fs-order에서의 솔리톤의 진행

Soliton Propagation at fs-order

Seung-Ho Han and Q-Han Park
Department of Physics, Kyung Hee University
email:freedawn@photon.kyunghee.ac.kr

Studies of soliton propagation along optical fibers are very important since the advent of high bit-rate optical transmission. It has been researched through the formalism of inverse scattering method, recently matrix potential method by Park and Shin[1] in case of nonlinear Schr\"odinger equation(NLS). N-soliton solution of the NLS has been known to propagate stably with some oscillation, which has been analyzed in many papers.[2]

Now considering the propagation of the optical soliton to the order of femto-second, new terms are added to the NLS, i.e., third-order dispersion, Raman effect, and self-steepening effect. What we want to show is that even if a higher-order term, e.g., self-steepening effect, on the NLS is considered, we can have a exact soliton, especially 2-soliton solution, which is analyzed by Min and Park[5]. In this paper, we consider the case of adding the self-steepeing term to the NLS, called modified nonlinear Schr\"odinger equation(MNLS).

$$i\frac{dU}{d\xi}+\frac{1}{2}\frac{d^2U}{d\tau^2}+N^2[|U|^2U+is\frac{d}{d\tau}(|U|^2U)]=0 \qquad \text{---------------(1)}$$

In that case, it has been known that there exists the phenomenon called soliton decay when N-soliton propagate, that is, they continue to separate one and another with propagation inside the fiber so that they cannot form a bound state. Golovchenko et al.[3] and Ohkuma et al.[4] have argued this phenomenon by the computer simulation. They have considered the propagation of sech-type solution in MNLS in their simulation, that is, having taken the self-steepening term as perturbation. Even if Ohkuma et al. have written the exact 1-soliton solution of MNLS in their paper, they use a sech-type soliton in their computer simulation. But N-soliton solution on the MNLS can be obtained by inverse scattering method, especially Min and Park[5] obtained 2-soliton solution of DNLS-type equation,

$$i\frac{d\Psi}{dT}=-\frac{d^2\Psi}{dX^2}+i|\Psi|^2\frac{d\Psi}{dX} \qquad \text{-------------------(2)}$$

The 2-soliton solution of eq.(2) is given by Min and Park's paper.[5] Based on their 2-soliton solution and eq.(2), considering some transformations we have eq.(1). But we cannot calculate the explicit solution, so that instead of eq.(1) we consider the following equation:

$$i\frac{dY}{d\xi}=\frac{1}{2}\frac{d^2Y}{d\tau^2}+N^2[|Y|^2Y+isY^2\frac{dY^*}{d\tau}+s^2N^2|U|^4U] \qquad \text{---------------(3)}$$

The 2-soliton solution of eq.(3) can be calculated from the solution of Min and Park's paper. Then from the solution, the period of 2-soliton and the amplitude ratio of 2-soliton are obtained:

$$z_0 = \frac{8\pi}{|\alpha^2 - \beta^2|} \qquad \text{-----------------(4)}$$

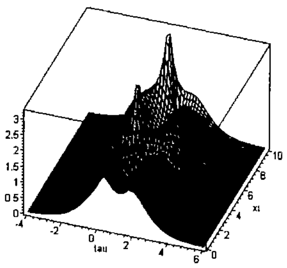
$$\text{amplitud ratio} \approx \left|\frac{\beta}{\alpha}\right| \left(\frac{2+(\alpha s)^2}{2+(\beta s)^2}\right)^{1/4}$$

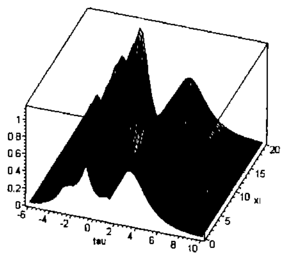
Following pictures are the propagation of the 2-soliton. From those pictures, we can see the periodic motion of the 2-soliton. It is different from what Golovchenko et al.[3] and Ohkuma et al.[4] are expected.

It is worth considering the interaction of 2-soliton. If α and β have different signs, two solitons repels each other. On the contrary, if same signs, they attract each other. The value of s contribute to this phenomenon. Figures show the change of the interval of two peaks according to changing s. It means that the change of the angular frequency or the input pulse width of 2-soliton gives the change of interval of two solitons.($s=1/(\omega_0 T_0)$) Thus the parameters that can control the interval of peaks are α, β, and s. However, the soliton period does not influenced by s.(See eq.(4))

Now it is necessary to compare the case of MNLS with NLS case. N times one soliton of MNLS case does not depart each other like that of NLS case. That is, N-sech solution of NLS transforms to N sech-solitons as evolved, but N times one soliton of MNLS does not evolve to N solitons. It means that N times one soliton of MNLS does not equivalent to N-soliton.

First figure represents the case of α=2, β=3, and s=0.2, and second α=2, β=-1, and s=2.





References

[1] Q-H.Park, and H.J.Shin, Phys. Rev. A 57, 4621 (1998).

[2] G.P.Agrawal, Nonlinear Fiber Optics, 3nd ed.(Academic Press, 2001), chap.5.

[3] E.A.Golovchenko, E.M.Dianov, A.M.Prokhorov, and V.N.Serkin, JETP Lett. 42, 88 (1985).

[4] K.Ohkuma, Y.H.Ichikawa, and Y.Abe, Opt. Lett. 12, 516 (1987).

[5] H.Min, and Q-H. Park, Phys. Lett B 388, 621 (1996).