The Feasibility of Rotational and Vibrational Raman Spectroscopy for Thermochemistry Measurements in Supersonic Flames

Doctoral Dissertation Thesis Defense

Alex Bayeh

BS, 2008 Texas A&M University

Chair of Advisory Committee: Dr. Karpetis
Committee members: Drs. Bowersox, Girimaji & North

April 11th, 2013
2:00 pm – 4:00 pm
H.R. Bright Building - HRBB 702

Abstract

High speed chemically reacting flows are important in a variety of aerospace applications, namely ramjets, scramjets, afterburners, and rocket exhausts. To study flame extinction under similar high Mach number conditions, we need access to thermochemistry measurements in supersonic environments. In the current work a two-stage miniaturized combustor has been designed that can produce open supersonic methane-air flames amenable to laser diagnostics. The first stage is a vitiation burner, and was inspired by well-known principles of jet combustors. We explored the salient parameters of operation experimentally, and verified flame holding computationally using a well-stirred reactor model. The second stage of the burner generates an external supersonic flame, operating in premixed and partially premixed modes. The high Mach numbers present in the supersonic flames should provide a useful test bed for the examination of flame suppression and extinction using laser diagnostics. We also present the development of new line imaging diagnostics for thermochemistry measurements in high speed flows. A novel combination of vibrational and rotational Raman scattering is used to measure major species densities (O2, N2, CH4, H2O, CO2, CO, & H2) and temperature. Temperature is determined by the rotational Raman technique by comparing measured rotational spectra to simulated spectra based on the measured chemical composition. The independent assessments of density and temperature allows for measurements in environments where the pressure is not known a priori. In the present study we applied the diagnostics to laboratory scale supersonic air and vitiation jets, and examine the feasibility of such measurements in reacting supersonic flames.

Alex Bayeh is a PHD candidate in the Aerospace Engineering Department working under the supervision of Professor Adonios Karpetis. His research interests are in the areas of high speed combustion and laser diagnostics. In 2009 he received a National Defense Science and Engineering Graduate (NDSEG) fellowship funded by the Air Force Office of Scientific Research, and in 2013 received the U.S. Senator Phil Gramm Doctoral fellowship.