Generation of pulse trains with high-repetition-rate in anomalous dispersion decreasing fibers

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Abstract—Optical pulse generation and compression have been numerically studied in anomalous dispersion decreasing fibers (DDF). We show that evolution of modulation instability (MI) observed with chirped wave packets in tapered fibers produces the mechanism for generation of ultra-short pulses with high repetition rates. The role of modulation instability and Raman self-scattering has been also discussed. The simulations show that pulse chirping enhances self-Raman scattering at early stages of pulse propagation and improves compression of the generated pulses. It is also shown that the presence of amplitude and frequency modulation of the seed wave provide essential impact on the pulse train formation. The new method for increasing the pulse train repetition rate through frequency modulation of the seed wave has been proposed.

Keywords — Dispersion decreasing fibers; modulation instability; pulse trains; soliton-like pulses.

SUMMARY

Self-similar evolution of ultra-short pulses propagating in a fiber is of particular interest in fiber optics. Such pulses are commonly referred to as “similaritons”. A linear frequency modulation i.e. chirp, assumes a squared time dependent phase term typical for self-similar solutions and depends on the gain and dispersion parameters [1]. Passive fibers can exhibit an effective gain determined by the spatial distribution of group velocity dispersion (GVD). With normal GVD ($\beta > 0$), asymptotic parabolic pulses evolve self-similarly in uniform fiber amplifiers with the constant gain and in passive fibers with spatially varying dispersion profile [2]. It was demonstrated that the pulse with arbitrary shape after propagation in a passive fiber with hyperbolically decreasing normal dispersion transforms into an asymptotically parabolic similariton.

Self-similar pulses propagating in fibers with anomalous GVD ($\beta < 0$) represent another type of similaritons. The exact solutions of NLSE for this dispersion regime and waveguides with spatially variable parameters have been obtained in the form of soliton pulses with a linear chirp [1]. It should be noted that exact solutions describing the dynamics of soliton pulses in passive dispersion decreasing fibers (DDF) are of particular interest for fiber pulse compressors because this propagation regime is accompanied by rapid pulse compression and pulse chirp increase [3].

In this work anomalous DDF are proposed for applications in optical pulse compressors and generators. We have derived exact solutions for chirped soliton-like pulses propagating in anomalous exponentially decreasing dispersion fibers. We have identified two stages in self-similar dynamics of these pulses. The initial stage of quasi-linear pulse compression is significantly affected by the initial pulse chirp. For pulses with shorter duration, the quasi-linear stage is almost suppressed by nonlinear factors providing an effective compression of pulses without initial chirp.

For anomalous DDF waveguides we have distinguished an advanced stage of MI, which causes pulse train generation. We have proposed a new method for increasing the pulse train repetition rate through frequency modulation of continuous wave. It has been shown that the pulses generated in anomalous DDF due to nonlinear MI effects are asymptotically similar to the chirped soliton pulses. The effect of Raman self-scattering on pulse generation in anomalous DDF has been studied. In the important regime of nonuniform amplitude modulation of long pulses, this mechanism causes pulse train generation with high peak powers and formation of the pulses with giant peak power, i.e. an optical rogue wave. This effect is of interest for many applications in opto-electronics, in particular, in modulators, decoders, delay lines, etc. It is found that initial pulse chirp enhances self-Raman scattering at early stages of pulse propagation and improves compression of the generated pulses.

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