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Generation of periodically modulated plasma optical fibers and applications[1]

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We report the generation of up to $\sim$ 3cm long periodically modulated plasma waveguides that allow μm-scale control of the instantaneous intensity and phase velocity of a guided ultra-intense femtosecond laser pulse. This is accomplished by focusing an auxiliary spatially modulated laser pulse onto cluster jets. We can control the depth and period of the waveguide axial modulations, as well as the plasma ionization stage, electron density and guided spot size. The method is highly tunable and extremely stable, with controllable modulation periods as short as 35 μm and as long as 3 mm. Single-mode propagation at $>10^{17}$ W/cm^2 in these guides has been demonstrated using argon, nitrogen, and hydrogen clusters. A high degree of waveguide uniformity and shot-to-shot consistency is attained. We review several applications of our new device. Efficient direct electron acceleration by a radially polarized laser pulse can be achieved by quasi-phase matching in an axially modulated plasma waveguide [1]. High-harmonic generation could be quasi-phase matched [2] at extremely high orders. Finally, recent calculations [3] show that these channels could convert multi-millijoule femtosecond laser pulses into terahertz radiation with high efficiency. [1] A. York et al., Advanced Accelerator Concepts Conference 2006; [2] H. M. Milchberg et. al., Phys. Plasmas **3**, 2149 (1996); [3] T. Antonsen et al. Bull. Am. Phys. Soc. **50** (2005).

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