Visualizing and quantifying ionic wind speeds in ring-type plasma actuators using Schlieren Image Velocimetry

Abdurrahman Musazay, Percy Atuiri, Matthias Lindner, Philipp Buchner, Clemens Jaroschek, Peter Bickel, Rupert Schreiner,
Faculty of Applied Natural Sciences and Cultural Studies, OTH Regensburg, Germany
E-mail of corresponding author: abdurrahman.musazay@oth-regensburg.de

ABSTRACT

Plasma actuators are active flow control devices that operate by ionizing air to generate a body force that results in an induced airflow known as ionic wind [1]. Accurately measuring this ionic wind is critical for evaluating actuator performance. Traditional visualization and quantification methods such as hot-wire anemometry, Pitot tubes, and standard Particle Image Velocimetry (PIV), are often intrusive, require physical probes or flow-seeding particles, and such as in the case of PIV, are often expensive. The Schlieren imaging technique offers a non-intrusive alternative that visualizes fluid density gradients [2]. This work presents a methodology to extract velocity information from these visualizations using Schlieren Image Velocimetry (SIV). Instead of tracking seeded particles as one does with PIV, we track the naturally occurring density fluctuations within the wind flow patterns across the Schlieren frames. By applying the cross-correlation algorithms inherent in standard PIV software to these images, we compute spatially resolved ionic wind velocity vectors [3]. This diagnostic approach is implemented on ring-type plasma actuators, which, due to their radial symmetry, result in a body force that is directed perpendicular to the surface (Figure 1). Analysis reveals wind velocities exceeding 4 m/s for an actuator with diameter 32 mm, 150 µm thick dielectric, and operated at 1 kHz with 10.4 kV peak-to-peak applied voltage. Our work demonstrates that quantitative flow maps of the induced wall jets can be acquired, and that SIV is an effective and inexpensive alternative for both visualizing and quantifying the ionic wind generated in plasma actuators.

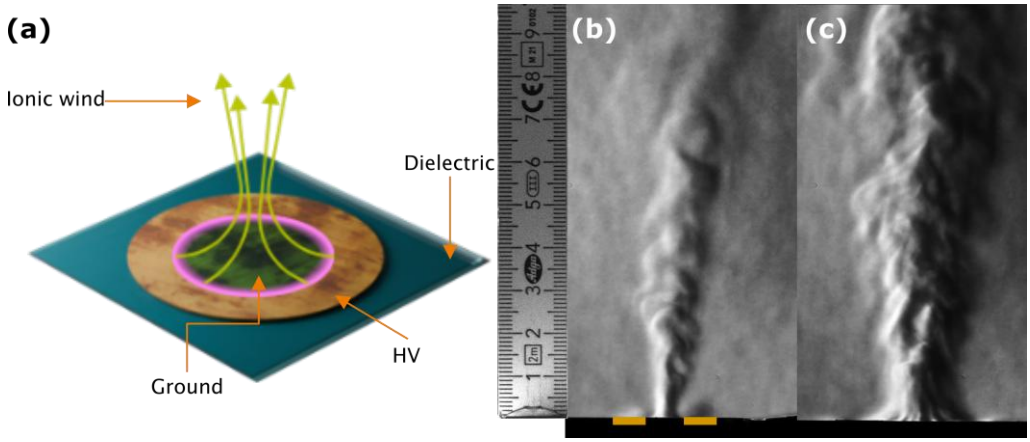

Figure 1: (a) Schematic of the ring-type plasma actuator depicting the vertically directed ionic wind. Schlieren visualization of the ionic wind generated in ring-type plasma actuators of (b) 8 mm, and (c) 32 mm inner diameter. The placement of the electrodes in this side-view is superimposed in orange.

References

[1] Roth, J. R., et al., "Boundary layer flow control with a one atmosphere uniform glow discharge surface plasma.", 36th Aerospace Sciences Meeting and Exhibit, Vol. 1 (1998)
[2] Settles, G.S., “Schlieren and Shadowgraph Techniques: Visualizing Phenomena in Transparent Media.”, 1st Edition, Springer, Berlin (2001)
[3] Thielicke, W., et al., “PIVlab - Towards User-friendly, Affordable and Accurate Digital Particle Image Velocimetry in MATLAB.”, Journal of Open Research Software, 2 (2014)