Abstract

Spectral conversion, that can be obtained in nonlinear fibers when pumped with femtosecond laser sources, is a powerful technique which allows for generation of non-standard wavelengths outside the available gain media, including Ytterbium, Erbium, Thulium and Holmium. These nonlinear effects, when combined with Yb- or Er-doped fiber lasers, can be used either as sources operating in the spectral range of 1300 or 1700 nm which is of particular interest of biomedical imaging, or as seedings for Tm- or Ho-doped fiber amplifiers, as an alternative to Tm- or Ho-doped fiber lasers.

The Dissertation begins with the theoretical analysis of different phenomena affecting an ultrashort pulse propagating in an optical fiber. The impact of dispersion as well as various nonlinear effects, that can occur for high intensities of the light confined in an optical fiber, is discussed. The concept of microstructured silica fiber is analyzed and the simulation examples of soliton self-frequency shift effect (SSFS) and supercontinuum in such a fiber are given. The theoretical part of the thesis ends with the description of different methods that are used for characterization of the short pulse, such as dispersive Fourier transform, pulse-to-pulse coherence, FROG measurement, and intensity noise.

For the purpose of the doctoral thesis, numerous simulations have been performed to model and adjust both the pulse and the fiber parameters to obtain required spectral range. Three chapters of the thesis are devoted to experimental setups that have been demonstrated and discussed. First, the analysis of the SSFS generated in a microstructured optical fiber for two pumping sources: EDFL and YDFL is presented. Generation of the SSFS in the range of 1.42-1.67 µm for YDFL pumping and 1.70-1.95 µm for EDFL pumping has been obtained. The frequency-shifted solitons are highly coherent and birefringent which makes them suitable to be used in applications such as optical coherence tomography and as seedings for Tm-doped fiber amplifiers.

The next experiment concentrates on the comparative study of the SSFS and ANDi-SC effects generated in microstructured optical fibers with opposite dispersion profiles. The characterization of both phenomena are presented, including measurements of optical spectra, coherence, shot-to-shot stability, and intensity noise. The results reveal that both nonlinear effects, despite being generated in fibers with different signs of dispersion, can feature excellent noise properties. What is more, both effects can successfully be used as seedings for Tm-doped fiber amplifiers.

The next Chapter covers the analysis of the spectral compression phenomenon in a dispersion-increasing fiber. The theory of the spectral compression effect is given and the numerical simulations are performed leading to finding the optimal structure of the dispersion-increasing fiber. Such a fiber is used to build a narrow-linewidth laser source that provides widely tunable optical solitons in the wavelength range of 1620-1900 nm with linewidths between 0.43-1.11 nm. The spectrally-compressed solitons are eventually amplified in a Tm-doped fiber amplifier optimized for this wavelength range to obtain power levels satisfactory for later applications as a swept-source.

The last Chapter contains summary of the performed experimental results. A list of most important research achievements is provided and the outlook for future plans is given.

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