Nonlinear self-compression of few-cycle millijoule
mid-IR pulses and their filamentation in ambient air

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The phenomenon of nonlinear pulse self-compression is enabled by a balanced interplay between the positive nonlinear dispersion, resulting from self-phase modulation, and the negative linear dispersion of the nonlinear medium. For wavelengths in the short-wave mid-IR range, self-compression regimes can be tuned with relative ease owing to a large reserve of anomalous dispersion in both hollow-waveguide and bulk propagation geometries. We demonstrate that in the sub-mJ energy range self-compression to a near single-cycle duration can be performed in a Kagome-lattice hollow fiber (Y.Y. Wang, et al., *Opt. Lett.* 36, 2011, pp. 669–671), whereas in the multi-mJ range self-compression in bulk crystals leads to a ×3 duration reduction and an increase in the peak power. Both types of self-compression schemes hold promise for few-cycle strong-field applications. Nonlinear bulk self-compression is particularly attractive for enhancing the pulse parameters of recently developed λ=4 μm high-energy parametric sources (G. Andriukaitis, et al., *Opt. Lett*. 36, 2011, pp. 2755-2757) where the pulse bandwidth is limited by the phase matching and absorption in KTA crystals. By placing a Brewster-oriented 2-mm-thick YAG plate after a focusing lens at a distance of tens of centimeters ahead of the focal plane it is possible to transform 10-mJ 94 fs pulses at 3.9 μm into 9-mJ 33-fs 3-optical-cycle-long pulses. Through self-compression the peak power of the pulses is increased to 250 GW which is above the critical power of self-focusing in air at atmospheric pressure. Previously, due to the lack of peak power, femtosecond filamentation in gas at this wavelength was only possible in high-pressure gas cells (D. Kartashov, et al., *Opt. Lett.* 38, 2013, pp. 3194-3197). The ability to generate 3.9-μm filaments in ambient air opens up the opportunity to explore the advantages of this long wavelength for filament-induced nitrogen lasing (D. Kartashov, et al., *Phys. Rev. A.*, 86, 2012, pp. 033831).

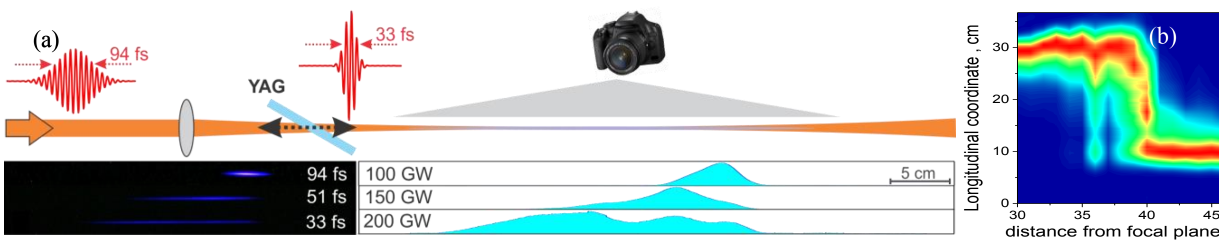

Fig. 1. Mid-IR filamentation in ambient air with bulk-self-compressed pulses. (a): Length dependence of the visible part of the filament in air on the distance between the 75-cm lens and bulk Brewster-oriented 2-mm thick YAG. (b): Filament position and length dependence on the YAG translation along the focused 3.9 um beam.