Optical Emission Spectroscopy of a Femtosecond Laser Induced Filament Plasma for the Guiding of HV Discharge in Air

Q Gutierrez[1], A Houard[1], and T Clark[1]

[1]*LOA, ENSTA Paris, CNRS, Ecole Polytechnique, Institut Polytechnique de Paris, 91762 Palaiseau, France, 181 chemin de la Hunière, Palaiseau, France. Contact Phone: +33786186865*
Contact Email: quentin.gutierrez@ensta.fr

Intense femtosecond lasers in the gigawatt range have demonstrated various applications [1]. Under such high laser intensities, strong nonlinear optical effects occur, such as Kerr self-focusing of the beam. A laser pulse propagating in air can then become intense enough to ionize the air and create a long, thin plasma channel [2]. This phenomenon, known as filamentation, has the ability to efficiently guide high-voltage (HV) electric discharges in open air [3]. Filament-guided discharges have been demonstrated at laboratory scales (kV to hundreds of kV range) [4] (see Fig. 1a), as well as at a large scale for lighting over a 50-meter distance using a high-energy, high-repetition-rate YAG laser [5]. Various applications have been proposed such as the plasma antenna [6] and the laser lightning rod [5]. In this study, we analyze the characteristics of the plasma during the different stages of the guided discharge: from the initial filament (Fig. 1a), to the streamer propagating between the electrodes, and finally the spark phase, during which a significant current flows from the HV electrode to the grounded electrode (Fig 1b).

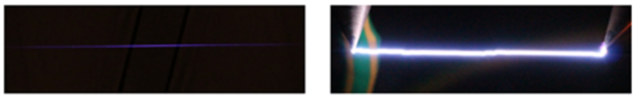

Figure 1: a) Filament induced by a focused 50 mJ, 100 fs laser pulse. b) Guided discharge (15 kV, D = 4 cm, 30 µs)

We investigate the influence of the laser parameters (pulse duration, energy, repetition rate and numerical aperture) on the filament properties and their subsequent impact on the HV discharge guiding effect in open air. Optical Emission Spectroscopy (OES) has been used to estimate some important plasma features such as temperatures (T_{rot}, T_{vib}, T_e, T_g) and density (n_e, n_g). This approach was also used to study the different phases of a guided discharge, from streamer to spark, in order to provide a comprehensive characterization of the laser guiding of HV discharges.

References

[1] W Sibbett, A A Lagatsky and C T A Brown, Opt. Express **20**, 6989 (2012); DOI: 10.1364/OE.20.006989

[2] A Couairon and A Mysyrowicz, Phys. Rep. **441**, 47 (2007); DOI: 10.1016/j.physrep.2006.12.005

[3] S Tzortzakis, B Prade, M Franco, *et al.*, Phys. Rev. E **64**, 057401 (2001); DOI: 10.1103/PhysRevE.64.057401

[4] L Arantchouk, G Point, Y Brelet, *et al.*, J. Appl. Phys. **116**, 013303 (2014); DOI: 10.1063/1.4886582

[5] A Houard, P Walch, T Produit, *et al.*, Nat. Photonics **17**, 231 (2023); DOI: 10.1038/s41566-022-01139-z

[6] Y Brelet, A Houard, G Point, *et al.*, Appl. Phys. Lett. **101**, 264106 (2012); DOI: 10.1063/1.4773492