} and a 0.1 Hz QCL linewidth[7].

We have used this ultra-stable and frequency controlled mid-infrared source to perform high resolution spectroscopy on various molecular species of fundamental, atmospheric and astrophysics interest such as methanol, ammonia or trioxane, with a few kilohertz uncertainties on line positions using sub-Doppler saturated absorption spectroscopy in a multipass-cell[8].

Here, I will discuss our latest efforts in order to improve these spectroscopic measurements, by realizing cavity enhanced measurements. I will show results on methanol achieving a few hundreds of Hz uncertainties on molecular frequencies, I will then present investigations on various sources of noise currently limiting our signal-to-noise ratio and perspectives for improvements. These results enhance our ability to meet the needs for our ongoing efforts towards studying the variation of

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fundamental constants[3] or testing fundamental symmetries, such as the measurement of the tiny parity-violating energy difference between enantiomers of a chiral molecule[1,2], via precise molecular spectroscopy. Furthermore, it can contribute to the enrichment and refinement of the HITRAN database[9], which can be highly beneficial for the fields of astronomy[10] and atmospheric physics[11], providing valuable data for accurate modeling and analysis.

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