Interaction between a pulsed plasma jet and the surface of a liquid – Characterization of the discharge regimes and the hydrodynamic flows induced inside the liquid

Subject: **M2 Internship followed by a PhD Thesis** at the University of Poitiers, Funded by the ANR HYDROCAPS Project

Internship allowance (M2): €700 net per month

PhD salary: €2300 gross per month (€1850 net) + €160 if teaching duties are assigned

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Context of the internship:

Over the past decade, the scientific community's interest in plasmas interacting with liquids has steadily increased. The strong chemical reactivity of **plasma–liquid interactions** gives rise to applications in many fields such as agriculture, nanomaterial synthesis, medicine, and water treatment, in a perspective of sustainable development. Plasma is generated by applying a high voltage between at least two conductive electrodes, which induces an electrical discharge that forms the plasma. In the case of plasma–liquid interactions, these electrical discharges are most often generated in the gas phase above the liquid surface.

Consider the example of a discharge produced from a needle positioned a few millimeters above the surface of the liquid, to which a DC high voltage of a few kV is applied (Figure 1a). In this configuration, the chemical species generated at the needle propagate toward the liquid surface, penetrate the liquid, and interact with the chemical species already present within it. In reality, the situation is much more complex, since the plasma–liquid interface is the site of numerous physical and chemical phenomena. Among these, we are particularly interested in the **hydrodynamic phenomena** that appear both at the surface and within the bulk of the liquid. Depending on the plasma type, these liquid flows may result from different physical mechanisms: shear layer at the gas–liquid interface due to the gas flow within the discharge itself (ionic wind or gas flow in the case of a plasma jet), thermal convection, the Marangoni effect caused by a surface tension gradient, or electrical forces acting on ions located mainly at the gas–liquid interface but also within the liquid. These flows play a fundamental role in transporting species within the liquid. Consequently, it is essential to analyze them in detail to properly control plasma–liquid processes.

The scientific literature on this topic is relatively limited, as only about 20 articles have focused on the study of liquid flows induced by a plasma. Furthermore, the mechanisms responsible for these flows are not clearly identified because they are difficult to investigate. **The subject is therefore fascinating and almost unexplored.**

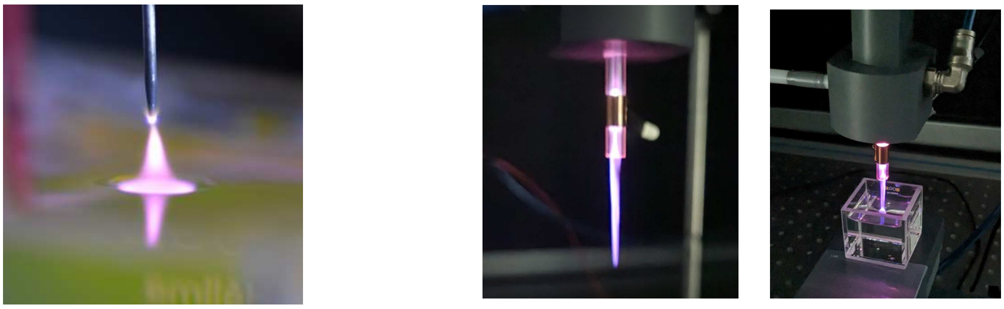
In this context, the “Electrofluidodynamics” (EFD) team of the PPRIME Institute (University of Poitiers, CNRS UPR 3346) initiated **a new research theme on this topic** several years ago. The team has received significant funding from the Labex INTERACTIFS and the INTREE Graduate School (EUR). To date, the EFD team has studied the electrical characteristics of various types of cold plasmas (corona discharge, glow discharge, dielectric barrier discharge, and helium plasma jet powered by a sinusoidal high voltage) and has characterized the flows induced by these plasmas using advanced optical diagnostics.

Beginning in early 2026, the EFD team, in collaboration with the GREMI laboratory in Orléans, will start a new research project funded by the French National Research Agency (ANR). This project will support an M2 internship and a PhD thesis. **The EFD team is therefore seeking a candidate to first carry out an M2 internship (march-september 2026), followed by a PhD thesis (from October 2026) in a scientific field related to cold plasmas and fluid mechanics.** If a candidate already holds a master’s degree, then it may be possible to start the PhD earlier, from April 2026 onward.

Internship research topic:

In this project, a **pulsed plasma** jet will first be studied and characterized using electrical measurements and optical diagnostics (intensified iCCD camera). This will form the first part of the thesis. The next objective of the project will be to establish a link between the chemical activity within the liquid and the flows induced in the same liquid by the plasma jet. Chemical analyses and measurements will be carried out at GREMI in Orléans. In Poitiers, experimental work will focus primarily on the study of fluid flows using optical systems such as Schlieren imaging and PIV (Particle Image Velocimetry). For further information regarding the internship and the PhD thesis, candidates are requested to contact the scientific coordinator of the project at the University of Poitiers (Eric MOREAU, eric.moreau@univ-poitiers.fr).

To illustrate this research topic, Figure 1 shows two examples of plasma photographs used in our previous studies. Figure 2 shows an example of the velocity field of the mean flow generated within the liquid in the case of a positive corona discharge (I = 30 µA). One can observe that the flow generated within the discharge (ionic wind) deforms the liquid surface where the discharge impacts it, and that the discharge produces two counter-rotating vortices on each side of the impact point, resulting from an upward force and surface force. Finally, Figure 3 shows the velocity field of the ionic wind produced within a dielectric barrier corona discharge established between a needle and the surface of a liquid.



(a) (b)

Figure 1. Photo of two types of cold plasmas: DC glow discharge between a needle tip and the liquid surface (a), helium plasma jet (b).

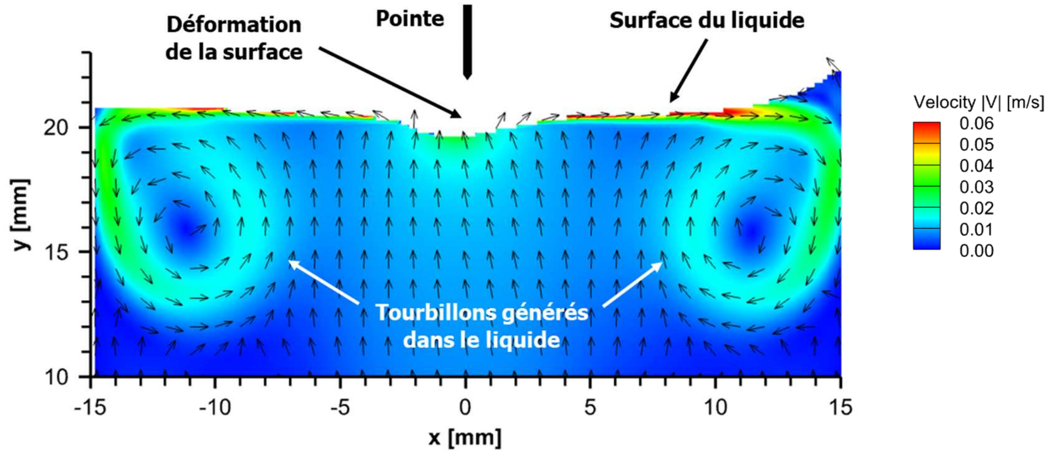


Figure 2. Time-averaged velocity field of the flow induced inside a liquid by a DC positive corona discharge (I = 30 µA).

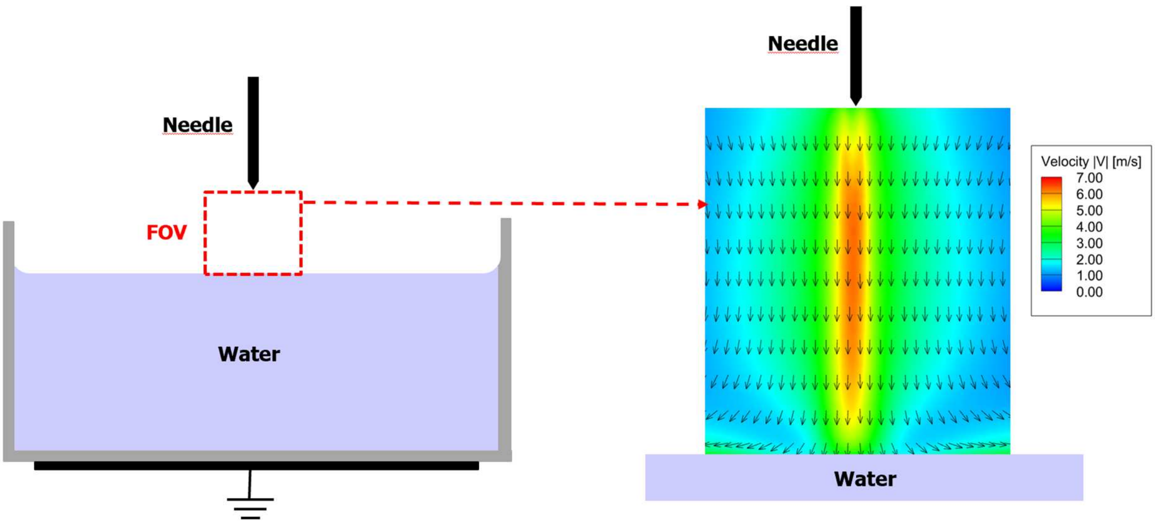


Figure 3. Velocity field of the ionic wind produced by a dielectric barrier discharge between a needle and the surface of a liquid.