Gas temperature and NO density measurements in atmospheric pressure plasmas

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Optical emission spectroscopy and laser induced fluorescence are applied to an atmospheric pressure microwave plasma jet of helium and air. The LIF spectra are time and wavelength resolved, and are used to determine the rotational temperature, and absolute density of nitric oxide. A comparison is made to the rotational temperatures found by OES, and detailed motivation of these temperatures as the gas temperature is given.

Atmospheric pressure plasmas are studied for their applications in biomedicine, for example wound healing and bacteria inactivation. Nitric oxide (NO) produced by the plasma is believed to play a major role in many processes in living cells. We studied this NO production in an atmospheric pressure plasma jet, by means of passive and active spectroscopy. We compared two methods: Optical Emission Spectroscopy (OES), and Laser Induced Fluorescence (LIF). By measuring rotational spectra, we are able to determine the temperature and density of NO.

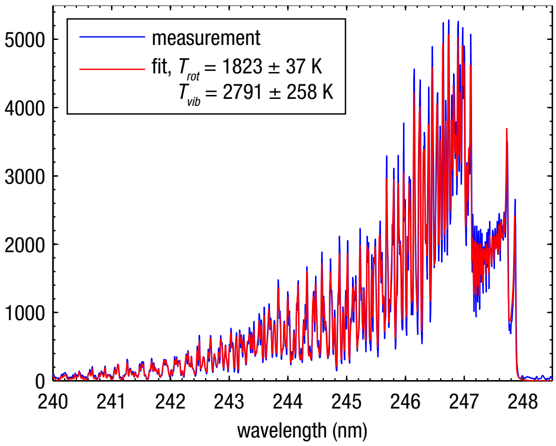

Fig. 1: *Rotational spectrum of NO, measured by optical emission spectroscopy.*

Our plasma source is a microwave jet, flushed with a mixture of helium with 3% air, in an open air environment [1]. We applied OES to determine the rotational spectrum of the NO $A\,^2\Sigma - X\,^2\Pi$ $(v = 0-2)$ vibrational band. The partly resolved spectrum is fitted to determine the rotational temperature (see for an example figure 1).

LIF is applied using a high repetition rate dye laser system (around 226 nm at 4000 Hz) to excite the NO $X\,^2\Pi - A\,^2\Sigma$ $(v = 0-0)$ transition. The fluorescence is measured with a monochromator and a photomultiplier which is connected to a multi channel scaler. This system allows us to measure the rotational LIF spectra wavelength resolved (used to determine the rotational temperature) and simultaneously time resolved (used to determine the quenching).

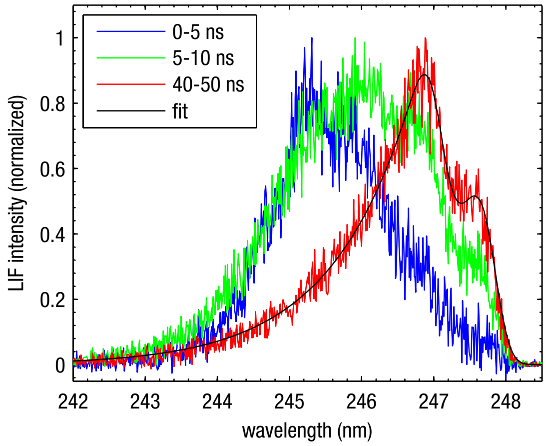

Fig. 2: *Rotational spectrum of NO, measured by laser induced fluorescence. The laser excitation is done at high rotational number ($J = 33.5$). The graphs show the signal measured at different time delays after the laser pulse. The fitted rotational temperature after* 40 *ns is* 1482 $\pm$ 52 *K.*

The rotational temperatures found by OES and LIF differ, which could be explained by the time it takes for the thermalization of the non-thermal rotational distribution caused by the production mechanism of the excited state (both by plasma processes or laser), see e.g. [2]. The time and wavelength resolved spectra allow us to visualize the rotational energy transfer, an example of which is shown in figure 2.

The absolute density of NO X ground state is determined by calibrating the LIF signal with a known density of NO. We found spatially resolved densities, in the order of 20 ppm inside the plasma, and an increase in the afterglow.

References

[1] B Hrycak et al. 2010, Eur. Phys. J. D, 60(3), 609-619.

[2] P Bruggeman et al. 2010, Plasma Sources Sci. Technol. 19 015016