25 J – 45 TW LASER BASED WHITE-LIGHT LIDAR

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ABSTRACT

We report on the first results of the highest power Lidar system (25 J, 45 TW) until now. Its capabilities correspond to one order of magnitude higher peak power and 100 times more energy than the Teramobile. At these extreme power levels it is a particular challenge to understand laser propagation and the potential use of it. The filaments density, length, and supercontinuum generation were completely unknown at these power levels, and it was questionable whether such ultraintense lasers could even propagate in the atmosphere or whether they would just collapse on themselves shortly after the laser exit.

INTRODUCTION

In the last years, a strong interest has been raised for the use of laser filamentation to improve the Lidar technique [1].Filaments [6] arise in the non-linear propagation of ultrashort, high-power laser pulses in transparent media. They result from a subtle balance between Kerr-lens focusing and defocusing by self-induced plasma. Filaments could improve Lidar in several ways. They generate a white-light continuum which can be used as a "white-light laser" [2] to perform multiparameter measurements, as we have demonstrated recently by simultaneously measuring the temperature and relative humidity of the air, as well as the droplet size distribution within a cloud. [3]. Here, the aerosol size distribution could be determined by analyzing the multiple scattering pattern of the beam at several wavelengths, taking benefit of the broad spectrum of the continuum. Besides, the active Kerr focusing within the filaments allows to deliver intensities as high as 10^{14} W/cm^2 at remote distances hundreds of meters or more away [4], far beyond what diffraction-limited linear focusing would yield. Such high intensity can excite non-linear effects *in situ*. For example, we showed that it is possible to excite 2-photon excited fluorescence (2-PEF) remotely, and perform non-linear Lidar measurements to detect and identify biosimulants [5]

The above-described experiments have been performed with the unique mobile femtosecond-Terawatt laser system *Teramobile* [6]. However, further development of white-light and non-linear Lidar requires to optimize the laser source. While the signal acquired during a given time interval in elastic Lidar is directly proportional to the average power of the laser, the efficiency of non-linear processes depends on the peak power of the incident laser pulses. Since the state-of-the-art ultrashort laser technology does not allow to increase simultaneously the peak power and the repetition rate, an optimal tradeoff has to be determined for each application. The perspective for such a tradeoff raises the need to better characterize the propagation of ultrahigh energy and ultrahigh power laser pulses in the atmosphere, and especially to characterize the spectrum and the generation efficiency of the white-light continuum. Experimental studies are all the more necessary that full numerical simulations of the propagation of large and powerful beams turn out to be out of reach of current computing capacities.

EXPERIMENTAL SETUP

We addressed this issue by investigating the propagation of pulses from the *Alisé* laser facility vertically in the air. *Alisé* is a chirped pulse amplification (CPA) laser system with 6 stages of Nd:glass amplifiers. It provided up to 25 J pulses at 1053 nm, with a spectral width of 7 nm. Its pulse duration could be varied from 600 fs to 60 ps. The beam was transported from the main laser hall to an auxiliary room where the grating compressor was located near to the laser output port in the roof of the building. A full set of laser diagnostics, including a beam profile analyzer and a pulse length measurement by either a single-shot autocorrelator or a streak camera.

RESULTS AND DISCUSSION

Backscattered light slightly off-axis (50 cm) Lidar detector consisting of a 20-cm telescope equipped with three channel detection with a sensitivity range in the visible and near-infrared. Band-pass filters disposed in front of each photomultiplier allowed to measure the Lidar signal from the white-light continuum in different spectral regions. In parallel, the beam was imaged from the side, from an off-axis distance of approximately 30 m, by two imaging devices, an iCCD camera (1024 x 1024 pixels, 1 µrad angular resolution and 1 mrad field of view) and a color-frame, digital CCD camera.

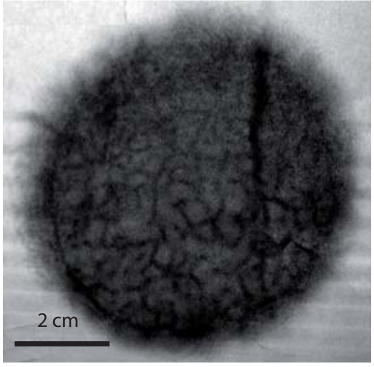

Figure 1. Beam profile atfter ~ 10 m propagation

Once launched in the air, Kerr effect is initiated in the beam, resulting in multiple filamentation across the beam profile (Figure 1). The filament number is about proportional to the pulse peak power, as expected from previous measurements at lower power [7]. Figure 2 displays a color-frame CCD side image of the beam. The altitude corresponding to the bottom of the white-light column, which is the signature for filamentation, is clearly pushed away from the laser source for chirped laser pulses. Obviously, longer pulses, i.e. lower peak powers, push the filament onset avay, as can be seen from the higher beginning of the white-light beam. This strong altitude dependence on the chirp and pulse duration of the laser beam shows that filamentation of ultra-high power, multijoule laser pulses can be controlled remotely by changing the laser parameters, as had already been observed for sub-Joule pulses of the *Teramobile* [4,6]. The reach of the white-light Lidar in vertical measurements has been measured to exceed 15 km, even in spectral bands in the visible, far away from the infrared wavelength of the incident laser : with 45 TW peak power, this is the most powerful laser measurement ever performed to our knowledge.

CONCLUSION

Although preliminary, these results are encouraging for the use of multi-joule, ultrashort laser pulses in future non-linear Lidars. Further investigation is in progress to quantitatively measure the spectrum of the white-light laser source and its generation efficiency as a function of the altitude and the laser parameters.

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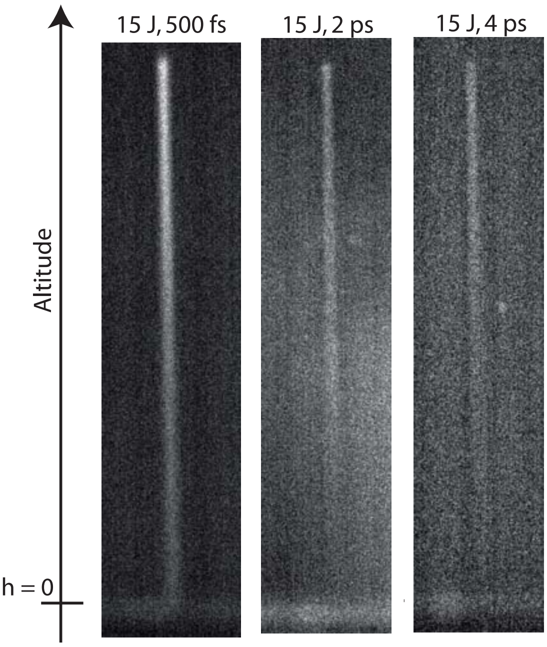

Figure 2. Chirp dependence of the filament onset. Chirps corresponding to longer initial pulses duration, i.e. lower peak powers, result in a further filament onset, so that the white-light is generated at higher altitudes.

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