# Long range propagation of femtosecond self-channelled laser pulses in air

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**Abstract**: Using a multiterawatt femtosecond laser, we have studied long distance filamentation in air as a function of initial pulse chirp. Ionized channels are observed over several hundred meters.

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Several applications, such as remote multi-component pollutant detection, lightning protection, long range propagation of light bullets and production of secondary sources rely on femtosecond filamentation [1]. This term refers to the self-channelling of femtosecond laser pulses in the form of stable high intensity light filaments. This phenomenon was discovered in the late nineties with lasers emitting at infrared wavelengths. Filaments diameters around 100 µm and peak intensities below $10^{14}$ W/cm$^2$ were observed, sufficient to leave in their wake plasma strings with an initial density around $10^{16}$ cm$^{-3}$.

Much less information is available with pulse powers much larger than the crititical power for self-focusing ($P \gg P_{cr}$). We report on experimental results concerning the propagation of intense short laser pulses along a long horizontal path d > 500 m. We use a multiterawatt laser, called Teramobile, which delivers up to 200 mJ per pulse, with a pulse duration of 100 fs. A systematic study has been performed as a function of the initial laser chirp.

For small chirps (short initial pulse), a bright broad band continuum is created over the first 50 meters. The beam then propagates within a cone of 1 mrad, with no marked high intensity spots (see Fig. 1a). For larger initial negative chirp, the beam breaks into a multifilamentation pattern (see Fig. 1b). Ionization could be detected over a distance of 300 meters (see Fig. 2). These results are well reproduced by numerical simulations using a 3d+1 dimensional propagation code with the proper initial laser conditions. Finally, for even longer negative chirps, bright light tubes, without significant ionization, propagate over at least 2 km (Fig.1c). Thus, depending on the initial chirp conditions, one can maximise either a) white continuum generation, b) the electron density at fixed location, or c) the length of intense light strings.

[1] Kasparian, J., M. Rodriguez, G. Méjean, J. Yu, E. Salmon, H. Wille, R. Bourayou, S. Frey, Y.-B. André, A. Mysyrowicz, R. Sauerbrey, J.-P. Wolf et L. Wöste, *Femtosecond white light filaments: a new tool in atmospheric research*, Science page 61, vol. 301 (2003).

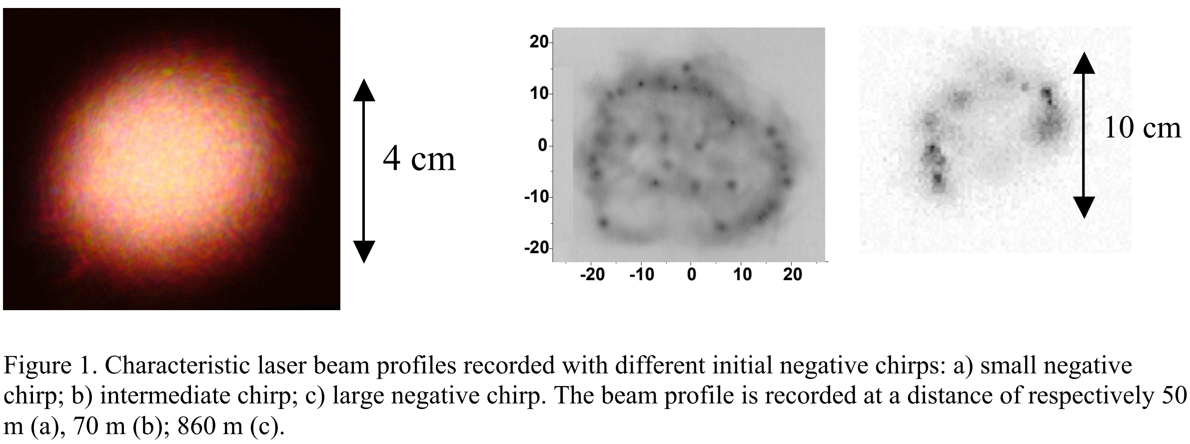


Figure 1. Characteristic laser beam profiles recorded with different initial negative chirps: a) small negative chirp; b) intermediate chirp; c) large negative chirp. The beam profile is recorded at a distance of respectively 50 m (a), 70 m (b); 860 m (c).

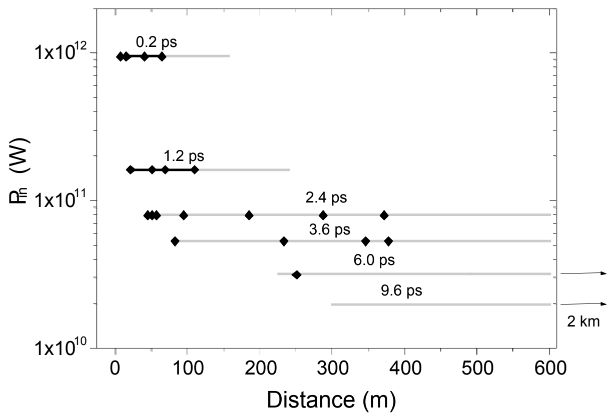


Figure 2: Distance of filamentation for different values of the negative initial chirp, expressed in terms of pulse stretching. The pulse without chirp has a duration of 100 fs. The black lines and black points refer to location where air ionization could be detected, grey lines to distances where bright light channels are observed.