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Formation of rogue waves from the locally and periodically perturbed condensate

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The one-dimensional focusing nonlinear Schrodinger equation (NLSE) on an unstable quasi-monochromatic plane wave (condensate) background is the fundamental physical model, that can be applied to study the development of modulation instability (MI) and formation of rogue waves. The complete integrability of the NLSE via inverse scattering transform (IST) enables the decomposition of the initial conditions into elementary nonlinear modes: breathers, continuous spectrum waves and finite-gap solutions. The small localized/periodic condensate perturbations (SLCP/SPCP) that grow as a result of MI have been of fundamental interest in nonlinear physics for many years. Here, we demonstrate that Kuznetsov-Ma and superregular localized NLSE breathers play the key role in the dynamics of a wide class of SLCP [1]/ SPCP. During the nonlinear stage of MI development, collisions of these breathers lead to the formation of rogue waves. We present new scenarios of rogue wave formation for randomly distributed breathers as well as for artificially prepared initial conditions. For the latter case, we present an analytical description based on the exact expressions found for the space-phase shifts that breathers acquire after collisions with each other. We demonstrate the presence of Kuznetsov-Ma and superregular breathers in arbitrary-type localized condensate perturbations by solving the Zakharov-Shabat eigenvalue problem with high numerical accuracy using the standard Fourier collocation method [2]. Then we study the link between periodic and localized IST approaches describing MI. Focusing on periodic condensate perturbations we however find that if the size of periodic domain is sufficiently large, the existence of localized wave structures - breathers, is allowable. In this case such breathers should be considered as a limit of finite-gap periodic solutions with very narrow gap size. Finally, we show that the Kuznetsov-Ma and superregular breathers are presented in arbitrary-type periodic condensate perturbations using the mentioned Fourier collocation method supplemented by the wavefield periodization procedure suggested in [3]. Author thanks the support of the Russian Science Foundation (Grand No. 14-22-00174).

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