Two-photon absorption laser-induced fluorescence measurement of atomic Oxygen density in an atmospheric pressure air plasma jet

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Introduction:
• In this work we use Two-photon Absorption Laser Induced Fluorescence (TALIF) to investigate atomic oxygen density [O] in an atmospheric pressure plasma jet which uses air as the gas source for the plasma. The RF power deposited into the plasma is varied by changing the voltage in the system power supply and the resulting atomic oxygen density is measured. The TALIF system is calibrated using photoysis to generate a known number density of atomic oxygen and measuring the resulting TALIF signal. Calibration typically involves using Xe gas to generate TALIF signals as it uses similar excitation and fluorescence wavelengths to the atomic oxygen TALIF scheme. However, Xe is an expensive gas to work with particularly if flowing it through an atmospheric plasma so in this work we use photoysis of atmospheric O$_2$ content to generate our calibration TALIF signal.

Photolysis:
• A laser is used to dissociate O$_2$ molecules producing a known atomic oxygen population. The laser pulse also interacts with these O atoms over the course of the pulse causing two-photon excitation. The resulting TALIF signal is recorded. The amount of [O] produced depends on the wavelength, photon fluence and molecular O$_2$ density [O$_2$] the laser beam interacts with. The dissociation energy of O$_2$ is 5.17 eV so once the photon energy of the laser exceeds this value [O] will be generated.

A. Single laser shot: 

\[ \lambda = 225.6 \text{ nm} (E_{\text{photon}} = 5.5 \text{ eV}) \]

- Single photon absorption
- Photo-dissociation of O$_2$ $\rightarrow$ 2 O atoms

As the resulting atomic oxygen density is a function of the laser energy, [O] will vary over the course of the laser pulse. Using this correction factor we can relate the TALIF signal $S_{\text{TALIF}}$ to the atomic oxygen density $[O_{\text{cal}}]$ produced by photoysis and so calibrate the system.

\[ S_{\text{TALIF}} = S_0 \frac{[O_{\text{cal}}]}{[O]} \]

Results:
• Atmospheric air was used to get a calibration TALIF signal.
• The plasma jet air flow was turned on and the laser power supply voltage was increased from 80 V to 140 V. TALIF signals were recorded at each voltage.
• The air flow TALIF signal was subtracted from the Plasma-On signal to get the TALIF signal due to O produced in the plasma jet.
• The [O] number density was calculated using the calibration relationship:

\[ [O] = \left( \frac{S_0}{S_{\text{TALIF}}} \right) [O_{\text{cal}}] \]

Discussion:
• Atomic oxygen density is measured in an air atmospheric pressure plasma jet using TALIF.
• Typically use Xe to calibrate the system but this is expensive.
• A photolysis scheme using O$_2$ in air is used to calibrate the system.
• By taking account of the temporal dynamics of the [O] density generated over the course of a laser pulse the same laser pulse can be used to both photo-dissociate the atmospheric O$_2$ and also to generate a TALIF signal that can be used for calibration purposes if know the local air pressure and temperature.
• The hot species produced by photoysis can lead to (i) increased quenching and (ii) loss of species from the laser focal zone so need to take both of these effects into account.
• The results are plotted and show that [O] increases by a factor of 3 as increase the voltage from 80 V – 140 V on the plasma jet system used.

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