Probing plasma-liquid temperature with Raman spectroscopy

MacFeely, K. T.[1], Rich, C. C.[1], Clay, C. D.[1], Bruggeman, P. J.[1], Frontiera, R. R.[1]
[1]*Department of Chemistry, University of Minnesota Twin Cities, Minneapolis, United States*

Abstract: In this contribution, I report on the construction of a Raman laser system to measure the effective temperature of reporter ions in a liquid film jet irradiated by nonthermal, helium fed atmospheric pressure pin-to-surface discharge-driven plasma jet using Raman spectroscopy.

1. Introduction

Temperature plays an important role in overcoming activation energy barriers but much about the physical effects of plasma-liquid interactions, such as temperature of the solution during and after irradiation, are still not well understood. [1]

I have constructed a laser system to investigate the effective temperature of reporter ions in aqueous solution flowing through a liquid film jet during irradiation by a nonthermal, helium fed atmospheric pressure pin-to-surface discharge-driven plasma jet (Fig. 1a.).

By measuring vibrational energy level distribution, one can calculate the effective temperature using the following equation:

$$\frac{I_{AS}}{I_S} = \frac{(\omega_i + \omega_v)^3}{(\omega_i - \omega_v)^3} e^{\left(\frac{-\hbar\omega_v}{kT}\right)}$$

Where I_x is Stokes or anti-Stokes intensity, ω_x is excitation (i) or vibrational mode (v) frequency, k is the Boltzmann constant, T is temperature. [2-3]

2. Methods

Spontaneous Raman scattering measurements are made using a 532 nm diode pumped, continuous wave laser. The laser irradiates a Raman active analyte and photons are scattered with lower (Stokes) or higher (anti-Stokes) energies as shown in Fig. 1b. The light is collected with a 20x objective lens in a 180° backscattering geometry (Fig. 1c.) and sent to a monochromator and CCD camera.

A nonthermal, atmospheric pressure pin-to-surface discharge-driven plasma jet is used to irradiate an aqueous solution of reporter ions flowing through a liquid film jet. [4] The other side is exposed to 532 nm laser light as seen in Fig. 1c. By shifting the center wavelength, I can change the region scanned and collect Stokes and anti-Stokes spectra with adequate spectral resolution as seen in Fig. 1d. and 1e.

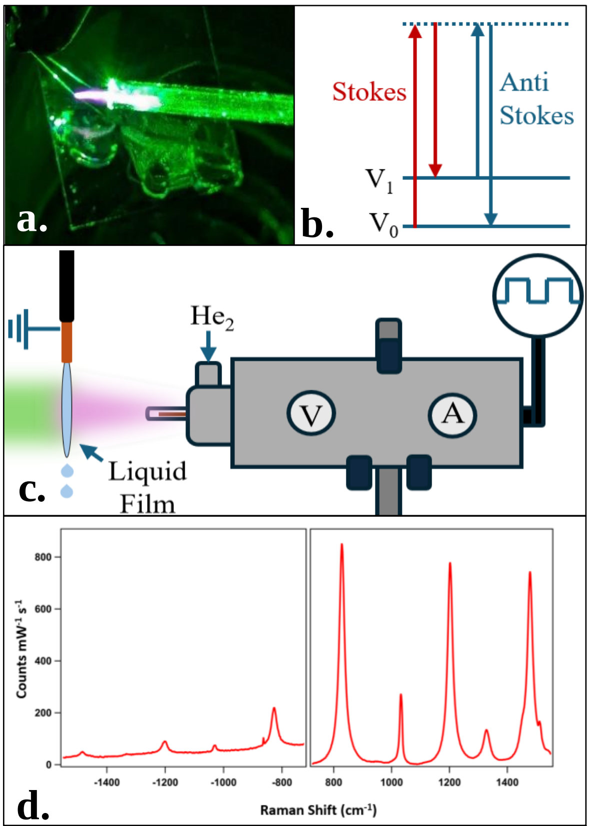

Fig. 1. (a.) Photograph of 532 nm light and plasma irradiating a liquid film (b.) Stokes and anti-Stokes Raman scattering energy level diagrams (c.) Schematic of image in (a.) (d.) anti-Stokes cyclohexane spectrum (left) and Stokes cyclohexane spectrum (right).

3. Results and Discussion

Figure 1 shows the measured anti-Stokes and Stokes (Fig. 1e.) spectra of cyclohexane. By comparing the ratio of anti-Stokes to Stokes intensities it is possible to determine the effective temperature of the population sampled. Future work will use this system to characterize the *in situ* temperature of the solution upon plasma irradiation.

4. Conclusion

This contribution highlights the construction of a laser system to enable Raman thermometry measurements. Through these measurements I seek to understand the impact of nonthermal plasma irradiation on the effective temperature of reporter ions in solution.

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