Introduction to Diode Laser Sensors

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Introduction

Diode-laser sensors based on line-of-sight absorption spectroscopy provide unique capabilities for fast and accurate in situ measurements of a variety of important parameters, including species concentrations, temperature, pressure and velocity. These sensors utilize the light from tunable semiconductor diode lasers and fast semiconductor detectors to monitor incident and transmitted intensities.

Diode lasers, developed by the telecommunications industry in the wavelength region from 1300-1650nm, are robust, reasonably economical, and readily compatible with optical fibers to facilitate measurements in practical systems and in remote locations. Furthermore, the outputs of multiple lasers can be combined (wavelength-multiplexed) into a single fiber using off-the-shelf fiber-optic components to enable simultaneous absorption measurements at multiple wavelengths along a common path, thereby providing means of monitoring multiple flowfield quantities simultaneously and of removing interference extinction effects, e.g. due to contaminated windows or particulates in the flow.

Although the technology is less advanced, diode lasers are available for sensing applications outside the telecommunications bands, and are available at most wavelengths between 390 and 2000nm. In addition, we recently acquired novel new diode laser sources based on difference frequency generation in the region near 3mm.

Application: Propulsion and Combustion Control

Over the past decade, diode laser sensors have been developed at Stanford and elsewhere for measurements of a range of parameters in laboratory- and industrial-scale combustors. Our early work focused on developing sensors for O2 and H2O concentration and temperature, as well as measurements of velocity and gasdynamics quantities such as mass and momentum flux. These systems, which utilized diode lasers operating near 760nm (to access O2 transitions) and 1.3-1.4mm (for H2O), were driven by scramjet and other high-speed propulsion applications.

Subsequently, we developed diode laser sensors for soot concentration and temperature and for pollutant species such as CO, NH3 and NO2, and we performed the first combustion control experiments based on diode laser sensing. In the latter work, a forced incinerator was controlled by sensing temperature at a repetition rate of 3kHz and this signal was used to vary the phase and amplitude of acoustic drivers in the fuel (or oxidizer) flow. The resulting control system was very fast (with a response time less than 100 milliseconds) and enabled dramatic reduction in pollutant emissions.