Can uneven bathymetry freeze water-wave breathers?

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The nonlinear Schrödinger equation is a robust model for describing the evolution of surface gravity wave-packets over arbitrary bathymetry. Both the dispersive and the nonlinear coefficients turn out to depend on the fluid depth \cite{1,2}. Its variation along the propagation direction provides a new degree of freedom to tailor the wave-packet evolution, in analogy to what has been obtained in optical fibers with varying dispersion \cite{3}.

We investigate how the nonlinear stage of modulation instability can be frozen by varying the water bottom from intermediate to large depth giving rise to an increase of the magnitude of the nonlinear coefficient within the focusing regime. We consider the case of an abrupt bathymetry change at the maximal focusing point. With the help of a three-wave truncation, we provide analytical conditions on the occurrence of freezing. We present numerical simulations of the full model and the experimental confirmation in a water wave flume experiment. We show that the effects of high-order nonlinear terms and dissipation do not dominate the evolution, making the freezing quite a robust phenomenon.

Our results help clarify how the breathing evolution of water wave-packets can be dynamically controlled and to understand the impact of bathymetry on extreme-wave lifetimes.

References

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