Research Statement

Development of a Laser Based Technique for the Measurement of Water in Supersonic Combusting Flows

The development of scramjet propulsion is a critical activity for better access to space and for new high speed aircraft. Earth and climate observation, space exploration, and many existing technologies such as GPS and telephone communication depend on our ability to have reliable space access. Currently rocket engines provide a way to get to orbit, however scramjets would present a safer, cheaper option. In order to advance scramjet technology, accurate ground testing in wind tunnels and computer models must be developed and validated.

One issue regarding scramjet propulsion is accurately measuring the combustion efficiency, or the fraction of fuel burned during combustion[1]. In a scramjet, combustion takes place supersonically once fuel is added to the air stream. When burning hydrogen or a hydrocarbon fuel, water vapor is produced as a byproduct of combustion. If the water vapor concentration can be measured, the combustion efficiency can be quantified.

The University of Virginia has a Supersonic Combustion Facility with a scramjet combustor. The air supply is continuous and electrically heated as to avoid adding vitiates, or contaminates, into the stream[2]. This gives the facility a unique capacity to do water vapor measurements without the effects of these contaminants[1]. Wind tunnel testing provides a way to collect combustion data without the high cost and risk of flight testing. It is also helpful in developing accurate numerical models[2].

The University of Virginia has received NASA funding to work in collaboration with NASA Langley on measuring water vapor concentration through tomographic spectroscopy. Spectroscopy is the process of using a laser to determine absorption through a medium. In this case, an infrared laser will be used to measure water vapor content of combustion flows[3]. Tomography is a reconstruction technology that produces a two-dimensional image from a series of line-of-sight measurements[1]. Tomography is commonly used in medical CAT scans. However, in this case, the technique will be applied to the wind tunnel. These two processes will determine the water concentration. In order to measure combustion efficiency, the water flux must be also be determined by measuring the velocity of the flow[4].

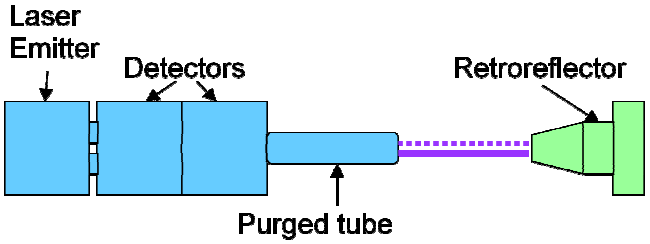

Figure 1: A diagram of the laser apparatus. The infrared laser beam is reflected back towards the detector where the absorption is measured.

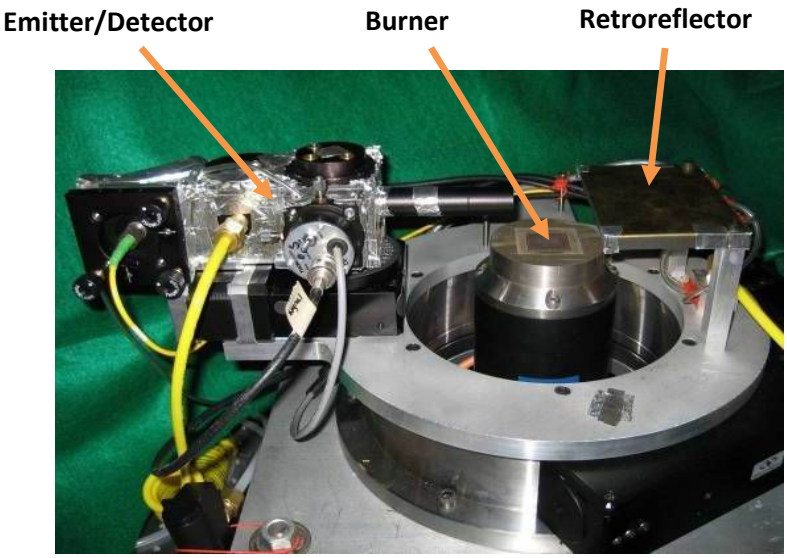

Figure 2: A photograph of the laser apparatus diagramed in Figure 1.

In order to advance the tomographic spectroscopy technique, experiments are being run by a graduate student at UVa on a flat flame burner with a know flowfield[3]. I will be assisting the graduate student in the application of techniques to the flame burner experiment. In particular, I will assist in the spectroscopic analysis of the data and examine techniques for tomographic reconstruction. I will also assist with velocity measurements at the exit of the scramjet. Supporting this project are the Principle Investigator Dr. James McDaniel, the co-Investigator Dr. Christopher Goyne, and Dr. Glenn Diskin from NASA Langley. Provisions for an undergraduate research assistant have not been budgeted in the project, but with VSGC funding I can help accelerate the progress of the experiment.

References

(1) McDaniel, J.C., Goyne, C.P., "Combustion Efficiency Measurement for Ground Test and Basic Hypersonic Research" University of Virginia Proposal to NASA, 2006.

(2) Goyne, C.P., Rodriguez, C.G., Krauss, R.H., McDaniel, J.C., McClinton, C.R. "Experimental and Numerical Study of a Dual-Mode Scramjet Combustor" AIAA Journal Vol. 22, No. 3, May-June 2006 pp 481-489.

(3) Bryner, Elliot, Diskin, Glenn S., Goyne, Christopher P., McDaniel, James C., Krauss, Roland H. "High Temperature Spectroscopic Parameters for Water Vapor Measurements in Combustion Environments" AIAA Paper 2006-433 44th AIAA Aerospace Sciences Meeting and Exhibit, Jan. 9-12 2006, Reno, Nevada.

(4) Bryner, E.B., Diskin, G.S., Goyne, C.P., McDaniel, J.C., Krauss, R.H., Slate, T.A. "Water Vapor Concentration Measurement in High Enthalpy Flows Using Infrared Absorption" AIAA Paper 2003-4580 39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, 21-23 July 2003, Hunstville, Alabama.