Wavelength Modulation Spectroscopy Sensors for Scramjet Flows

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Motivation

As scientists and engineers design and build the next generation of aircraft capable of employing air-breathing propulsion from subsonic through hypersonic flight regimes, new measurement techniques must be developed to characterize the complex, high enthalpy flows expected in these devices. In this research we use tunable diode laser absorption spectroscopy (TDLAS) to provide quantitative benchmark data for hypersonic ground test facilities. Without intruding into the flow field, these sensors can provide spatial and temporal resolution of important parameters such as velocity, temperature, and species concentration.

Overview

Our TDLAS sensors operate by passing multiple colors of near-IR light through the exhaust gas of a model scramjet combustor. Each color is tuned in wavelength to a water vapor absorption transition. The gas temperature can be calculated from the ratio of absorbance from two transitions. In scanned-wavelength direct absorption spectroscopy this is achieved by repeatedly scanning each laser across an absorption feature. However, in harsh, noisy environments such as a scramjet combustor, the signal to noise ratio is improved using wavelength modulation spectroscopy (WMS).

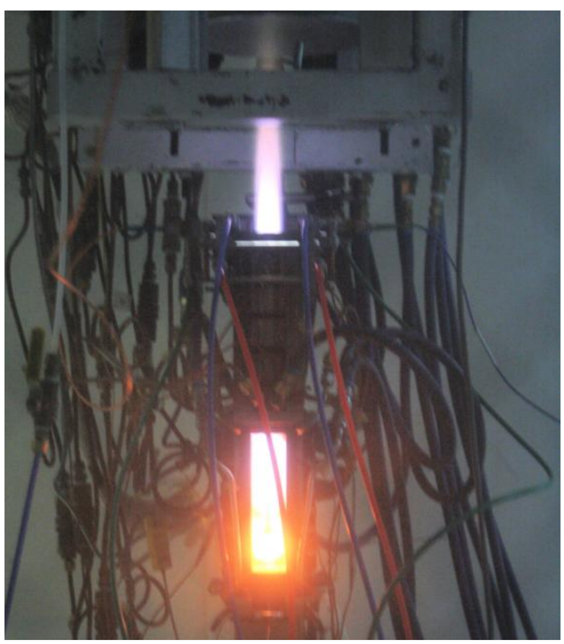

Figure 1: Optical diagnostics are valuable tools for investigating the flow phenomena in harsh conditions such as this supersonic dual-mode model scramjet combustor at the University of Virginia. The lower window shows the scramjet combustor. The upper glow is from hot exhaust gases exiting into the atmosphere.

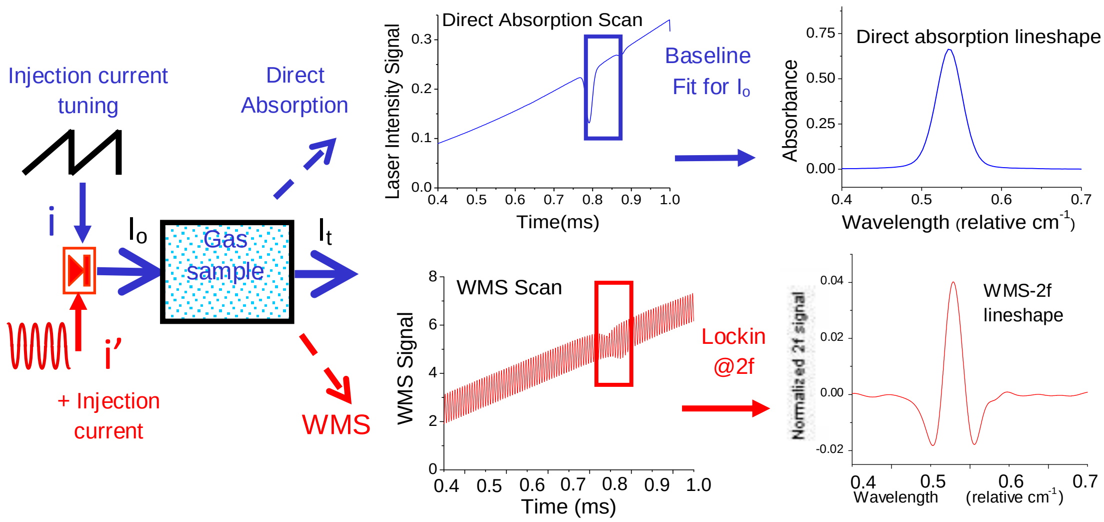

Figure 2: Comparison of direct absorption (upper) and WMS (lower) scans and lineshapes.

Figure 2 shows how the laser injection current is modulated and scanned across the absorption feature for direct absorption and WMS. In our research we normalize the second harmonic of the WMS signal (WMS-2f), which contains absorption information, by the first harmonic signal, which contains information of the laser intensity. The result is a sensor that is resilient against the harsh conditions experienced during scramjet operation and capable of providing valuable characterization of the flow field.

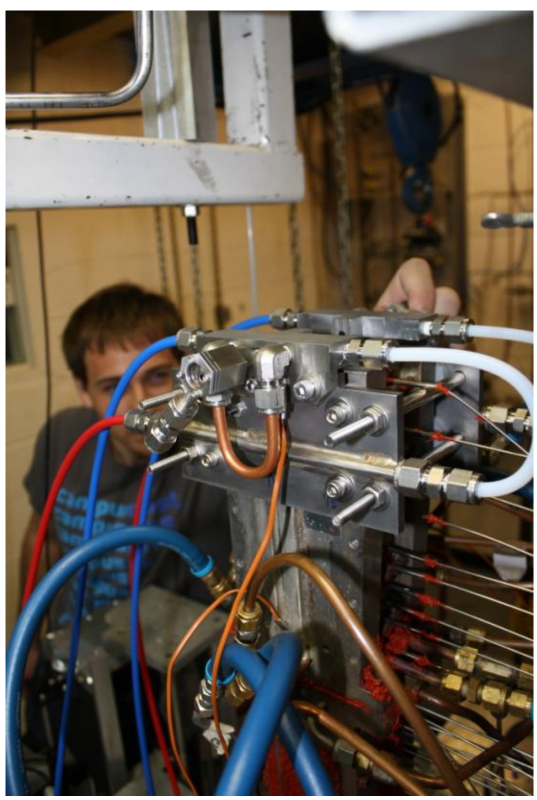

Figure 2: Graduate student Chris Goldenstein installing the TDLAS sensor at the University of Virginia.

Next Steps

The first measurements in this research campaign investigated diagnostic strategies at the exit of the University of Virginia combustor. In the near future, the scope of measurements will widen to include the combustion chamber and the ability to translate the sensor to provide spatial resolution. In addition to measurements on the combustion product H_2O, future work will investigate measurements of hydrocarbon fuels, oxygen, and CO_2. Research will also be extended to other ground-based hypersonic testing facilities such as the ATK-GASL HYPULSE tunnel and ultimately flight instrumentation.

References

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