Near-IR Fuel Sensing for Pulse Detonation Engines

Principal Investigator: Dr. Ronald K. Hanson

Research Associates: Dr. Jay Jeffries; Dr. David Davidson

Research Assistant: Ethan Barbour

Overview

In the past few years, our research on diode laser sensors has been driven by problems associated with pulse detonation engines (PDEs), which present significant measurement challenges and important opportunities for control. In this work we have found that monitoring fuel concentration and temperature is especially needed, both to investigate operating characteristics of PDEs and to provide input to control schemes. Primary effort has been directed toward sensing ethylene (C2H4), since this fuel has good detonation properties and has been widely used by current PDE investigators, though most of the underlying laser-based sensing concepts can be extended to other fuels, including JP-8 and JP-10, in the future. Here we report our work to develop and apply a sensor for C2H4 concentration and temperature, including studies at Stanford and at the Naval Postgraduate School (NPS)(in Monterey, California) in which this sensor has been used successfully for engine control. In the Stanford work, the sensor is used to ensure repeatable and full engine fueling, with minimum fuel wastage, and consequently uniform impulse per PDE cycle. At NPS, the sensor has been used in a control system to minimize engine misfires and increase repetition rate.

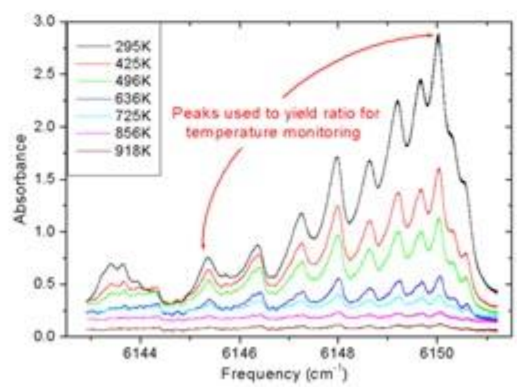

Figure 1: Q-branch of C2H4 near 1.62 mm at different temperatures.

Measured in a static cell with 20 cm absorption path length, pure C2H4 at 1 atm.

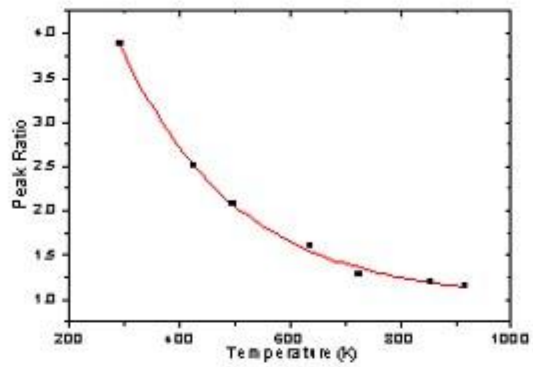

Figure 2: Ratio of the two peaks indicated in Figure 1 showing sensitivity of temperature sensor.

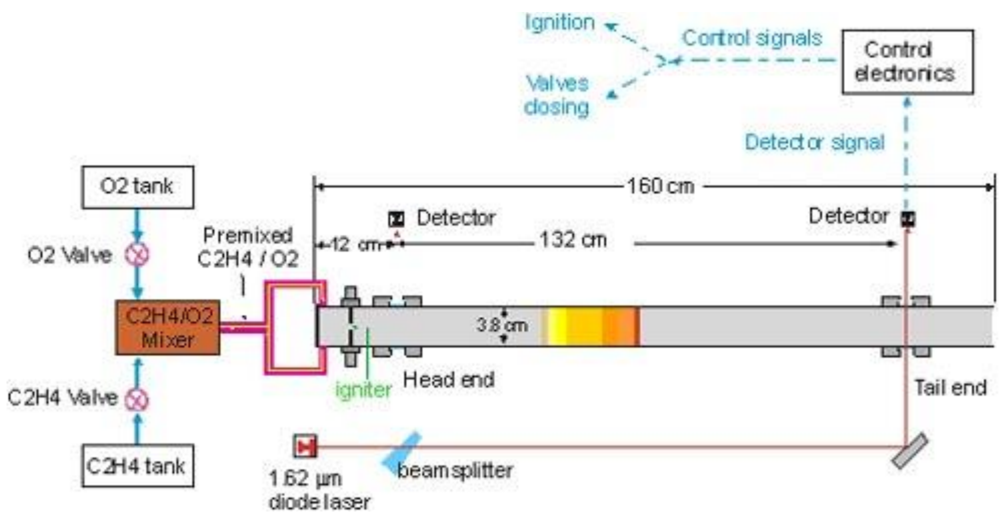

Figure 3: Schematic of C2H4 sensor applied to Stanford PDE for monitoring and control.

The absorption feature utilized for sensing C2H4 is shown in Fig. 1; this feature, which peaks at 6150 cm-1 (1.625 micron), is known as the Q-branch and is a dominant feature of this overtone band of C2H4. Stronger absorption bands of C2H4 occur at longer wavelengths, but these are not accessible with current diode lasers. The strong temperature dependence of the Q-branch has been exploited to allow simultaneous measurements of temperature, using a simple ratio of peak heights; the sensitivity of this method is indicated in Fig. 2. The sensor has been used primarily to evaluate and control PDE fueling. For example, as shown in Fig. 3, measurements made near the exit of the tube are used to ensure that the tube is filled (but not overfilled) with the prescribed fuel-oxidizer mixture, and that the timing for closing the fill valves and triggering the ignition event occur at the optimum time. Figure 4 shows data obtained with and without the control system, confirming the ability to obtain a constant level of impulse (per PDE cycle) even though the flow rate through the fuel and oxidizer fill valves declines with time (owing to the finite volume of the fuel and oxidizer supply tanks) over a number of PDE cycles.

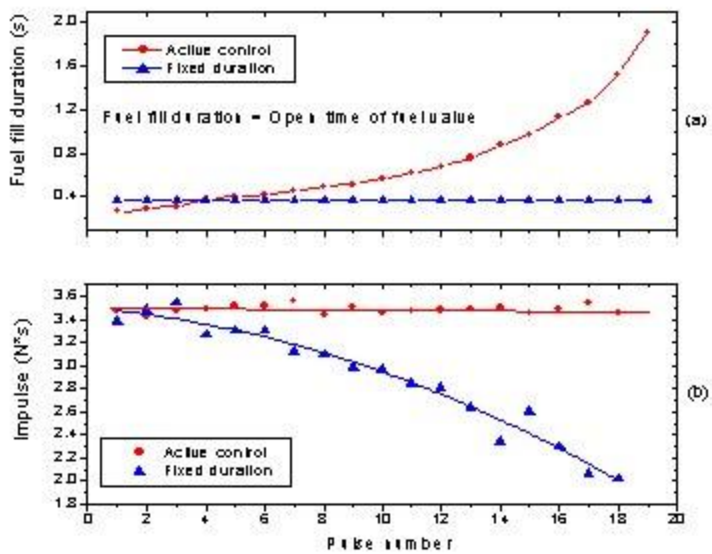

Figure 4: Demonstration of active control using a diode laser sensor to optimize fuel consumption and achieve uniform impulse per PDE cycle. (a) comparison of fuel fill duration, and (b) comparison of impulse per cycle between fixed duration case and active control case