Retrieving Spectral Phase of Ultrashort Optical Signals Based on Self-Phase Modulated Spectra Measurements in Fibers with Kerr Nonlinearity

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Ultrashort optical signals play a significant role in manifold applications. This attaches great importance to the development of simple, robust and cost-effective methods of phase retrieving, especially for ultrafast photonics dealing with very low energy pulses. It should be noted that free-space techniques of pulse retrieving are now sufficiently well established such as FROG (frequency-resolved optical gating) and SPIDER (spectral phase interferometry for direct electric-field reconstruction) [1]. Their numerous modifications as well as some other original methods with different advantages and benefits for particular tasks have also been proposed to avoid some drawbacks of the above methods [1].

This contribution is devoted to recent progress of our team in the development and investigation of the method and algorithms for retrieving spectral phase of an ultrashort optical signal from the fundamental spectrum and two self-phase-modulated spectra obtained in fibers with Kerr nonlinearity based on silica or highly nonlinear chalcogenide glasses. A fairly universal approach has been developed, which is applicable to laser sources both in the telecommunication range and far beyond it. In this method, there are no ambiguities in phase recovery associated with the direction of the time axis, the choice of the phase sign, uncertainty at points with zero spectral intensity, etc. The method does not require the generation of the 2nd harmonic; therefore, there is no limitation on the spectral width of the measured signals directly related to the bandwidth of the used nonlinear crystals.

Various modifications of algorithms for processing experimental spectral data have been developed and investigated, which make it possible to retrieve phases of optical signals with different spectral and temporal structures. The basic algorithm is developed on the basis of the Gerchberg-Saxton (GS) algorithm [2]. However, this algorithm does not guarantee convergence to the global minimum of the target function. To overcome this limitation, we have developed additional approaches based on genetic algorithms or optimization of the polynomial phase by the brute force search of the polynomial coefficients with reasonable steps (with further retrieving non-polynomial spectral additions by GS algorithm).

It has been demonstrated experimentally that silica fibers are promising for retrieving ultrashort signals in the telecommunication range; the results have been in good agreement with independent measurements by the FROG technique. We have also numerically shown that the use of chalcogenide fibers as nonlinear elements is advisable in the wavelength range of 2 μm and beyond, but especially at wavelengths noticeably exceeding 3 μm, where fibers based on many other glasses have a fundamental limitation due to high optical losses. Fibers based on chalcogenide glasses are promising for retrieving signals with low energies and/or peak powers due to their huge Kerr nonlinear coefficients, which are 3-4 orders of magnitude higher than those for standard silica telecommunication fibers.

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References

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