# Development of a Technique For Separating Raman Scattering Signals from Background Emission With Single-Shot Measurement Potential

Introduction

Raman scattering is a powerful technique for quantitatively probing high temperature and high speed flows. However, this technique has typically been limited to clean hydrogen flames because of the broadband fluorescence interference which occurs in hydrocarbon flames. Fluorescence can also interfere with the Raman signal in clean hydrogen flames when broadband UV lasers are used as the scattering source. A solution to this problem has been demonstrated.[1,2] The solution to the fluorescence interference lies in the fact that the vibrational Q-branch Raman signal is highly polarized for 90° signal collection and the fluorescence background is essentially unpolarized. Two basic schemes are available for separating the Raman from the background. One scheme involves using a polarized laser and collecting a signal with both horizontal and vertical laser polarizations separately. The signal with the vertical polarization will contain both the Raman and the fluorescence while the signal with the horizontal polarization will contain only the fluorescence. This is the approach followed in Refs. 1 and 2. The second scheme involves polarization discrimination on the collection side of the optical setup. For vertical laser polarization, the scattered Q-branch Raman signal will be vertically polarized; hence the two polarizations can be collected separately and the difference between the two is the Raman signal. This approach has been used for the work found herein and has the advantage of allowing the data to be collected from the same laser shot(s). This makes it possible to collect quantitative Raman data with single shot resolution in conditions where interference cannot otherwise be eliminated.

Experimental Setup

The experimental arrangement consists of a Heinken burner, a Lumonics Broadband Krypton Fluoride excimer laser (248.6 nm), a McPherson 1 m UV spectrometer, a computer controlled Princeton Instruments intensified CCD camera system, a pulse generator and a calcite crystal used for separating polarizations. The schematic found in Fig. 1 shows the experimental setup including appropriate optics for focusing the laser beam over the burner and collecting the resulting signal. The schematic includes the essential electronic connections needed for proper operation of the camera in the gated, synchronized mode. The pulse/function generator was used to fire the laser on the positive going pulse and the camera on the negative going pulse. This allowed the function generator pulse width to be used as a delay. The 15 ns. laser pulse was centered on a 100 ns. camera gate using a pulse monitor from the FG-100 pulse generator and a photomultiplier (not shown) looking at stray light from the laser beam. The key element which is unique for this setup is the polarization separator. This crystal separates a beam of unpolarized incoming light into horizontal and vertical components separated by 4 mm. The crystal was placed just inside the slit of the spectrometer. A mask approximately 3mm in diameter was placed in from of the slit resulting in a pattern on the detector composed of two strips of light, each containing one spatial dimension and one spectral dimension.

Raman Scattering Setup
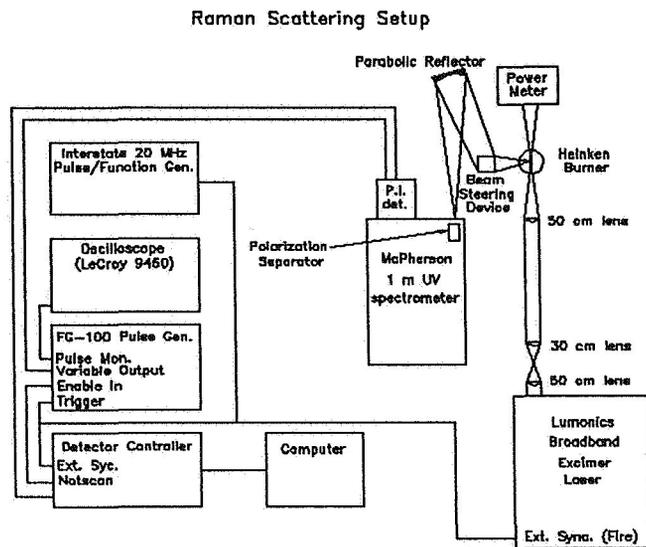
Figure 1

The immediate form of the data is electronic images of the horizontally and vertically polarized components of the collected scatter. The image shown in Fig. 2 represents a sample of the raw data. The vertically polarized light appears on the left band and the horizontally
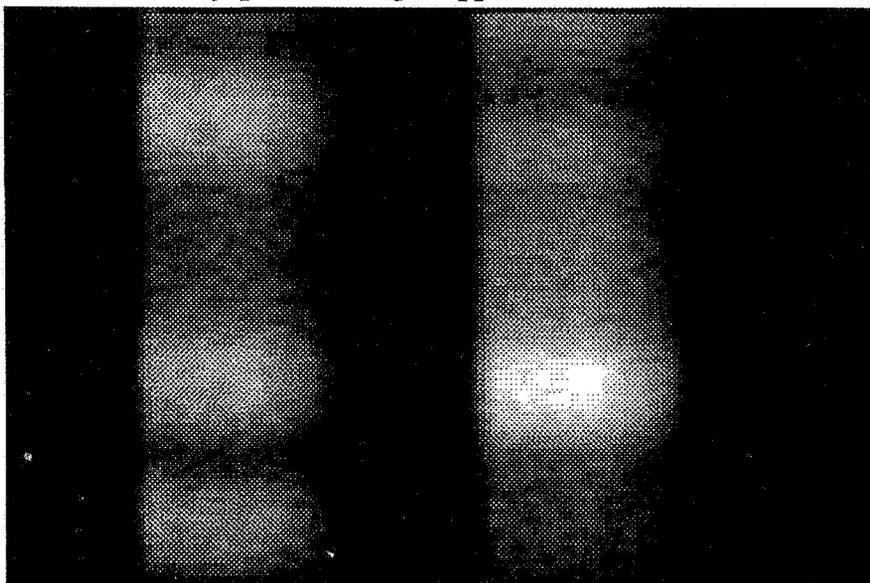

Figure 2: Image of spectrally resolved scattering signal along a line separated based on polarization

polarized light appears on the right band. The spectral direction is along the vertical axis with wavelength increasing from bottom to top and the horizontal direction represents distance along a linear probe volume. This particular image was collected in a lean flame (OF = 4) with the spectrometer set at 269.8 nm. (This wavelength corresponds to the approximate center of the

image.) The horizontally polarized band is generally brighter because the spectrometer passes horizontally polarized light preferentially; however, some bands appear on the vertically polarized section which are not present on the horizontally polarized image. These areas represent Raman scatter. The two polarizations are normalized for collection efficiency and then their difference is taken to extract the Raman spectrum. This process is illustrated by the plots shown in Figs. 3 and 4.

Lean Flame
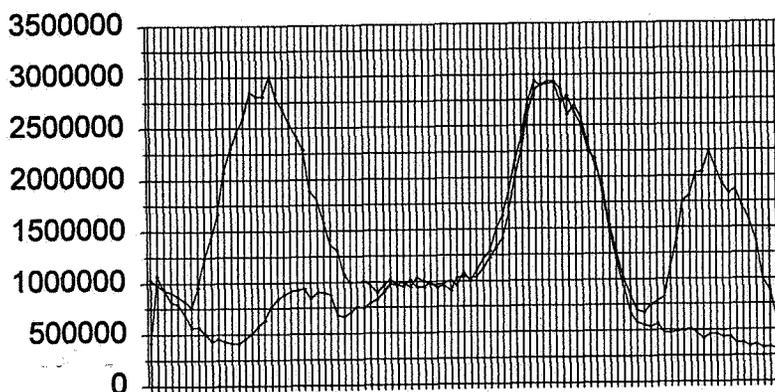
Figure 3: Plot comparing vertically and horizontally polarized components of induced scatter

Lean Flame, O2 and N2
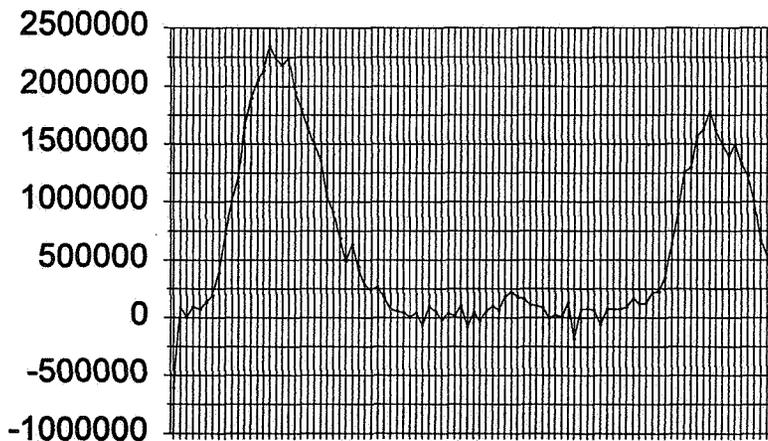
Figure 4: Difference between horizontal and vertically polarized components (Raman Signals for N_2 (left) and O_2 (right))

The data for figs. 3 and 4 was taken from a 500 shot average image and then binned in the spatial direction for maximum signal strength. The spatial averaging is possible because the

the spatial direction for maximum signal strength. The spatial averaging is possible because the linear probe volume segment for this image is contained entirely in the core of the flame where the conditions are uniform on a time-averaged basis.

The procedure for measuring temperature with the data available in this report is to collect data in a known flame condition to determine the correlation between the Raman signal and the number density, conduct Raman measurements in and unknown flow field at a known pressure, calculate the number density from the Raman signals and then calculate the temperature using ideal gas. It should be pointed out that, with a narrowband laser, the temperature can be determined directly from the shape of the Raman signal and then number densities (and partial pressures) can be determined from the total Raman signal strength. (This approach will be proposed for future hydrocarbon technique development.

Summary

A novel technique for extracting Raman signals from interference has been demonstrated. This technique offers single shot measurement potential, quantitative use of Raman signals obtained using broadband UV lasers and the possibility of obtaining quantitative Raman data in hydrocarbon flames.

References

1. Grunefeld, G., Beushausen, V., and Andreson P., "Interference-free UV-laser-induced Raman and Rayleigh measurements in hydrocarbon combustion using polarization properties," Applied Physics B 61, 473-478.

2. Hartfield, R., "Thermodynamic Measurements in a High Pressure Hydrogen-Oxygen Flame Using Raman Scattering from a Broadband Excimer Laser," Report for NASA/ASEE Summer Faculty Fellowship Program, August 1995.