Observation of Multiple Pulse-Splitting of Ultrashort Pulses in Air

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Abstract: We present experimental data on multiple-pulse-splitting of ultrashort pulse propagation in air. Pulse splitting occurs before spatial collapse to a filament. The threshold power for pulse splitting is 7GW for a 315fs chirped pulses at 800nm.

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1. Introduction

It has been shown in 3+1 dimensional Kerr-nonlinearity self-focusing models, that group velocity dispersion [1] is responsible for the temporal pulse-splitting of ultrashort pulses during propagation [1]. Previous experiments have demonstrated pulse splitting due to the Kerr nonlinearity for short pulse propagation in bulk [2] or gaseous media [3]. However, studies in gaseous media are often in a focused geometry, and use pressurized gaseous media [4]. This experiment elucidates the relationship between pulse splitting and spot-size change and does not use any optic to initiate self-focusing [4]. We find pulse splitting occurs at a distance merely 0.7x the diffraction length and occurs before spatial collapse to a filament. In addition, multiple pulse splitting is also observed. Peak fluence information from the beam-profile is monitored, indicating nonlinear loss mechanisms. We believe this is the first data on multiple pulse-splitting events in air.

2. Experimental Setup

Our pulses are produced with a chirped-pulse amplification Ti:Sapphire laser system capable of delivering 150GW of power after compression. For these experiments, the system is run at <25GW (200fs-1ps, 1-5mJ). Before entering the compressor, the beam passes through a 4mm-diameter soft fused silica apodizing aperture, imposing a near-Gaussian profile on the beam. One meter after leaving the compressor, a beam-splitter transmits 5% of the beam for energy measurement and reflects the remainder for propagation down a 10m path. A CCD camera images the spatial profile of the beam incident on an alumina-plate screen. The brightest pixel from each image is recorded as a measure of the peak fluence (time integrated intensity) of the beam. For data presented here, we monitor the peak fluence, spatial profile and temporal pulse profile of a 315fs pulse, with a single-short second harmonic autocorrelator at a distance 11m from the compressor as the incident energy is varied.

3. Results

Figure 1 shows the peak fluence vs. pulse energy. The onset of self-focusing is evident in the region A – C in Fig. 1 as the peak fluence increases nonlinearly with laser energy. However, even up to energies of 4mJ, a fully collapsed filament is not observed. Interestingly, there are two plateau regions beginning at 2.5 and 3.6mJ. Although we do not yet fully understand these regions, we speculate that some nonlinear absorption processes take place during propagation or on the alumina surface. The corresponding autocorrelation traces for the locations A – F in Fig.1 are shown in Fig. 2. The onset of pulse splitting is evident by the three-peak autocorrelation trace at location C when the peak power is 7 GW, which is sustained through location E. Further splitting occurs at location F when the incident laser energy is 4mJ. Correlating the temporal change with the spatial profile, there is a progressive shrinkage of beam waist. At the point when the pulse splits, the beam diameter is only ~40% of its original size, far from total collapse. Numerical simulations by Bouma [5] have shown that pulse splitting and spatial collapse occur at the same time. The difference may be due to the initial chirp condition of the pulse in the experiment.

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Figure 1. Data for 11m with labels corresponding to autocorrelation traces (see Figure 2) at their recorded energies.

Fig. 2 Autocorrelation traces corresponding to labeled positions in Figure 1. Pulse splitting initiates at point C in Figure 1 (C). The pulse remains split in this manner until point E, where shoulders appear indicating a third pulse. The split into three pulses is clearly shown in F. The autocorrelation traces are not normalized to the intensity profile.

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