Energy consumption has increased dramatically as the world advances and becomes more industrialized. Over the next twenty five years, the U.S. Department of Energy expects the energy demand to increase by 29% with majority of the new energy coming from natural gas (methane). Another promising fuel source for power generation and transportation is the biofuels. The biofuel use in the US is shown to have increased substantially in the last decade. There are serious environmental concerns associated with greenhouse (e.g. carbon-dioxide) and toxic gas emissions (e.g. nitrogen oxides and aldehydes such as propanal) due to deriving energy from natural gas and biofuel combustion. In this doctoral study, a shock tube experimental setup was designed, assembled, and tested in order to study the ignition as well as thermal decomposition characteristics of two types of fuels: methane (the major natural gas component, which is also a major intermediate during higher order hydrocarbon ignition and pyrolysis) and propanal (an oxygenated hydrocarbon found in the exhaust emissions of biofuels). A laser diagnostics using semi-conductor type laser diodes in the infrared region for measurements of methane and propanal gas concentrations was developed and used with the shock tube. This diagnostics also enabled the interference-free detection of methane during the course of propanal pyrolysis. The experimental measurements highlighted the areas in which refinement of reaction kinetic models was required. The current research provided information on the ignition delay times as well as concentration time-histories of fuels (e.g. propanal or methane) and intermediates (e.g. methane). The knowledge gained during this doctoral study is vital for the accurate modeling of emissions due to combustion of fuels.

The dissertation discusses the details of the four following items: 1) design, assembly, and testing of a shock tube setup as well as a laser diagnostics apparatus for studying ignition characteristics of fuels and associated reaction rates, 2) measurements of methane and propanal infrared spectra at room and high temperatures using a Fourier Transformed Infrared Spectrometer (FTIR) and a shock tube, 3) measurements of ignition delay times and reaction rates during propanal thermal decomposition and ignition, and 4) investigation of ignition characteristics of methane during its combustion in carbon-dioxide diluted bath gas. The main benefit and application of this work is the experimental data which can be used in future studies to constrain reaction mechanism development.