Parabolic pulse characterization in the far field of dispersion in a passive nonlinear fiber

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***Abstract* - We investigated properties of ultrashort parabolic pulses formed in the far field of dispersion in a passive nonlinear fiber through numerical modeling. It is found that the shape of pulses in the far field of dispersion differs from parabolic one, as compared to the near field of dispersion. However their temporal and spectral intensity shapes are more stable over the fiber.**

Last years intensive efforts were devoted to the theoretical and experimental investigations of parabolic pulses formed in fiber amplifiers [1]. These pulses called similaritons hold their temporal and spectral shape with a scale factor over the nonlinear normal dispersive fiber with gain and moreover they hold a linear chirp. Similaritons are attractive for such implementations as pulse amplification, pulse compression, pulse synthesis. However, for many applications, parabolic pulse generation schemes based on passive fiber components are preferable. Therefore it has been proposed applications of dispersion decreasing fibers [2] and fiber Bragg grating [3] to obtain parabolic pulses. But the simplest way was found based on passive nonlinear pulse reshaping in a normally dispersive fiber [4]. The last one was investigated in the near field of dispersion (fiber length doesn't exceed the dispersion length). It turns out that some optimal combination of the initial pulse power and fiber length according to the initial pulse shape can provide a parabolic pulse at the system output. Recently was experimentally demonstrated that it is possible to obtain parabolic pulses in the far field of dispersion in passive nonlinear fiber as well [5, 6]. These pulses have spectronic nature. Here we investigate the properties of these new pulses and compare it to the pulses generated in the near dispersion field.

In order to analyze pulse reshaping in the nonlinear and dispersive fiber we solve numerically nonlinear Schrödinger equation (NLSE) using symmetrical SSFM method [7]. We use following notations for the dispersion length L_D, nonlinear length L_{NL}, soliton order N and normalized length ξ:

$$L_D = T_0^2/\beta_2,\ L_{NL} = 1/(\gamma P_0),\ N = \sqrt{L_D/L_{NL}},\ \xi = z/L_D, \quad (1)$$

where P_0 - initial pulse peak power, T_0 - initial pulse width, β_2 - second order dispersion, γ - nonlinear coefficient.

We used initial Gaussian pulse in our modeling with all parameters chosen so, that $N = 4$. Fig. 1 and Fig. 2 show normalized temporal intensities of pulses in the near and far field of dispersion at different fiber lengths.

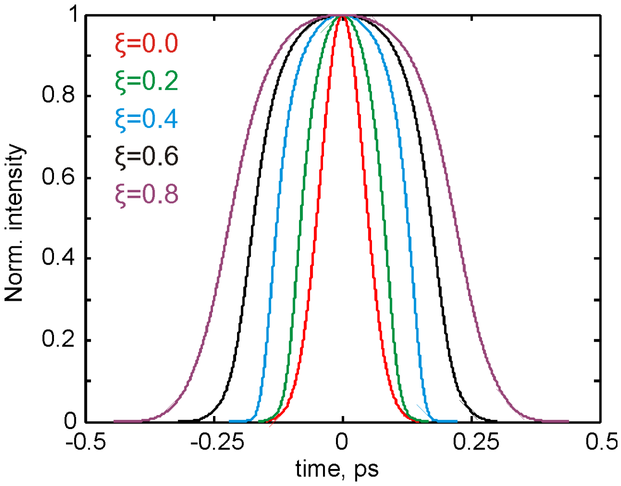

Fig. 1. Normalized temporal intensity of pulses in the near field of dispersion at different fiber lengths ($N = 4$).

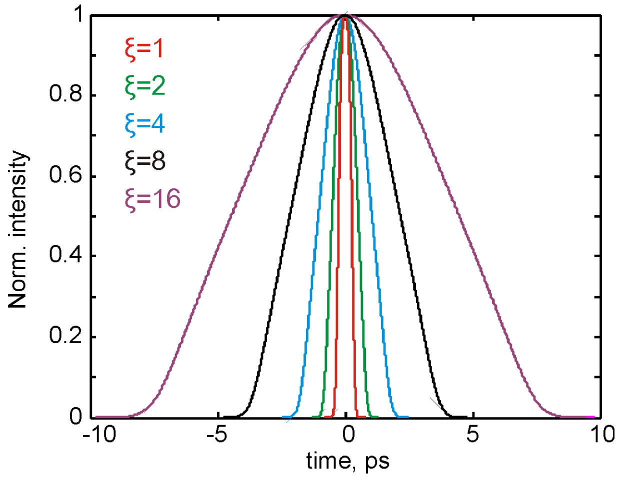

Fig. 2. Normalized temporal intensity of pulses in the far field of dispersion at different fiber lengths ($N = 4$).

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One can see from Fig. 1 that pulse shape changes sufficiently as compared to the initial Gaussian. At the fiber length $\xi = 0.2$ pulse shape is the closest to the parabolic one [4]. In the far field of dispersion (Fig. 2) pulse shape is much more stable and changes with a scale factor. Next we investigated pulse spectrum transformations. Fig. 3 shows that pulse spectrum changes sufficiently as well as temporal shape of pulse in the near field of dispersion. Spectrum transformations at $\xi \leq 0.4$ are similar to the pure SPM effect [7]. But after $\xi \geq 0.6$ initial tendency is changed and spectrum transforms to the nearly parabolic shape. From Fig. 4 we can see that after $\xi \geq 4$ spectrum shape actually remains unchanged. This is the key feature of pulse transformations in the far field of dispersion in nonlinear fiber.

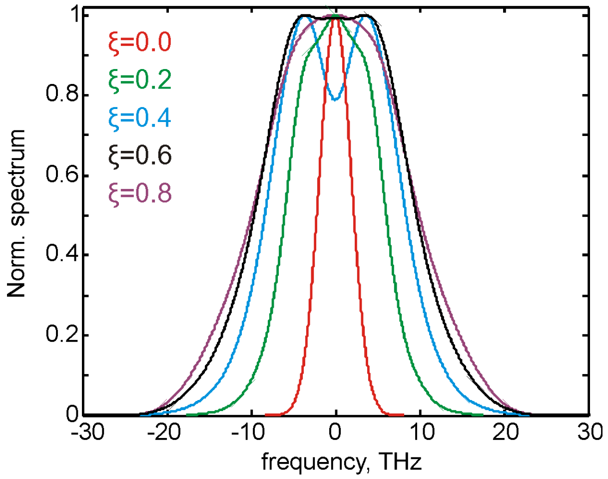

Fig. 3. Normalized spectrum of pulses in the near field of dispersion at different fiber lengths ($N = 4$).

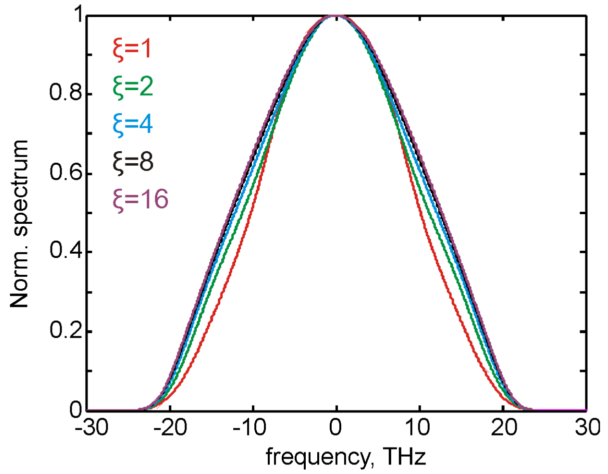

Fig. 4. Normalized spectrum of pulses in the far field of dispersion at different fiber lengths ($N = 4$).

Owing to unchanged spectrum the temporal dispersive lens effect in the far field of dispersion provides the same shape of temporal intensity as spectrum has [8]. Such pulses generated owing to the temporal dispersive lens and having temporal shape similar to the initial spectral shape are known as spectrons [8].

Important question is how far the shape of these pulses differs from the parabolic one. We estimated this imperfection using misfit parameter M between the pulse intensity profile and a parabolic fit of the same energy [4]. We found that misfit parameter in the near field of dispersion (for optimal parameters $\xi = 0.2$) is $M = 0.04$ and in the far field of dispersion ($\xi = 8$) $M = 0.09$.

To conclude, we investigated properties of ultrashort parabolic pulses formed in the far field of dispersion at passive nonlinear fiber and compared to those one formed in the near field of dispersion. We have shown that the former pulses have unchanged spectrum and more stable temporal shape. However, the imperfection of parabolic pulses in the far field of dispersion is two times worse as compared to optimal parabolic pulse shape in the near field of dispersion.

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