Detector Assessment for 1D Single-Shot Spontaneous Raman Scattering for Temperature and Multi-Species Measurements in Flames

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Keywords: Spontaneous Raman Scattering, Temperature, species number density, Combustion

HIGHLIGHTS

• A Pockels cell shutter is used as optical gating for backilluminated-CCD (BI-CCD) and electron multiplying CCD (BI-EMCCD) for spontaneous Raman scattering measurements in flames.
• Accuracy and uncertainties of temperature and concentration measurements with BI-CCD and BI-EMCCD are compared to those with ICCD.
• Pockels cell shutter offers time gates comparable to ICCD, and it makes BI-CCD, the most efficient detection systems for single-shot temperature measurements.
• The BI-EMCCD is the powerful tool for best detectability of low concentration species such as CO.
• The measurements with ICCD are limited to density measurements with large probe volume.

ABSTRACT

The critical aspect of 1D single-shot Spontaneous Raman Scattering (SRS) experiments in flames is the requirement of high efficiency of the detection system associated with a fast temporal gating. Single-shot SRS measurements in flames are performed either with ICCD or with back-illuminated CCDs associated with a fast shutter. Two types of back-illuminated CCD detectors are used: a back-illuminated CCD (BI-CCD) and electron multiplying CCD (BI-EMCCD). The purpose of the present paper is to compare the three detectors: the ICCD with its intensifier gating and the back-illuminated CCDs with a Pockels cell shutter developed in a previous work (Ajrouche et al, 2015). The accuracy and uncertainty of 1D single-shot SRS measurements of temperature and density are quantified in nearadiabatic CH4/air flames. This is performed for N2 number density (high signal levels), and CO number density (low signal levels) corresponding to signal close to the detectability limit. The temperature is determined by modeling the vibration-rotation spectra of N2 offering advantage of not requiring reference temperature and the modeled spectra are used as smoothed spectra to determine the instantaneous number densities. On one hand, the BI-CCD with the Pockels cell shutter is the most efficient detection systems in extreme low light situations for single-shot temperature measurements, and on the other hand the BI-EMCCD is the most powerful tool for best detectability of low density species.