Using an EMCCD camera for high resolution one-dimensional Raman spectroscopy

Oliver Knauer, University Erlangen-Nürnberg (June 2010)

Application Note

Introduction

To investigate the heat and mass transfer phenomena across the phase boundary of single boiling bubbles in binary mixtures, simultaneous determination of species concentration and temperature in the vicinity of the boiling bubble is needed. The measurements also have to be non-invasive not to influence the occurring transport phenomena. Thus, an optical measurement technique is used and the spontaneous Raman scattering (SRS), based on inelastic light scattering, suits the requirements very well. Its advantages are a species specific Raman shift and a quantifiable signal intensity, which directly scales with the number of probed molecules. This allows the simultaneous detection of several species with only one excitation source. The temperature is measured via the temperature sensitive signature of the OH vibrational bond between 3100 and 3700 cm^{-1}. Besides its advantages, SRS also has one disadvantage that restricts it for several applications. The SRS signal intensity is very weak compared to the elastic scattered light. In order to get an applicable signal you need high excitation energy and a sensitive and perfectly optimized detection system. Therefore, we used the EMCCD (Electron Multiplying Charge Coupled device) camera Andor Newton DU971N-BV (1600 x 400 pixels of 16 x 16 μm^2) as a detection device. With its electron multiplying gain register, it has a much higher sensitivity than a conventional CCD camera and allows the detection of very weak spectra at high S/N ratios and fast readout speed. Moreover, it has got a quantum efficiency of more than 90% in the detected wavelength range.

Experimental Setup

The experimental setup is shown schematically in figure 1.

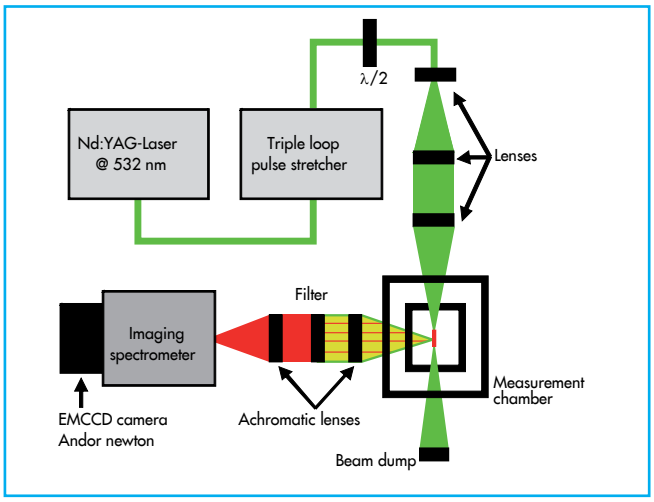

Figure 1: Experimental setup

As excitation source, we used a frequency-doubled Nd:YAG laser, which emits pulses of 8 ns (FWHM) duration at a repetition rate of 10 Hz and single-pulse energy with a maximum of 300 mJ at 532 nm. An optical pulse stretcher temporally stretches the laser pulses to insert more excitation energy into the measurement chamber without destroying the windows or causing laser-induced plasma. The direction of polarization of the laser is rotated perpendicular to the scattering plane via a λ/2-plate. A telescope expands the laser beam and focuses it into the measurement chamber. Two achromatic lenses collect and focus the scattered light onto the entrance slit of an imaging spectrograph (Acton, 275 mm focal length, grating with 600 lines / mm). A notch filter blocks the elastic scattered light. The spectrograph separates the incoming signal into its spectral components, while the spatial information parallel to the propagation direction of the laser is conserved, and displays it on the chip of the EMCCD camera. In the 400-pixel axis of the EMCCD-camera, which represents the spatial information from the line shaped probe volume, 20 pixels are binned to one superpixel. Thus, the 3.2 mm long probe volume is resolved into 20 increments with a resolution of 160 µm. The exposure time of the camera is 10 µs and the CCD chip is cooled down to -80 °C to reduce dark current. The EM-Gain is adjusted to a factor of 6, for a clean as possible acquisition of the recorded Raman spectra, as the S/N ratio was the highest with this adjustment.

Results

The acquired Raman spectra of different compositions at one temperature are shown normalized in figure 2.

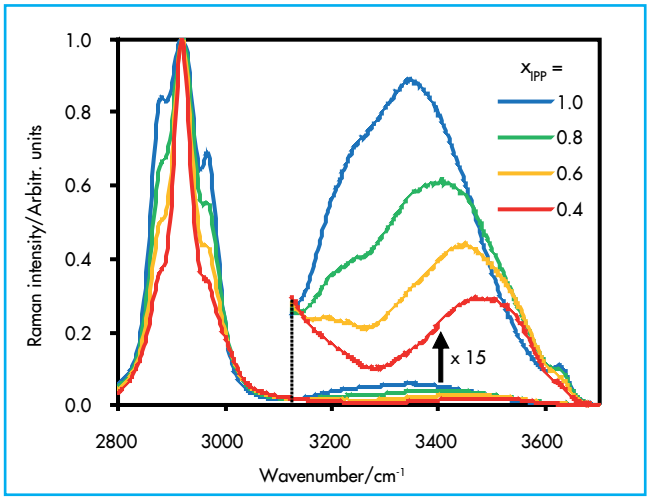

Figure 2: Raman spectra of acetone-isopropanol mixtures with different compositions at the same temperature

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It can be seen that the signal intensity of the O-H bond Raman signal between 3100 cm^{-1} to 3700 cm^{-1} decreases with a decreasing isopropanol volume fraction in the mixture. From the ratio of the O-H bond signal intensity from 3145 cm^{-1} to 3695 cm^{-1} to the C-H bond signal intensity from 2790 cm^{-1} to 3045 cm^{-1} the isopropanol volume fraction can be determined. To demonstrate the high resolution of the applied EMCCD camera Andor newton, Raman spectra of isopropanol at different temperatures are shown in figure 3.

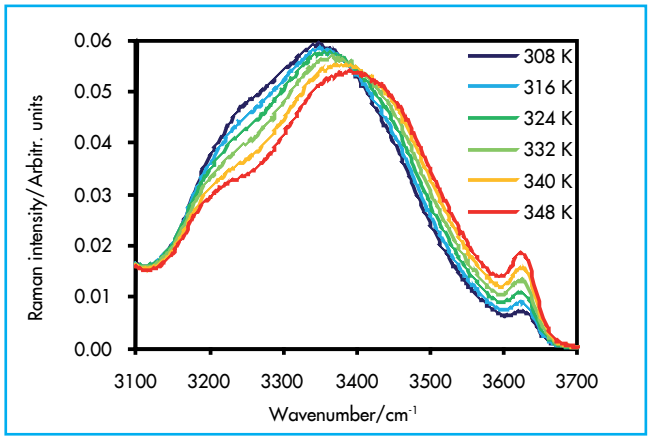

Figure 3: Raman spectra of isopropanol at different temperatures

The minor differences in the shape of the O-H vibrational bond with changing temperature, that enable the determination of the temperature, can still be resolved very accurately. Thus, the applied optical measurement setup together with the used EMCCD camera has a great potential for high resolution one-dimensional Raman spectroscopy.

Contact

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