Manipulation of helium barrier discharges by laser surface interaction

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1. Introduction

The characteristic effect determining the behavior of barrier discharges is the charge accumulation on the dielectric surfaces during the discharge breakdown. These accumulated surface charges form an inverted electric field whereby the discharge disappears. After the reverse of the external applied voltage, this field enhances the external electric field and the discharge ignites at a lower applied voltage. Furthermore, the surface charges are less strongly bound on the dielectric and easier to remove by secondary processes. This reduces as well the breakdown voltage. To investigate both influences of the surface charges on the discharge breakdown, the idea is to remove surface charges by laser photons and to analyze the induced effect on the discharge.

2. Experiment

The object of investigation is a helium barrier discharge at 500 mbar in a 3 mm gap using two 0.7 mm thick glass plates ($\varepsilon_r = 7.6$) as dielectrics. The applied voltage has a frequency of 2 kHz and an amplitude in between 700 and 1200 V. The discharge is characterized by deriving the gap voltage and discharge current from the measurement of the transported charge across an external capacitance. Besides, the spatially resolved optical emission is measured by a monochromator and a photomultiplier tube. The manipulation of the surface charges is performed by a Nd:YAG laser at its second harmonic wavelength of 532 nm.

3. Results

A typical example for the laser surface interaction is shown in figure 1, where the laser is fired during the pre-phase of the glow-like discharge. As visible, the discharge ignites earlier after the laser pulse. The maximal discharge current and the gap voltage drop during the discharge pulse are reduced. Furthermore, the area covered by the discharge current profile reveals a reduced transferred charge as well. The optical emission intensity shows that the propagation of the cathode-directed ionization front slows down after laser surface interaction.

The explanation of this behavior is that the laser photons release electrons from the negatively charged cathodic dielectric. These additional electrons enhance the ionization rate during the pre-phase of the discharge wherefore the discharge ignites earlier. It is remarkable that only few electrons are necessary to induce this effect, otherwise a laser-induced current would be measurable.

To proof this explanation, 1D fluid simulations are performed assuming a release of 1 pC within about 10 ns. These simulations show the same behavior as the experiment: The discharge ignites earlier and the propagation speed of the cathode directed ionization front is smaller. Furthermore, the increase in the ionization rate by the additionally released electrons is clearly visible.

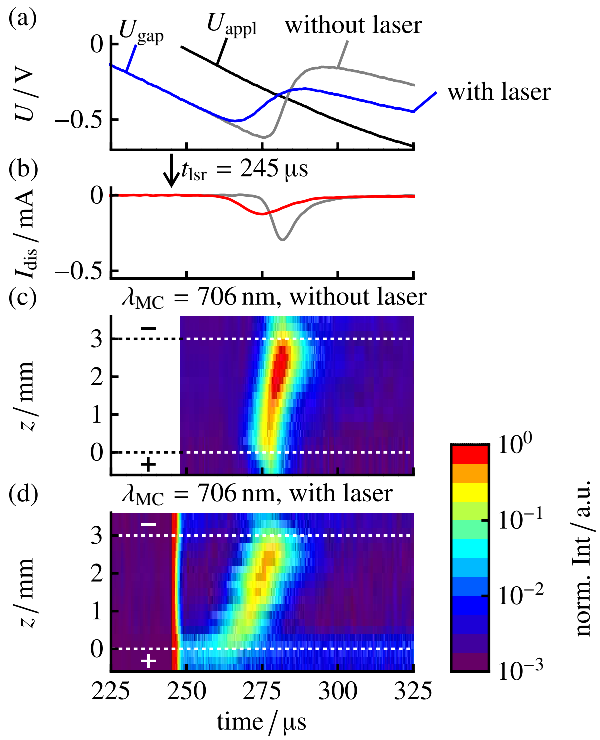

Fig. 1: *(a) Applied and gap voltage, (b) discharge current and optical emission for (c) the undisturbed and (d) laser disturbed discharge. In (a) and (b), the undisturbed discharge is represented by gray lines.*

4. Outlook

Besides these exemplary results, a systematic variation of the laser firing time, the vertical laser position and the laser pulse energy are done. Furthermore, a comparison with the fundamental laser wavelength at 1064 nm and the investigation of different dielectrics is planned to learn about the binding energy of the surface charges on the dielectric. This should be combined with surface charge measurements using the opto-electric Pockels effect.