Modulation Instability of Wave Packets Propagating in Inhomogeneous Nonlinear Fiber

I O Zolotovskii¹, V A Lapin², and D I Sementsov¹

¹Quantum electronics and optoelectronics, Ulyanovsk state university, 7, Tap, kv. 78, 432032, Ulyanovsk, Russia. Contact Phone: +79278195746
Contact Email: lva2013@yandex.ru

Modulation instability (MN) – the growth of small harmonic perturbations of a continuous wave is an effect characteristic of many nonlinear systems supporting the propagation of localized waves, the nature of which is related to the combined action of nonlinear and dispersion effects [1].

In this paper we investigate the conditions for the onset and existence of a modulation instability of wave packets propagating in a nonlinear optical fiber with a dispersion of group velocities that depends on the fiber length [2,3]. By means of numerical methods, the time profiles of a modulated wave propagating in such a fiber are obtained.

The possibility of decay of a quasicontinuous wave packet into a sequence of ultrashort pulses with a shorter duration and a larger amplitude than nonlinear light guides with a dispersion-independent dispersion is shown.

Dynamics of the temporal envelope of a WP with allowance for the dispersion effects and the nonlinearity of a Kerr medium in a moving coordinate system is described by the following equation for the amplitude [1,3,4]:

\[
i\frac{\partial A}{\partial z} - \frac{d_2}{2} \frac{\partial^2 A}{\partial \tau^2} + i\gamma |A|^2 A = 0,
\]

where \( \tau = t - z/v_g \) is the time in the running coordinate system, \( v_g \) – the group velocity of the wave packet, \( \gamma \) – the dispersion parameter of the group velocities, and \( \gamma \) – the nonlinearity parameter.

As an example, consider a fiber with an exponential distribution along its length of the DDF [3,4]:

\[
d_2 = d_{20}\exp(-qz).
\]

In Fig. 1 presents the results of a numerical solution by the method of stepwise Fourier transforms [1] of Eq. (1), which determines the propagation dynamics of a modulated signal of the form:

\[
A(0, \tau) = \sqrt{F_0} [1 + m \cos(\Omega_{\text{mod}} \tau)]
\]

at the following values of the optical fiber parameters: the modulation depth \( m = 0.01 \), the group velocity dispersion \( d_{20} = -1 \times 10^{-26} \text{ s}^2/\text{m} \), the initial power, the nonlinearity parameter \( \gamma = 10^{-2} \text{ W}^{-1}\text{m}^{-1} \), the inhomogeneity parameter \( q = (0, 3, 5, 7) \times 10^{-3} \text{ m}^{-1} \) – Fig. 1(a,b,c,d) and the modulation frequency \( \Omega_{\text{mod}} = \omega_m \), where \( \omega_m \) is the detuning frequency at which the integral gain increment reaches a maximum. It can be seen from these dependences that in the case of an inhomogeneous fiber with a small value of the inhomogeneity parameter, the process of pulse broadening is much weaker than in the case of a homogeneous light guide, where the process of pulse compression is cyclically replaced by the process of their broadening, thanks to this effect one can obtain pulses with a much higher degree of compression.
Acknowledgements: This study was supported by the Ministry of Education and Science of the Russian Federation (project No. 14.Z50.31.0015 and a state contract) and the Russian Science Foundation (project no. 16-42-02012).

References