# Electric Field and Charge Density Measurements in the Atmospheric Pressure RF Plasma Jet

Inna Orel[1], Nikita D. Lepikhin[1], Dirk Luggenhölscher[1], Zoltan Donko[2], Uwe Czarnetzki[1]
[1]*Faculty of Physics and Astronomy, Ruhr-University Bochum, Bochum, Germany*
[2]*Institute for Solid State Physics and Optics, HUN-REN Wigner Research Centre for Physics, Budapest, Hungary*

**Abstract:** The atmospheric pressure RF plasma jet is investigated by E-FISH electric field measurement supplement by phase resolved emission spectroscopy. The jet is similar to the COST-jet with modifications allowing the laser diagnostics. Operation is in He with 0.5 % admixture of $N_2$. Measurements are performed with temporal and spatial resolution. Electron and ion densities are derived from the data and compared to *ab-initio* PIC/MCC simulations.

## 1. Introduction

The so-called COST-jet [1] is a standardized RF driven atmospheric pressure plasma source. It is typically operated in He with admixtures of molecular gases in the percentage range. A large wealth of experimental data on various radicals and excited species has been acquired over the years by various laboratories. However, to the best of our knowledge, so far no direct experimental data exist on the electric field and the charge densities in the jet. In this work we report for the first time model independent measurements of these basic plasma parameters. Further, the absolute electron current density is derived. The results are in excellent agreement with *ab-initio* PIC/MCC simulations and confirm a former theory on the non-neutrality of the discharge [2].

## 2. Methods

The design of the COST-jet has been slightly modified in order to allow a laser beam to pass along the discharge gap for the electric field measurement by the E-FISH technique [3]. Further, the gap width between the electrodes has been enlarged from the original 1 mm to 1.5 mm. Operation is in He with 0.5 % admixture of $N_2$. The entire setup is mounted in a sealed chamber to ensure defined operation conditions. Special emphasis was on the absolute field amplitude calibration as well as on the spatial and temporal calibrations.

## 3. Results and Discussion

Figure 1 shows the spatially (along the discharge gap) and temporally (over on RF period) resolved electric fields in comparision to the prediction by the PIC/MCC simulation. In a first step, these data are evaluated to determine the mean electron density in the center of the discharge. In order to perform this analysis, the electric field dependent mobility is calculated using the local BOLSIG+ Boltzmann solver [4]. Neglecting the small temporal variation of the electron density in the center, then allows for the derivation of the electron current density in a second step. In the third step, the temporally varying electron densities at all position outside the center can be derived. Finally, in the fourth step, the time averaged fields and electron densities are inserted into Poisson's equation to derive the static ion density profile. The results clearly demonstrate that the discharge is non-neutral throughout the gap, i.e. the temporal mean electron density is significantly higher than the ion density. All these data are in excellent agreement with the PIC/MCC predictions.

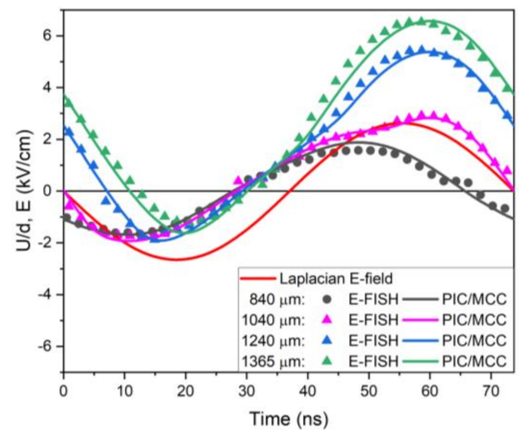


**Fig. 1**. Spatially and temporally resolved measured and computed electric field in the RF plasma jet. The indicated positions are referring to the distance from the grounded electrode.

## 4. Conclusion

For the first time laser electric field measurements have been successfully performed in a COST-jet-like atmospheric pressure RF plasma jet. From these data, the current density and the spatially and temporally resolved electron densities as well as the static ion density distribution are derived using only fundamental physical parameter relations. The results are in excellent agreement with *ab-inito* PIC/MCC simulation results. It is demonstrated that the RF-Jet is a discharge but not a plasma due to the lack of quasi-neutrality. This confirms a recent theory by Brinkmann et al. [2].

**Acknowledgement**

The work was supported by the German Science Foundation (DFG) in the frame of CRC1316 "Transient atmospheric plasmas – from plasmas to liquids to solids".

**References**

[1] J Golda et al 2016 JPhysD 49 084003.
[2] M. Klich et al 2022 PSST 31 045003.
[3] I. Orel et al., accepted for PSST DOI 10.1088/1361-6595/adad15.
[4] G J M Hagelaar et al. 2005 PSST 14 722.