USING ULTRAVIOLET LASER ABSORPTION SPECTROSCOPY TO MEASURE STATE-SPECIFIC POPULATION HISTORIES OF OXYGEN IN A HYPERSONIC ENVIRONMENT

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Accurate spectroscopic modeling is critical when measuring time-resolved, state-specific chemical kinetics of oxygen (O_2) in air. Here, a spectroscopic model was developed to simulate oxygen absorption cross-sections in the Schumann-Runge system under vibrational non-equilibrium conditions. The model calculates the spectral bound-bound O_2 cross-sections using a line-by-line calculation and convolutes this cross-section with the Gaussian lineshape of a pulsed laser system to yield an effective bound-bound cross-section. This effective bound-bound cross-section was then augmented with an effective bound-unbound continuum database to provide a total effective cross-section. Two wavelengths, 211.2 nm and 236.9 nm, were chosen for spectroscopic study, as the effective cross-sections at these wavelengths primarily probe the fourth (v"=4) and sixth (v"=6) vibrational levels of ground state O_2, respectively. Furthermore, the effective cross-sections at both wavelengths demonstrate strong sensitivity to vibrational temperature, and vary only slightly with translational and rotational temperature.

Cross-sections in shock-heated O_2 have been measured using a picosecond pulsed ultraviolet (UV) laser, and the results have been compared against the model developed here and the Spectrum Model developed by Bykova et. al. Cross-sections were measured behind reflected shocks in 2% and 5% O_2 in argon (Ar) mixtures around 211.2 nm and 236.9 nm up to initial post-reflected shock temperatures of 10,700 K and subatmospheric pressures. For both wavelength regimes, the experimental cross-sections agree to within 15% of the model developed here, and most experimental values fall within 10% of both spectroscopic models.

Using the spectroscopic model developed here to inform appropriate wavelength selection, the pulsed UV laser system becomes a tool for directly tracking both vibrational temperature and populations in specific vibrational modes of O_2 as it undergoes vibrational relaxation and dissociation behind strong shock waves. These population time histories provide important experimental data needed to evaluate current computational models that seek to capture the molecular energy transfer present in high-enthalpy airflows.