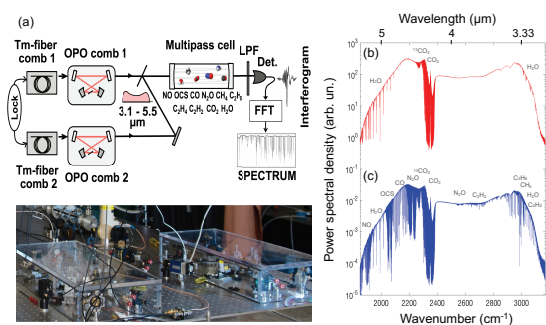


# MASSIVELY PARALLEL DETECTION OF TRACE MOLECULES AND ISOTOPOLOGUES WITH A SUBHARMONIC MID-IR DUAL COMB SYSTEM

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We use a pair of highly-coherent subharmonic GaAs optical parametric oscillators with an instantaneous span 3.1-5.5  $\mu\text{m}$  to demonstrate fast acquisition of 350,000 mode-resolved spectral data points and perform parallel detection in a mixture of 22 molecular species including  $\text{N}_2\text{O}$ ,  $\text{NO}$ ,  $\text{CO}$ ,  $\text{OCS}$ ,  $\text{CH}_4$ ,  $\text{C}_2\text{H}_6$ ,  $\text{C}_2\text{H}_4$ ,  $\text{C}_2\text{H}_2$ ,  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ , and their isotopologues containing  $^{33}\text{S}$ ,  $^{34}\text{S}$ ,  $^{13}\text{C}$ ,  $^{15}\text{N}$ ,  $^{18}\text{O}$ ,  $^{17}\text{O}$ , and  $^2\text{H}$  (deuterium) isotopes. We demonstrate all the benefits of the mid-IR dual-comb spectroscopy including broadband coverage, fast acquisition of massive spectral data, ppb-level sensitivity, comb-tooth resolved spectra (with finesse 4000) and absolute optical frequency referencing to atomic clock. We sampled molecular spectra with the comb-tooth spacing (115 MHz), however, thanks to the narrow comb

teeth (3-kHz absolute and 25-mHz relative linewidth between the two combs), much higher spectral resolution can be obtained in the scanning comb-tooth resolved mode. The Figure shows: (a) schematic of the dual-comb setup, (b) log-scale optical spectrum retrieved from a single coherently-averaged interferogram with an evacuated multipass gas cell, and (c) when the cell was filled with a mixture of gases. The two spectra are vertically offset for clarity.