High-temperature reacting systems are central to many fields including propulsion, power generation, and transportation. Studying such systems requires the use of experimental facilities such as shock tubes to obtain the relevant high temperature conditions, and non-intrusive diagnostic tools for monitoring parameters of interest in the reaction zone, including temperature and species concentration time-histories. Laser absorption spectroscopy offers high-speed, in-situ measurements of the reacting flow field and provides direct measurements of species concentrations and temperature. Applying absorption spectroscopy via different diagnostic strategies enables tailored measurements of these parameters across a variety of combustion systems for chemical kinetic model refinement and enhancing the fundamental understanding of combustion over a broader range of conditions, ultimately aiding in the development of more efficient and lower-emissions fuels and engines.

In this work, several mid-infrared (MIR) laser absorption diagnostic strategies providing varying amounts of spectral information were developed and applied for making simultaneous measurements of multiple species and temperature profiles in high-temperature experiments in combustion-relevant reaction systems. These strategies include a narrowband, fixed-wavelength scheme of multiple lasers for simultaneous species measurements in fuel-rich n-heptane combustion; a fast-scanning broadly tunable acousto-optically modulated external cavity quantum cascade laser scheme for simultaneous measurements of temperature and carbon monoxide concentration; and a broadband absorption diagnostic based on a MIR frequency comb generated via a subharmonic optical parametric oscillator (OPO) for simultaneous measurements of multiple species over a single line of sight and characterization of high-temperature absorption spectra. The MIR OPO-based broadband diagnostic system provides particularly spectrally rich data enabling measurements in mixtures of species with overlapping spectral features and application in a wide range of combustion systems and experimental conditions.