A new continuous-wave mid-infrared stimulated emission experiment beyond the Doppler limit

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We present a sensitive experimental method for molecular spectroscopy that can be used to determine ro-vibrational states using mid-infrared stimulated emission. Our infrared stimulated emission probing (IRSEP) experiment is based on using a narrow-line, continuous-wave Ti:sapphire laser beam (pump) to excite the molecules to an upper vibrational state and a continuous-wave, mid-infrared beam from an optical parametric oscillator (probe) to detect the stimulated emission by the excited molecules. Spectroscopic data are gathered by tuning the wavelengths of the beams. The molecules are probed before their velocity distribution is disturbed by collisions, which leads to a sub-Doppler resolution and full width at half maximum of the emission peaks below 10 MHz. The stimulated emission lines are measured with an accuracy of at least 0.005 cm^{-1}. We use the IRSEP experiment to observe and analyze the symmetric ro-vibrational state [21+] ($3\nu_1(\Sigma_g)$) of acetylene (C_2H_2). This state is not accessible via one photon transitions from the ground vibrational state. We use the least-squares method to determine that the band center is at 9991.9725 (12) cm^{-1} and the rotational parameters are B = 1.156145 (22) and D = 1.608 (87) $\times 10^{-6}$ cm^{-1}, where the uncertainties in parentheses are one-standard errors in the least significant digit.