Adaptive dispersion compensation for remote fiber delivery of near-infrared femtosecond pulses

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Delivery of ultrafast laser pulses over long distances has important applications for accelerator diagnostics and pump-probe experiments performed at future x-ray free-electron lasers and next-generation light sources [1-3]. Mechanical constraints and stability concerns make the transmission of light through an optical fiber a flexible alternative to free-space propagation. However large material dispersion and nonlinear effects inside the fiber core introduce technical challenges. Subpicosecond pulse transmission has been achieved over lengths in excess of a kilometer. These optical links operate at telecommunication wavelength near the zero dispersion point (1.55 μm) of standard single-mode fiber by using specialty dispersion compensating fiber [4]. Recently Chang et al. [5] used a spatial light modulator (SLM) in addition to the dispersion-compensating fiber to correct for higher-order dispersion. For Ti:sapphire lasers operating at 800 nm, the effects of dispersion are much more severe, and no dispersion-compensating fiber is readily available. The nonlinear response of the fiber ultimately limits the pulse energy and duration for these techniques. In particular, self-phase modulation can lead to spectral compression for negatively chirped pulses used in precompensation [6]. With proper dispersion compensation, the result of this nonlinearity is at best a longer, albeit transform-limited, pulse duration [7, 8]. Clark *et al.* [9] demonstrated group-velocity-dispersion-compensated 100-fs, 0.5 nJ pulses at 800 nm propagated through ~ 1m of fiber by use of combination of temporal and spectral compression. Their technique is scalable to longer distance with additional elements for the compensation of higher order dispersion but relies on fiber nonlinearity; consequently it is sensitive to the characteristics of the input pulse. More recently, hollow-core and photonic crystal fibers have been used for optical pulse propagation over short distances [10, 11]. These fibers have the advantage of low dispersion and nonlinear response; however, they are currently not scalable for long-distance application.

In this work, we demonstrate an alternative technique for the transport of femtosecond Ti:sapphire laser pulses through 150 m of standard single-mode polarization-preserving optical fiber by adaptive pulse shaping. We compensate in advance for the large group-velocity and higher-order dispersion of the fiber, so the fiber transport serves to compress the prechirped input pulse. At 800-nm wavelength, material dispersion of the fused silica core is expected to be the dominant source of dispersion [12]. Both group-velocity dispersion (GVD) and third-order dispersion (TOD) are significant for long-distance propagation (360 and 280 fs^3/cm, respectably). However, adaptive pulse shaping makes precise a priori knowledge of the dispersion irrelevant in our system [13]. One can accommodate relatively high pulse energies while linear pulse propagation is maintained by avoiding full compression in the optical fiber. Final pulse compression is performed external to the fiber, where the intensities are low, with a high dispersion glass rod.

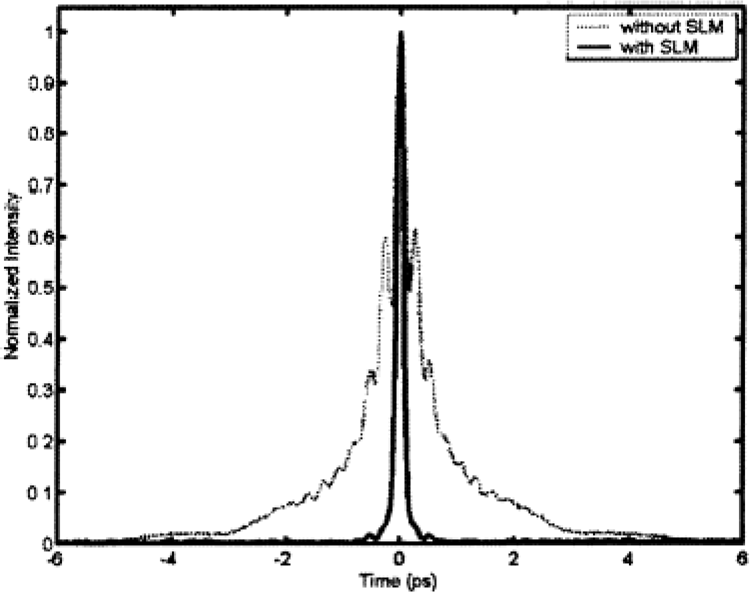

Figure 1. Autocorrelation of the output pulse from the fiber delivery system with and without adaptive pulse shaping. The pulse width with compensation is 130 fs FWHM (improved to 70fs with more bandwidth coupled to the fiber).

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