Sonography: a new method to measure laser filaments in air

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Abstract: The sound emitted from a filament was measured using a microphone. A model describes the sound emission mechanism, which allows to retrieve the light intensity as well as the free electron density in the filament.

OCIS codes: (010.1300) Atmospheric propagation; (190.4180) Multiphoton processes; (190.7110) Ultrafast nonlinear optics; (350.5400) Plasmas

High power femtosecond laser pulses propagating in air form long self-guided filaments [1]. The remarkable properties of a filament are white light generation by self phase modulation and plasma channel formation due to multiphoton ionization (MPI). These properties open exciting perspectives for applications such as white-light lidar [2] and laser lightning control [3,4]. The applications in turn stimulate the need for better characterizing the filamentation propagation.

We describe a new method to measure the MPI induced plasma channel associated to a filament. It consists in detecting the sound emitted from the plasma during its expansion. A microphone placed at 10 cm from the filament records the sound signal as a function of the propagation distance z (Fig.1). The slope changes in the microphone signal (marked with arrows in Fig. 1) indicate the starting and the ending of the filament, which extends over 4.5 m. We developed a model to describe the acoustic wave emission from the filament, which includes free electron generation by multiphoton ionization, optical energy absorption by inverse bremsstrahlung, and absorbed energy dissipation in shock wave emission. Results from the calculation show slight changes in the light intensity and the diameter over the filament, but in contrast, a change of three orders of magnitude for the electron density. Sonographic probing thus appears as a promising method for non destructive and real time characterization of filamentation in atmospheric scale experiments [5].

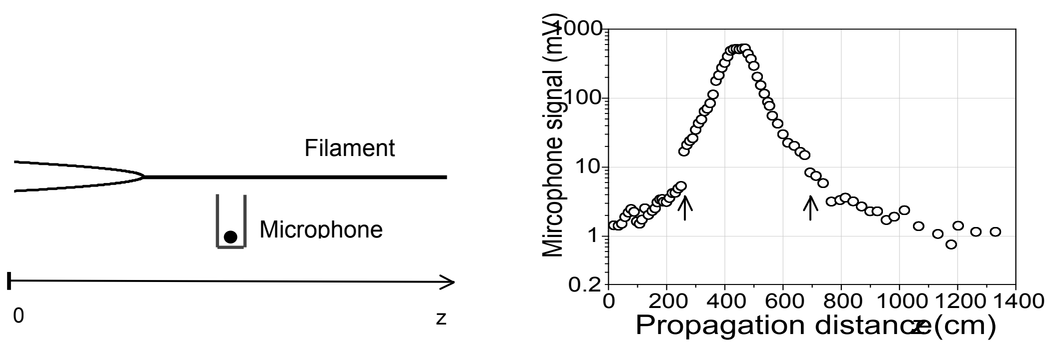

Fig. 1. Experimental setup and peak sound signal as a function of the propagation distance. The origin of the *z* axis indicates the position of the spherical focusing mirror with a 10 m radius of curvature.

References

1. A. Braun, G. Korn, X. Liu, D. Du, J. Squier, G. Mourou, “Self-channeling of high-peak-power femtosecond laser pulses in air ”, Opt. Lett. **20,** 73-75 (1995).
2. P. Rairoux, H. Schillinger, S. Niedermeier, M. Rodriguez, F. Ronneberger, R. Sauerbrey, B. Stein, D. Waite, C. Wedekind, H. Wille, L. Wöste, “ Remote sensing of the atmosphere using ultrashort laser pulses ”, Appl. Phys. B **71,** 573 (2000).
3. H. Pépin, D. Comptois, F. Vidal, C. Y. Chien, A. Desparois, T. W. Johnston, J. C. Kieffer, B. L. Fontaine, F. Martin, F. A. M. Rizk, C. Potvin, P. Couture, H. P. Mercure, A. Bondiou-Clergerie, P. Lalande, I. Gallimberti, “Triggering and guiding high-voltage large-scale leader discharge with sub-joule ultrashort pulses”, Phys. Plasmas **8**, 2532-2539 (2001).
4. M. Rodriguez, R. Sauerbrey, H. Wille, L. Wöste, T. Fujii, Y.-B. André, A. Mysyrowicz, L. Klingbeil, K. Rethmeier, W. Kalkner, J. Kasparian, E. Salmon, J. Yu, J.-P. Wolf, “Triggering and Guiding Megavolt Discharges Using Laser-Induced Ionized Filaments ”, Opt. Lett. **27,** 772-774 (2002).
5. H. Wille, M. Rodriguez, J. Kasparian, D. Mondelain, J. Yu, A. Mysyrowicz, R. Sauerbrey, J.-P. Wolf and L. Wöste, “Teramobile: a mobile femtosecond terawatt laser and detection system”, To appear in European Physical Journal -Applied Physics (2002). See also the Teramobile project web site: www.teramobile.org.