Diagnostics of atmospheric pressure plasma jets

A. West, J. Bredin, S. Schröter, K. Niemi, T. Gans, J. Dedrick, D. O'Connell, E.Wagenaars

York Plasma Institute, Department of Physics, University of York, York, YO10 5DD, UK

Atmospheric-pressure plasma jets (APPJs) are widely studied for potential applications in industry and healthcare. Plasma diagnostics play a pivotal role in developing an understanding of the science underpinning APPJs. This is essential to guarantee effective and safe use of these devices in applications. We present a picosecond Two-photon Absorption Laser Induced Fluorescence technique that is capable of directly measuring the effects of collisional quenching on the fluorescence decay and therefore allows accurate, absolute measurements of densities of N and O radicals in the open-air effluent of an APPJ. Additional power measurements allow the study of energy efficiency of N and O generation in APPJs as a function of operating frequency.

1. Introduction

Atmospheric-pressure plasma jets (APPJs) are examples of plasmas that can operate in open air, remain at room temperature and still have a non-equilibrium chemistry. The unique combination of characteristics of these APPJ devices makes them ideal tools for novel applications in industry and healthcare, e.g. surface modification of plastics, plasma medicine and photoresist removal [1-3]. Although it is clear that reactive species play a pivotal role in the success of APPJs in many applications, the exact mechanisms through which APPJs affect target surfaces remain largely unknown. Moreover, control of the mixture of reactive species production as a function of operational parameters is often empirical. Diagnostics of APPJs play an important role in further developing our understanding of the plasma chemistry and will enable increases in treatment efficacy.

2. Picosecond Two-photon Absorption Laser Induced Fluorescence

Two-photon Absorption Laser Induced Fluorescence (TALIF) is a well-known technique in low-pressure plasmas for the measurement of absolute densities of atomic species such as O, N and H. Unfortunately, application of this technique on APPJs that are operating under realistic conditions for applications, i.e. in open air and with complex admixtures, is not straightforward. The highly collisional environment of APPJs means that collisional quenching of the laser-excited state becomes significant and needs to be taken into account. For well-controlled atmospheres and simple admixtures the effect can be estimated using quenching coefficients [4], however under realistic operating conditions the identity and density of the quenching partners is unknown due to the complexity of the plasma chemistry. An alternative is a direct measurement of the fluorescence decay on sub-nanosecond timescales. We present a picosecond TALIF diagnostic which uses a sub-ns laser (30 ps) and iCCD camera (200 ps), which allows us to measure the quenching-affected fluorescence decay rate directly and deduce absolute measurements of O and N density maps in the open-air effluent of an APPJ.

3. Power measurements

Measurements of the power dissipated in the plasma are of critical importance not only for further developing our understanding of APPJs, e.g. via comparison with modelling, but also in applications, e.g. for the optimisation of energy efficiency. Conceptually, measuring power in a radio-frequency (rf) circuit is relatively straightforward; however in practice it often turns out to be difficult to perform these measurements due to the small powers dissipated and the mostly capacitive nature of the load. We present a flexible, 'post-matching' technique that is capable of providing accurate measurements of power dissipated in rf-driven APPJs. This diagnostic is subsequently used to investigate the efficiency of the production of reactive O and N species for different rf excitation frequencies (13.56 MHz - 40.68 MHz).

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5. References

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