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OPTICAL SPECTROSCOPY ON LASER-INDUCED IGNITION SPARKS AND OTHER SPACE-RELEVANT PLASMAS

Abstract

Recent efforts to establish laser-ignition to space propulsion have led to relevant experiments at the German Aerospace Center in Lampoldshausen. We present results of optical measurements regarding the ignition spark induced by a Q-switched Nd:YAG laser system that is focused inside a rocket combustion chamber as well as further laboratory experiments on space-relevant plasmas in order to shed light on their physical properties and chemical composition. The rocket combustor was fed by several coaxial injectors using liquid oxygen and either gaseous hydrogen or gaseous methane as fuel. The laboratory cavity, on the other hand, was filled with solitary gases or well-defined mixtures.

Optical investigations on the rocket combustor, conducted during hot fire tests at the European research test bench P8 (DLR), showed the temporal development of the ignition spark as well as the subsequent combustion for two distinct photon-wavelength regimes around 306nm and 430nm. The ignition process and the steady combustion phase have been visualized and recorded by a camera placed in the plume of the engine. Moreover, line-of-sight measurements on the breakdown location revealed crucial prerequisites for effective propellant ignition. It was found that the shear layer between LOX and the gaseous fuel was very turbulent and therefore several laser pulses were necessary to ignite the propellants. Laser-induced breakdown spectroscopy (LIBS) revealed spectral details of the plasma emission from the ultraviolet up to the near infrared regime. Using prominent atomic emission lines of the Balmer-series in hydrogen, plasma temperature values of more than 8000 Kelvin were determined. The McWhirter criterion for local thermal equilibrium conditions of the plasma was fulfilled regarding a critical electron number density within the ionized volume.

Further results of LIBS measurements on well-defined gaseous samples are shown in order to present a possible calibration tool for the equivalence ratio determination within the localized space of the plasma. The relative amount of propellants was determined using hydrogen/oxygen gas mixtures and their characteristic atomic emission lines. Hence, ROF values ranging from 30 to 40 could be determined for the volume of the ignition plasma in the cryogenic rocket combustor.

Due to its expedient properties regarding LIBS, pure helium was used for breakdown spectroscopy, in order to establish, automate and verify methods for optical plasma investigation. Plasma temperatures were derived as a function of several physical parameters.