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ULTRA-FAST LASER-ABSORPTION TECHNIQUES FOR PERFORMANCE CHARACTERIZATION OF ADVANCED AIRBREATHING HYPERSONIC PROPULSION SYSTEMS

Abstract

Advanced diode laser absorption spectroscopy-based sensors have become the go-to method for resolving thermodynamic properties of harsh and fast reacting flows associated with hypersonic propulsion systems. These techniques are now being turned to for understanding the complex process involved in such engines. As an example, Rotating Detonation Engines (RDEs) have been subject to an increased interest in the last decade due to the thermodynamic advantages gained through detonative combustion, their compact size, and high flow potential. The intent of this technology is to employ a detonation for releasing chemical energy which produces a shock that is accelerated by a supersonic reaction zone resulting in higher density and pressures than in deflagration combustion. The promise of pressure gain technologies is increased efficiency with lower emissions for power and propulsion systems. Pressure gain systems have been proposed in a variety of configurations with the Pulse Detonation Engines (PDEs) having received the greatest amount of research. However, RDEs offer the advantages of operating at much higher frequencies (by one to two orders of magnitude), and detonation is initiated only once (continuous detonation). These factors make RDEs simpler in design, produce a more continuous power output, and more compact.

The University of Central Florida (UCF) has partnered with Aerojet Rocketdyne (AR) and the National Energy Technology Laboratory (NETL) to develop fast, state of the art TDLAS instruments to resolve water concentration static temperature within an RDE. Here the development and testing of a TDLAS instrument utilizing a direct absorption technique to achieve MHz level measurements of H2O concentration and temperature in the combustion channel of an RDE are discussed. The sensor utilizes two wavelengths center around 2.5m to measure water temperature. Following this, only one wavelength is necessary to determine H2O concentration. Measurements are taken right before the exit of the RDE detonation channel. These data will allow resolution of change in total pressure at several flow conditions inside an RDE burning H2-air. In addition, an acousto-optically modulated quantum cascade laser (AOM QCL) system with fast tunable output is used to measure temperature and species concentration time-histories in shock-heated mixtures of CO. A mixture of CO, helium, and argon was shock heated to pressures around 9.5 atm and temperatures between 1100 – 1400 K in a shock tube and measured with the diagnostic system at rates up to 250 kHz. This system can be coupled with advanced propulsion systems being considered for hypersonic vehicles.