The memory effect of pulsed plasma jets in He, Ar and N_2

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When an atmospheric pressure plasma jet is excited by pulsed voltages with a kHz-range repetition frequency, plasma bullets are typically generated. One of their most notable properties is that they follow a fixed path. This behavior is generally ascribed to a memory effect, where the remnants of previous bullets provide a guiding channel for the new bullet to follow. In this work the development of the memory effect is investigated during the first several voltage pulses using a high frame-rate camera with image intensifier. Helium, argon and nitrogen are used as feed gas and flow into open air. For helium, all consecutive plasma bullets follow the same trajectory, with the exception of the very first one. In contrast, for argon and nitrogen the length of the trajectory develops during the first ~10 voltage pulses, which is shown to be closely related to transport of remnants in the gas flow.

1. Introduction

Atmospheric pressure plasma jets have received much interest in the past few decades for their numerous potential applications in materials processing and biomedicine [1]. When pulsed voltages in the kHz-range are used to to excite the jet, typically so-called ‘plasma bullets’ are visible in short exposure ICCD photographs. These plasma bullets are streamer-like discharges with the special property that they are very periodic and all follow the same fixed trajectory. This behavior is usually explained by a memory effect where the presence of discharge remnants from previous plasma bullets provide a guiding channel for the next bullet [1,2]. However, currently not much is known about the precise mechanisms and development of the memory effect during the first cycles of the plasma jet. In this contribution we show how the memory effect develops when helium, argon and nitrogen are used as feed gas and flow into open air. In addition, an experiment to investigate the role of charged species in the discharge remnants is discussed.

2. Development of the memory effect

To investigate the development of the memory effect, the trajectories of the discharges during the first few voltage pulses are recorded. This is done by photographing the optical emission with a high frame-rate camera with image intensifier, which makes it possible to record the trajectories of consecutive individual discharges up to several kHz repetition rates.

When using helium as feed gas, the trajectories of all plasma bullets are the same, with the exception of the very first one. The plasma bullets travel along, and are guided by, the outflowing stream of helium and the remnants of previous discharges only ensure that the jet reignites during the next voltage pulse.

In contrast, when either argon or nitrogen is used as feed gas, a development phase of about 10 cycles is observed. In these first 10 discharges the trajectory of the plasma bullet grows along the axis of the jet until it reaches its final length and becomes repeatable. By numerical simulation of the gas flow, it is found that the length of a trajectory corresponds to the distance particles have travelled in the flow starting from the first discharge. This implies that in this case the guiding mechanism is not just related to the presence of the outflowing feed gas, but rather to the presence of discharge remnants that are transported in the gas flow.

3. The role of charged species

Next we would like to know what species constitute the discharge remnants and what their role is. Previous work by Nijdam *et al* has shown the role free electrons in the guiding of positive streamers [3]. To investigate this for the pulsed plasma jet, another experiment is performed where an external electric field is applied perpendicular to the bullet’s propagation direction between two discharges. The first results using nitrogen as feed gas demonstrate that the trajectories can in fact be manipulated this way and hence that charged species play an important role in the memory effect.

References

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