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Spontaneous Raman Probe

DESCRIPTION

Spontaneous Raman scattering (SRS) is an inelastic process in which scattered light undergoes a frequency change characteristic to the internal energy levels of the irradiated molecules. SRS is a well-known spectroscopic method for combustion diagnostics, which provides gas temperatures and species concentrations in high temperature flows. SRS is relatively simple and less expensive compared to other laser techniques; its ability to operate through a single optical port is ideal for application in large industrial furnaces. Raman transitions are allowed for homonuclear diatomic molecules, such as N_2, O_2, or H_2, which cannot be measured by FT-IR. Raman scattering depends on the laser intensity, the fourth power of frequency, the concentration of scattering molecules, and the gas temperature. Gas temperatures are inferred by fitting experimental spectra to calculated profiles. Simulated N_2 Raman spectra at different temperatures are shown in Fig. 1.

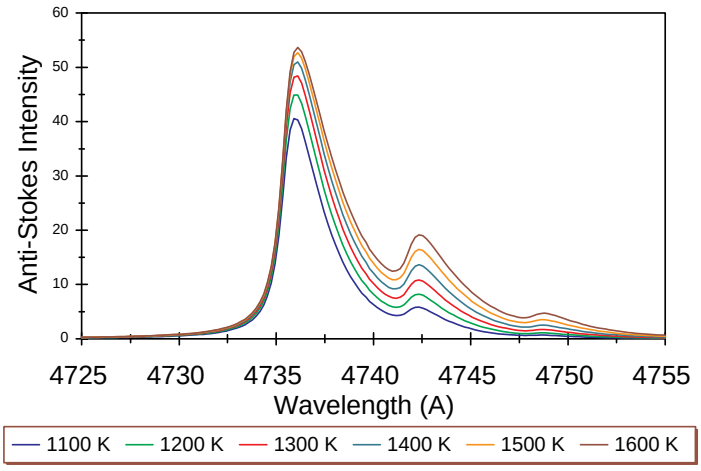

Fig. 1. Calculated N_2 anti-Stokes Raman spectra

SYSTEM DESIGN

A compact, pulsed Nd:YAG laser based, instrument is built to measure *in situ* absolute gas temperatures above 1000 K (see Fig. 2). The laser beam is focused onto the gas medium of interest by a quartz lens, which is mounted on the end of a 1.2-meter water cooled probe shown in Fig. 3.

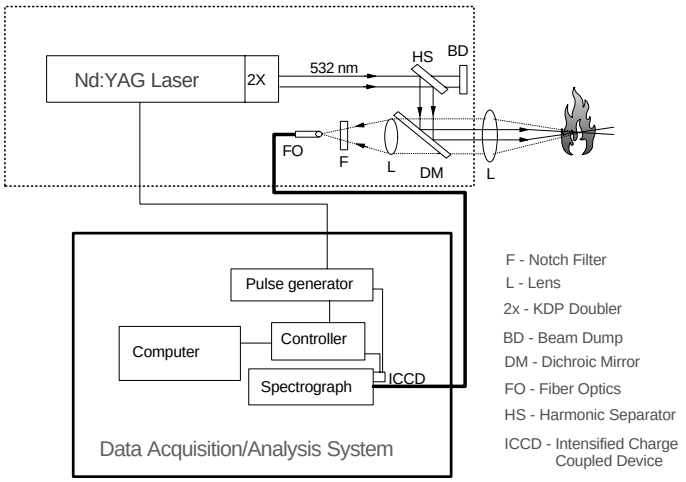

Fig. 2. Raman probe schematic.

The scattered Raman signal is collected with the same focusing lens and delivered to the input of a quartz optical fiber bundle. This optical configuration with coaxial back scattering collection has a good efficiency, and it is very insensitive to misalignment of optics. All of the optics except the focusing/collecting lens are built into an aluminum box which can be purged with nitrogen or dry air to prevent water condensation on the laser mirrors during field measurements. The optical fiber bundle delivers the Raman signal from the box to a 0.5-m monochromator equipped with 1200-l/mm and 2400-l/mm gratings and a CCD detector. Gated signal detection is used to significantly reduce background emission immanent in combustion environments.

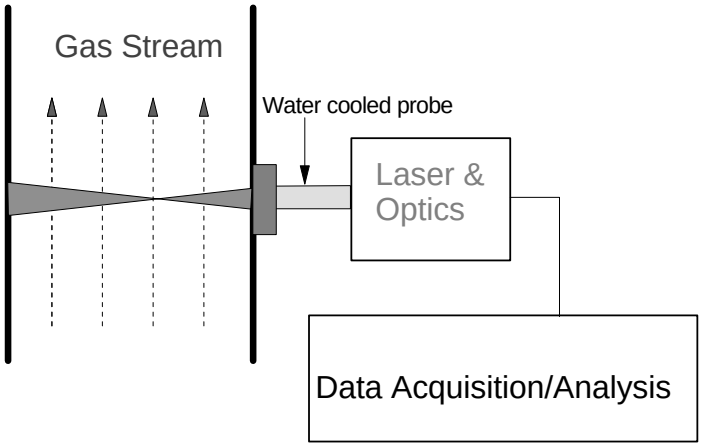

Fig. 3. Raman probe setup in a furnace.

PERFORMANCE CLAIMS

Raman thermometry does not require calibration, because all calculations are based on the well-known spectroscopy constants, and the accuracy of the inferred temperature depends on the accuracy of the spectroscopic data. The Raman probe can be successfully used in large industrial furnaces with requirements on the spatial resolution of the order of 10 - 20 cm along the beam axis. The spatial resolution along the axes perpendicular to the beam axis is on the order of 2 - 5 mm. Relative accuracy better than 1% was determined from a series of SRS data taken at temperatures ~ 1300 K. The lowest temperatures that can be measured with 10% accuracy are about 1000 K.

FIELD DEMONSTRATION

The Raman probe was successfully used for measuring the temperature profiles in a large industrial furnace during a week-long field trip. The temperatures measured with the Raman probe are in good agreement with corrected thermocouple measurements.

APPLICATIONS

Although the spatial resolution of the present design is on the order of several centimeters and time averaging about 100 s, the simplicity and robustness of the instrument make it very attractive for gas temperature and relative concentration measurements for major molecular species in large furnaces with steady thermodynamic conditions.

LIMITATIONS

Weak Raman signals require time averaging; therefore, SRS is not suitable for turbulent conditions.

Additional information about the Raman probe can be obtained by contacting:

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