In search of equilibrium in laser-produced cloud: role of pressure, chemical quenching, and plasma expansion

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The properties of laser plasma vary significantly depending on the pressure and composition of the environment, that makes it a promising emission source to imitate the radiation from various objects in atmosphere (meteor wake, airglow) and in outer space. We aimed to register spectra of FeO and CaO bands in laser plasma and vary conditions to make spectra profiles as close as possible to the ones observed during the Benešov bolide event. It allows to reconstruct the composition and behavior of meteor wake.

We fit synthetic CaO infrared system spectra by varying temperatures in the range from 1000 to 8000 K to the spectra measured in laser-induced plasma. It was found that the excitation (atomic species), vibrational and rotational temperatures of the experimental spectra indicate the absence of local thermodynamic equilibrium (LTE) and do not match each other. The atomic excitation temperature is close to 10000 K, vibrational temperature varies in the range of 3500–5000 K, while the rotational temperature is noticeably lower than ~2000–3000 K. Moreover, the specific values of rotational temperatures vary greatly from band to band. We also found the significant deviation of lines' wavelengths and transition probabilities between experimental spectra and model spectra based on EXOMOL data.

Calculation of the chemical composition of laser-produced clouds formed by laser heating of Fe and CaCO3 targets were performed. Timescales of main reactions with participation of Fe- and Ca-containing species were calculated using rate constants of the reactions. The results of calculations of equilibrium composition of laser-produced and impact-produced clouds are presented. Quenching conditions of chemical reactions in laser-produced and impact-produced clouds are found.

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