Temperature Sensing in Multiphase Flows

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Motivation

A precise knowledge of the high temperatures generated in the combustion process is important for the understanding of chemical reaction rates, process efficiency, and pollutant emissions. Currently there is a need for the study of real fuel blends including jet fuels, diesels, and bio-diesels. A new experimental protocol is being developed in our lab where the fuel is loaded as a liquid aerosol into a shock tube to study the chemistry of these low-vapor-pressure compounds after shock heating. Thus new diagnostics are needed, which can provide time-resolved gas properties behind the shock wave. Research is underway to develop a tunable diode laser (TDL) absorption sensor for precise temperature measurements in this environment, which includes light scattering and absorption by liquid aerosol.

Overview

CO_2 is a particularly important target gas as it is a primary combustion product of hydrocarbon fuels. Recently, distributed-feedback (DFB) diode lasers have become commercially available in the 2.5-2.9 μm region, allowing access to stronger vibrational bands of CO_2. In this study, we used wavelength modulation spectroscopy (WMS) for the precise temperature measurement of CO_2 gas in the presence of scattering interference by fuel aerosol.

Wavelength modulation spectroscopy with second-harmonic detection (WMS-2f) is best known for its ability to make sensitive measurements and reject noise. In this technique, the laser light is passed through the sample gas as the wavelength is rapidly (typically hundreds of kHz) modulated, and the 2f component is isolated from the transmitted signal by a lock-in amplifier. The gas temperature can be inferred from the ratio of WMS-2f signals from two transitions. The first harmonic (1f) of the detected signal is produced by injection current modulation and can be used to normalize the WMS-2f signal to account for non-resonant interference from emission, droplet scattering, and beam steering.

Fig. 1 (a) and (b) illustrates the measured WMS 2*f* and 1*f* signals for the CO_2 transition near 3633.08 cm^{-1} at different aerosol loadings. Although the magnitudes of 2*f* and 1*f* vary with aerosol loading in Fig. 1(a) and (b), the 1*f*-normalized 2*f* as shown in Fig. 1(c) does not vary over a large range of wavelength. The next step research is to apply this TDL sensor strategy to obtain accurate and fast temperature measurements in the aerosol shock tube during fuel chemistry experiments. Fig. 2 shows a proposed schematic for the characterization of this sensor in our shock tube facility.

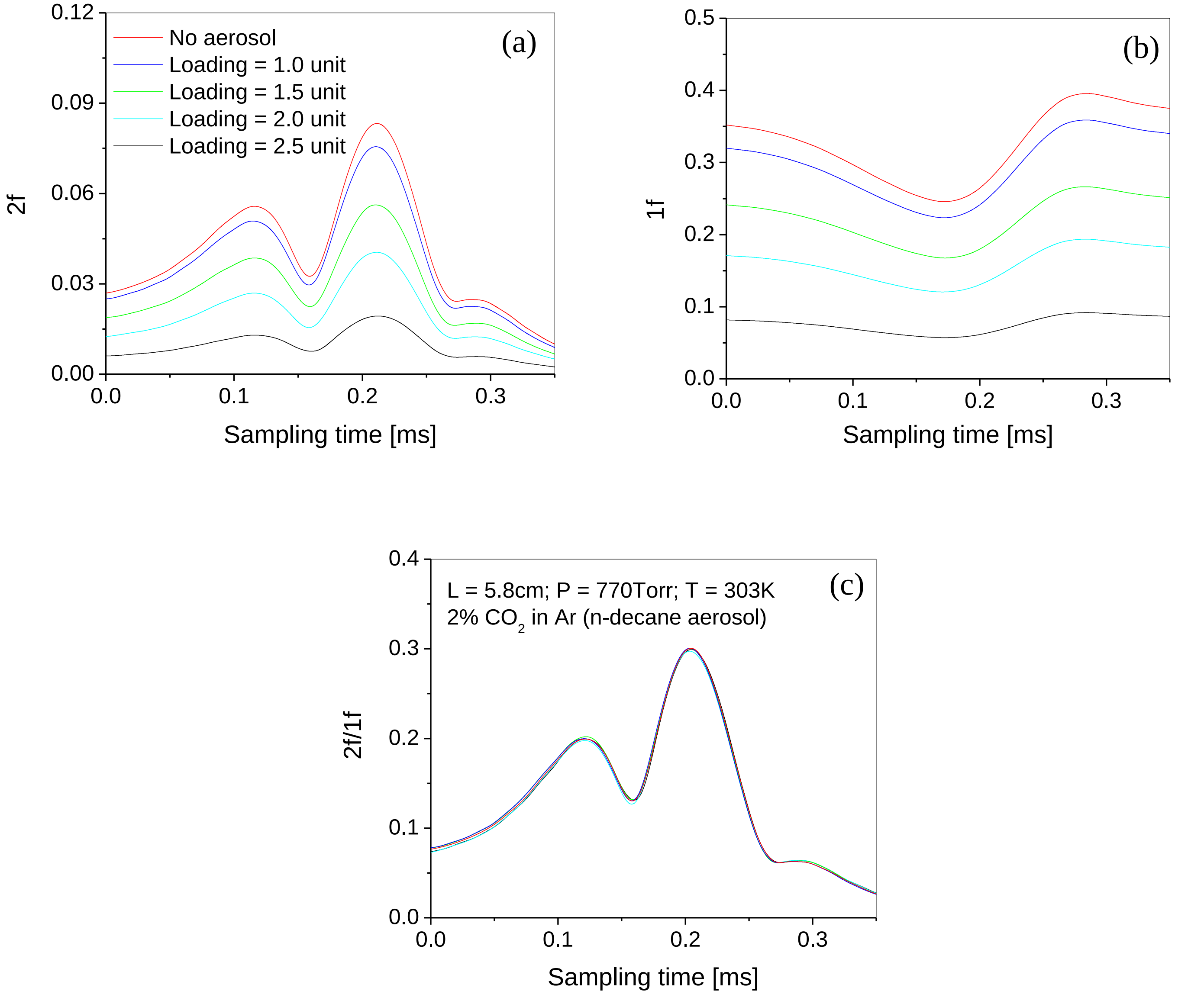

Figure1: Measured WMS- (a) 2f, (b) 1f and (c) 2f/1f signals in the aerosol cell for the CO_2 transition near 3633.08 cm^{-1} with different aerosol loadings; P = 770 Torr, T = 303K, L = 5.8 cm, X_{CO2} = 2% in Ar.

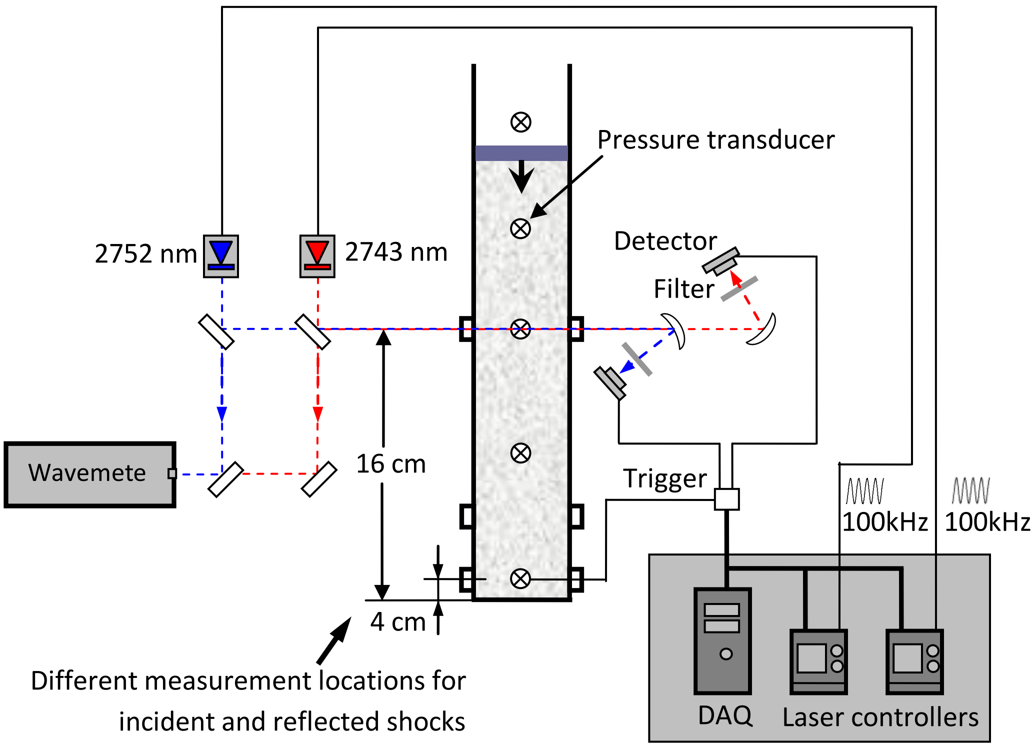

Figure2: Experimental setup in aerosol shock tube.