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Controllable Optical Rogue Waves by Modulated Coherent-Incoherent Nonlinearities in Inhomogeneous Fiber

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Abstract: The system under consideration is a coherently coupled nonlinear Schrödinger equation consisting of temporally varying coherent and incoherent nonlinearities. We investigate the impact of nonlinearity modulation in the dynamics of doubly-localized optical rogue waves appearing in Kerr-type nonlinear optical media. We explore the possibility of controlling bright-dark and bright-bright rogue waves possessing different localized structures by adopting the constructed rogue wave solution and similarity transformation through appropriately choosing the modulated nonlinearities by elliptic functions. We demonstrate our arguments by choosing two types of nonlinearities that can expose the existence of single and multi-peak (with double or multi-dip) symmetric/asymmetric rogue waves appearing on the periodic background and tunnelling through a barrier/well with modulations in their profiles.

Keywords: Rogue wave, Inhomogeneous optical media, Coherently coupled NLS equation

1. Introduction

The dynamics of localized nonlinear waves and their existence/interaction with other waves are attracting considerable in the past few decades. With the help of computational tools, it becomes relatively possible to investigate any theoretical model of either multicomponent or multi-dimensional nature possessing various categories of nonlinear waves. Much attention is being paid to localized waves such as solitons, breathers, and rogue waves, and so on. Considering the above intention and experimental observation, we aim to investigate the nature and evolution of rogue waves under a nonlinearity-managed optical fiber system. For this purpose, we consider the following two-component coherently coupled nonlinear Schrödinger equations describing the beam propagation in an optical fiber [1-3]:

$$iQ_{1T} + Q_{1XX} + \gamma(T)(|Q_1|^2 + 2|Q_2|^2)Q_1 - \gamma(T)Q_2^2Q_1^* - V(X,T)Q_1 = 0,$$
$$iQ_{2T} + Q_{2XX} + \gamma(T)(2|Q_1|^2 + |Q_2|^2)Q_1 - \gamma(T)Q_1^2Q_2^* - V(X,T)Q_2 = 0,$$

where X and T are the normalized distance and retarded time, while $V(X,T)$ denotes a graded refractive index profile. Further, the model consists of a constant second-order dispersion along with temporally varying incoherently-coupled (self-and cross-phase modulations) and coherently-coupled type four-wave mixing nonlinearities. There exist a considerable number of works providing a detailed study on solitons, breathers, and rogue waves of Eq. (1) and similar versions, for which one can refer to [4-6] and references therein.

2. Results and Discussion

We identify a similarity transformation that can relate Eq. (1) with varying coefficients to that of a constant-coefficient coupled NLS equation along with a condition as Riccati equation and the form of

modulated spatial and temporal parameters [7,8]. Using the known rogue wave [9], we construct an explicit form of rogue wave solution with temporally varying nonlinearity. The solution admits symmetric bright type doubly-localized rogue waves in both components as a simple case. Further, the rogue waves support bright, grey, and dark type asymmetric profiles having single or double peaks and two or multiple dips in amplitude, that can be altered by tuning the four arbitrary complex parameters apart from six real similarity constants used to manipulating them to appear on different background and undergo deformation/modulation of structure. To understand, we have demonstrated grey-bright and bright-dark rogue waves and their nonlinearity-controlled behaviour in Fig. 1. Here we can note that the rogue waves appear on the periodic background for $\gamma(t)=h_1+h_2\sin(h_3 t+h_4)$ and tunnel through a localized barrier when $\gamma(t)=h_1+h_2\,\mathrm{sech}^2(h_3 t+h_4)$ with modulations in their profiles.

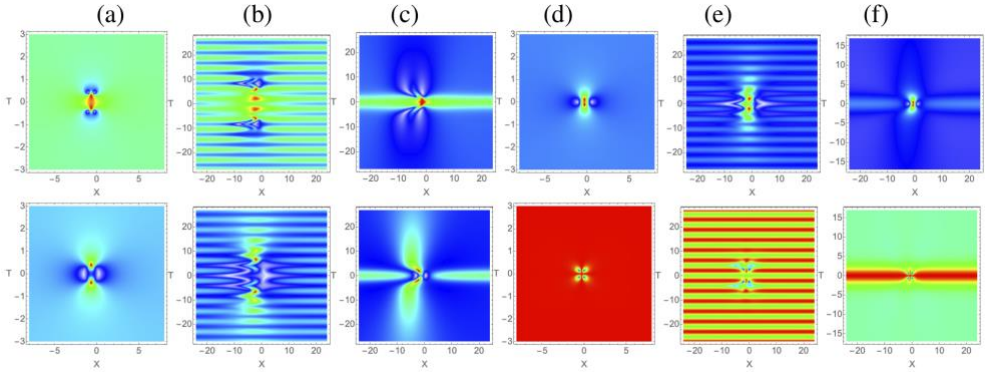

Fig. 1 (a) Grey-bright and (d) bright-dark rogue waves with constant nonlinearity. (b & e) Modulated rogue waves on periodic type for $\gamma(t)=1+0.5\sin(0.75\,t+0.25)$. (c & f) Manipulated rogue waves due to a localized barrier backgrounds for $\gamma(t)=1+1.5\,\mathrm{sech}^2(0.75\,t+0.25)$. Top panel: Q_1 and bottom panel: Q_2

3. Conclusions

Nonlinear waves (especially rogue waves) admitting different localized structures can be manipulated by appropriately choosing the temporally-varying nonlinearity in inhomogeneous optical fiber system.

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