Thesis Summary

論 文 の 内 容 の 要 旨

論文題目　Characterization of laser-induced discharge extending in various gas species

（様々なガス種中を進展するレーザー誘起放電の研究）

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Repetitively pulsed (RP) laser propulsion, is one of the concepts of beamed energy propulsion, which has the potential of placing kilograms of payload mass fraction into earth orbits. RP propulsion systems have the capability of increased multiple missions for a given time frame due to the utilization of an off-board reusable energy source (such as a laser-based launch equipment) located either on earth or in space. Compared to conventional chemical rocket systems, laser-induced plasma discharges for propulsive applications have high specific impulse and thrust, low lift-off weight, as well as being comparatively inexpensive

Laser supported detonation (LSD) is a propagation regime in which a laser-induced plasma discharge interacting with an irradiating incident laser beam, absorbs the beam energy and efficiently propagates an ionization wave capable of inducing thrust. LSD is an overdriven detonation in which the laser-induced discharge (LID) drives a shock wave. Transition of the LSD regime to a laser supported combustion (LSC) regime occurs when the intensity of the pulsed laser decays below a required threshold. In the LSC regime, the driven shock wave propagates adiabatically and results in inefficient transfer of energy for propulsion. Therefore, understanding the Physics of laser absorption and the energy conversion processes of an LID wave is necessary to design and develop efficient laser-propelled thrusters.

In this work, the LID extension velocity was measured in helium and argon gases using laser shadowgraph technique, with a CO_2 gas laser as the source for discharge induction. The dependence of the extension velocity on gas species and laser beam diameters were ascertained. A threshold value of the diameter, was necessary to uniquely define the velocity as a function of the laser intensity. The effective beam diameters Ds, sufficiently large to uniquely describe the velocity – intensity relationship and to eliminate lateral dissipation of energy were 5.1 mm in air and argon gases and 7.2 mm in helium gas respectively. Moreover, the slopes of the relation were different from that of Chapman-Jouguet detonation theory. The slopes were 1.18, 0.46 and 0.23 respectively, for helium, air and argon gases. These differences would be a key to understanding the physics of LID. This validates the hypothesis of this study that the LID propagation is a discharge-based phenomenon. Thus, the extension velocity U_{LID}, should be determined from discharge-based physics and not fluid dynamics.

U_{LID} was analytically obtained using Shimamura's 1-D LID photoionization model with experimentally obtained propagation properties of the induced discharge as input. The objective was to validate the model by comparing analytically obtained results to that of experiment. The electron number density and excitation temperature of the bulk plasma were obtained from optical emission spectroscopy experiment. The spectra obtained for the argon gas could not be classified as either from an optically thick or thin plasma. Thus, the measured properties of argon gas could not be used for the validation of the model. The 1-D LID model could reproduce the increasing slope tendency of the extension velocity as a function of the laser intensity in helium plasma. However, the absolute values of U_{LID} were 300% - 600% overestimated. This is because of the 100% utilization of absorbed energy for ionization assumption of the model. The model does not consider the consumption of absorbed energy for excitations of particles.

The amount of absorbed energy used for ionization was obtained to be 5% - 25% for the LID helium plasma. This contradicts the 100% utilisation of absorbed energy for ionization in the 1-D LID model. Based on the observed results of this work, the study concluded that higher excitation energies are necessary to sustain the induced discharge, especially in the low intensity region. Therefore, in order to improve the model, a two-step ionization process accounting for fractions of absorbed energy was proposed to be incorporated in to the 1-D LID model.