Abstract

Nonlinearity shaping in specialty tellurite glass optical fibers

by Tanvi Karpate

This dissertation presents specialized cases of microstructured and nanostructured optical fibers made of tellurite glass for the advancement of nonlinear optical femtosecond pulse propagation field. Under the scope of this dissertation, specialty optical fibers were designed, developed, and characterized for shaping their nonlinearity to obtaining a wide soliton detuning in the short-wave infrared wavelength range, low noise supercontinuum generation and analysis, and temporal pulse reshaping. The shaping of pulse propagation in optical fibers has been carried out in three ways; by dispersion engineering of fiber, by nonlinear propagation dynamics within the fiber, and by choosing and optimizing the material. Since this dissertation is focused mainly on short-wave (SWIR) wavelengths, tellurite soft-glass was chosen for fiber fabrication due to its high transmission in this wavelength range and high nonlinear response which enables attaining nonlinear dynamics with commercial standard femtosecond laser pumps.

The first research outcome of this dissertation is that a wide soliton detuning of 68.5 THz was attained using a suspended core fiber structure. The fiber was dispersion engineered for a flat anomalous dispersion in tellurite soft-glass to obtain Raman scattering-assisted self-frequency which facilitated the broad range of detuning in soliton from the pump center wavelength over short fiber lengths. This reduces the dependence on dispersion management for an end-to-end fiberized ultrafast system. The prominent soliton showed an input power-based tunability through the spectral range of 1560 nm (pump wavelength) upto 2400 nm when pumped with a 90 fs laser pulses from a robust mode-locked fiber laser. Such a soliton self-frequency shift-based light source, has the potential of being used as a source itself and also as a seed in amplifier systems for SWIR wavelengths that cannot be easily attained by commercial lasers.

The second research outcome of this dissertation demonstrates a low noise supercontinuum generation by designing an optical fiber for non-solitonic femtosecond pulse propagation with polarization maintaining properties. The fiber was shaped for all-normal chromatic dispersion with optimized hexagonal lattice parameters. A polarization maintaining (PM) variant of the fiber was also developed by structurally introducing birefringence in the fiber. Both the fibers successfully showed broad supercontinuum generation, which were then studied for their noise properties using real-time shot-to-shot dispersive Fourier transformation technique. The real-time noise measurements showed that the supercontinuum generated in PM fiber has less shot-to-shot noise as compared to the non-PM variant fiber. Thus the feasibility of PM fiber for low-noise octave-spanning coherent supercontinuum generation was successfully demonstrated.

As for the third research outcome of this dissertation, new dynamics leading to quasi-periodic temporal reshaping of a femtosecond pumped pulse were observed for a range of average power of the incident input pulses. The demonstrated temporal reshaping was attained in a tellurite glass-based graded-index multimode fiber, which was explored for spatiotemporal-spectral dynamics of pump femtosecond pulses. This study shows that the new observed dynamics, do not occur due to mode self-cleaning effects as earlier reported for long pump pulses. These

dynamics are rather attributed to the alternating influence of negative group velocity dispersion and self-phase modulation with positive group velocity dispersion which makes the GRIN fiber act like a classic grating pair compressor as a function of input power. The tellurite graded-index fiber developed also showed an octave-spanning supercontinuum under different pumping conditions. Thus the fabricated tellurite GRIN fiber shows a high degree of manipulation capabilities in terms of spectral, spatial as well as temporal propagation, making it a great potential for high power applications which require broadband light sources or spatially stable beam or all-fiber pulse compressors, under appropriate pumping conditions.