Probing molecular vapors with high frequency resolution for precision measurements and tests of fundamental physics

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There is an increasing demand for precise molecular spectroscopy, in particular in the infrared fingerprint window, whether it be for modelling our atmosphere, interpreting astrophysical spectra, testing fundamental physics or technological applications in quantum sensing and frequency metrology. I will present our efforts towards building new-generation infrared spectrometers specifically designed for precision vibrational spectroscopy of molecules in the gas phase. This includes amongst other things developing frequency stabilised mid-infrared lasers calibrated to some of the world's best frequency standards [1], miniaturizing and integrating molecular vapor cells, producing gases of polyatomic species at temperatures ranging from a few kelvins [3] to room temperature [1,2] or explore the opportunities offered by cutting-edge mid-infrared photonics technologies. These developments are at the forefront of frequency metrology and photonics, and have allowed us to carry out sub-Doppler spectroscopy of a variety of species of atmospheric, astrophysical, metrological or fundamental interest and measure absolute frequencies with record up to 12-digit accuracies [1,2]. Our experiments can find applications extending to the fields of compact molecular frequency references [2], atmospheric physics [1,2], tests of fundamental symmetries [3,5], measurements of variations of fundamental constants [1,6] or of the Casimir-Polder interaction with molecules [2].

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