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► **To cite this version:**

Philippe Bérard, Deanna A. Lacoste, C. Laux. Corona Discharges in Atmospheric Air Between a Wire and Two Plates. IEEE Transactions on Plasma Science, 2011, 39 (11), pp.2248-2249. 10.1109/TPS.2011.2162854 . hal-00669366

HAL Id: hal-00669366

<https://hal.science/hal-00669366>

Submitted on 22 Feb 2012

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Corona Discharges in Atmospheric Air between a Wire and two Plates

Philippe Bérard, Deanna A. Lacoste and Christophe O. Laux

Abstract – The corona discharge obtained in atmospheric air between a wire and two plates is presented. For the configuration studied and the voltage applied, the current is steady for the positive corona and exhibits Trichel pulses in the negative corona. The positive corona produces a homogeneous blue halo around the wire whereas the negative discharge produces evenly spaced spots on the wire surface. We verified the analytic prediction that the ionic wind varies as the square root of the mean current

for both the positive and negative polarities. The measured ionic wind produced by the positive corona is higher than for the negative corona. We propose an explanation for the difference of velocity between polarities.

Index Terms: atmospheric-pressure plasmas, corona, glow discharges, electrohydrodynamics, plasma measurements

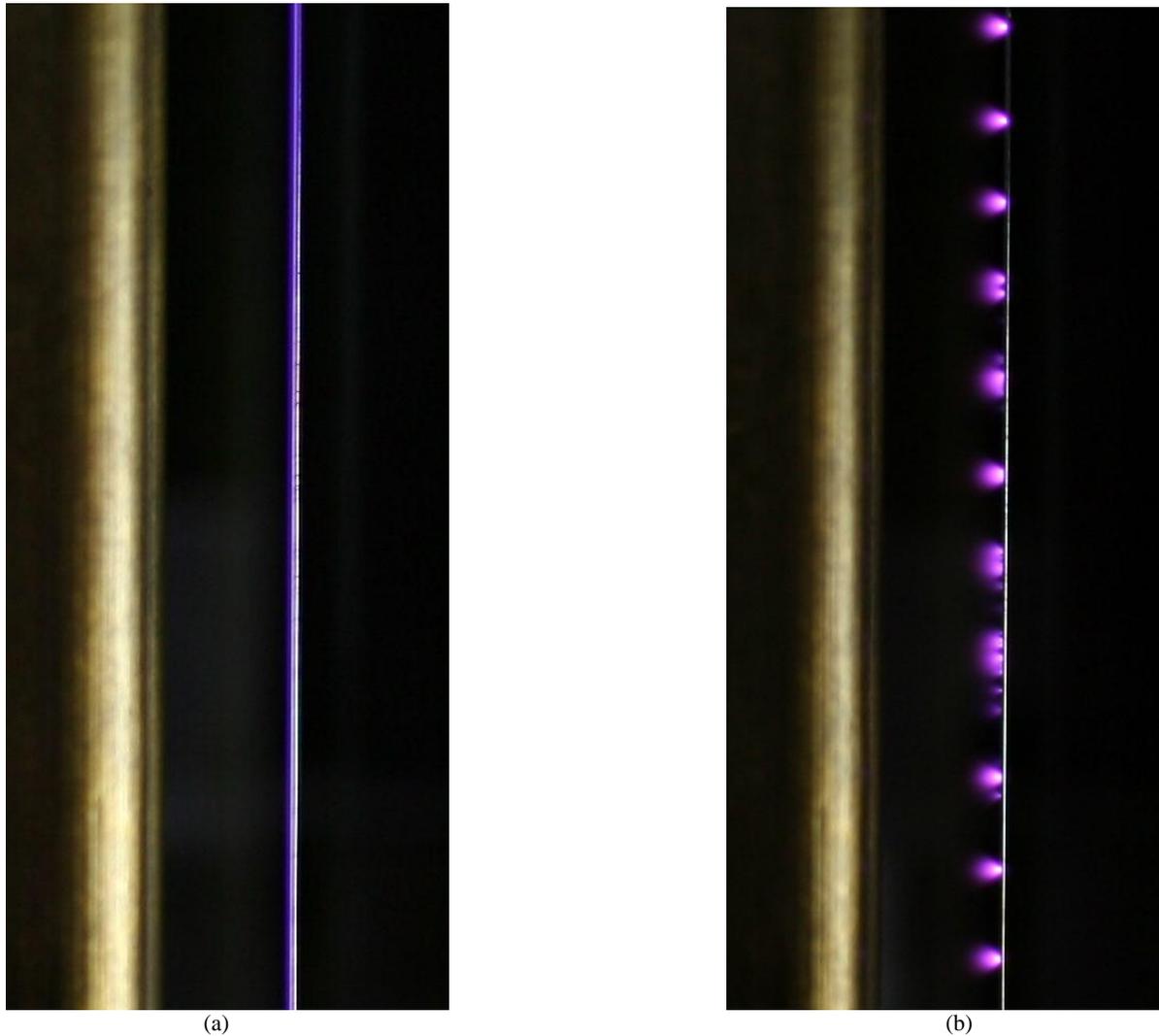


Fig. 1. Corona Discharges between a high potential wire and two grounded plates in air at atmospheric pressure and ambient temperature. (a) positive corona ($V = 14.2$ kV, $I = 1.5$ mA), (b) negative corona ($V = -10.5$ kV, $I = -1.3$ mA)

Manuscript received 30 November 2010; revised xxx.

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Publisher Identifier S XXXX-XXXXXXX-X

The ionic wind created by a corona discharge or a dielectric barrier discharge on the boundary layer of an airfoil has interesting potential applications for the purpose of reducing drag, controlling the transition to turbulence, and for flow actuation. For example, reference [1], has successfully demonstrated boundary layer reattachment of a low-speed flow on a surface. The work presented here is part of a parametric study [2]-[3] on a simple reference configuration to quantify the effect of the discharge and geometry on the flow velocity. We focus on the differences between the positive and negative corona discharges.

Our experimental setup is composed of a thin wire and two parallel plates, 20 cm in length, in air at atmospheric pressure and ambient temperature (see schematic on fig. 2). The wire is brought to a high DC voltage adjustable up to 20 kV (positive or negative polarity) with a FUG 140-20000 power supply, whereas the plates are connected to ground. We measured the flow velocity using hot wire anemometry.

The positive discharge (Fig. 1a) produces a homogeneous blue halo in the vicinity of the surface of the high potential wire. Its radial extension is about a tenth of millimeter. Its brightness increases with current and voltage. Electrical measurements show that both the current and voltage are steady. In contrast, the negative discharge (Fig. 1b) creates fairly evenly spaced luminous discharge cones between the wire and the plates. These cones are visually stable and produce an acute whistle. Their number and their brightness increase with current and voltage. Oscilloscope traces show current peaks on top of a DC current component, showing the pulsed nature of the negative discharge. These observations are similar to those reported in [4]. The mechanism of the discharge is not the same depending on the polarity, so it is interesting to compare the ionic wind velocity measured for each case.

Depending on the polarity, the ions responsible for the ionic wind are not the same: positive ions in the positive discharge and negative ions in the negative discharge. With the setup shown in Fig. 2, we verified that, for a given mean current, the flow velocity is higher for the positive corona than for the negative corona. Although the spark appears for a higher mean current in the case of the negative discharge, the velocity obtained with the positive corona discharge is always around 40 % higher than that obtained with the negative discharge. Such a difference in behavior cannot be explained by the presence of different ions in the two discharges, because the mobilities of the main positive and negative ions in air are comparable [5]. The different velocities in the positive and negative coronas can be explained as follows. For the negative discharge, the velocity

is plotted as a function of the mean current, i.e. an average of the DC and pulsed components. However, it was shown in [6] that the ionic wind produced during current peaks is significantly lower than that produced between pulses. As a result, when plotted as a function of the mean current, the velocity obtained with the negative corona should be lower than in the positive corona case.

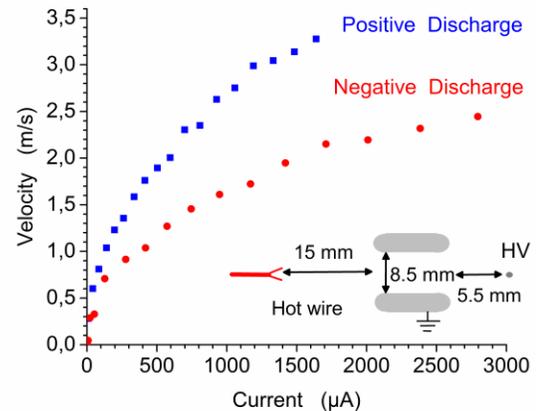


Fig. 2. Flow velocity measured with a hot wire device for the positive and the negative discharges in a wire-2 plate configuration.

In conclusion, the positive and negative discharges produce significantly different configurations of coronas, with a significantly higher ionic wind in the positive corona. A detailed parametric study of the ionic wind in positive coronas is presented in Refs. [2]-[3].

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