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The role of superregular breathers in the development of modulation instability

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The integrable model of modulation instability (MI) – the one-dimensional nonlinear Schrodinger equation (NLSE) is in the focus of research for many years. Recently a significant progress has been made in the understanding of MI long time consequences (nonlinear stage of MI). Namely, the role of continuous spectrum was studied in the work [1], another two works are devoted to integrable turbulence formation [2] and to the Fermi-Pasta-Ulam recurrence [3].
We proposed so-called superregular breathers scenario of MI in [4]. In this scenario instability evolves from small localized perturbations of the condensate to N pairs of breathers which moves in opposite directions leaving a nonperturbed condensate with changed phase behind them. Recently we observed superregular breathers in hydrodynamics and optics experiments [5]. Here we discuss the role of superregular breathers in general scenario of MI.
Furthermore we study another important question - the formation of freak waves from the perturbed condensate. To date two possible scenarios in the frame of NLSE have been described: 1) the collisions of Akhmediev breathers and 2) the rational solutions, such as Peregrine breather. In the first case the initial conditions usually include breathers of quite large amplitude.
In the case of rational scenario the solution is pure homoclinic, i.e. completely returns to initial unperturbed condensate. Meanwhile, results of numerical modeling of freak waves formation in more exact models like Euler equation and NLSE with higher nonlinearities demonstrate formation of breathers.
We present a new model of freak waves formation caused by particular collisions of superregular breathers. In the frame of this scenario extreme waves appear from small perturbations of the condensate and leave breathers, which never disappear.
We study special two-pair superregular breathers scenario as well as randomly distributed N pairs solution. The latter case can be considered as a kind of integrable turbulent state.

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