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# Rogue Waves: Early Warning vs Forecast

Nail Akhmediev (1), Adrian Ankiewicz (1), Jose-Maria Soto-Crespo (2), and John M. Dudley (3)

(1) Optical Sciences Group, Research School of Physics and Engineering, Institute of Advanced Studies, The Australian National University, Canberra ACT 0200, Australia , (2) Instituto de Óptica, C.S.I.C., Serrano 121, 28006 Madrid, Spain (jsoto@io.cfmac.csic.es), (3) Institut FEMTO-ST, UMR 6174 CNRS-Université de Franche-Comté, 25030 Besançon, France (john.dudley@univ-fcomte.fr)

Rogue waves in the ocean are well known to have disastrous consequences [1]. They appear both in the deep ocean and in shallow waters. In contrast to tsunamis and storms associated with typhoons that can be predicted hours (sometimes days) in advance, the particular danger of oceanic rogue waves is their sudden appearance as "waves that appear from nowhere" only seconds before they hit a ship. The grim reality, however, is that although their existence has now been confirmed by multiple different means, there remains uncertainty about their fundamental origins which hinders systematic attempts to study their characteristics and perhaps predict their appearance. Analysis of the spectral content of the full spectrum of waves on the surface of the ocean has already been studied in the context of the nonlinear wave propagation, and the Benjamin-Feir Index has been introduced as a measure of how the frequency content of the wave spectrum relates to the frequency band of instability gain [2]. This can indeed be applied in a significant forecasting context to identify sea state conditions that may be associated with an elevated probability for rogue wave appearance, providing important information allowing avoidance of particular ocean regions when mapping navigation routes.

This approach, however, is based on analysis of the spectral characteristics of the sea-state as a whole. Motivated by the experiments in optics, however, we focus here on how the spectral characteristics of the envelope of propagating waves could be used to reveal the presence of nonlinearity and rogue waves a short time before the appearance of a particular rogue wave event. That is, we are interested in particular signatures of the ocean wave dynamics that can be used as “early warning" indicators in all already agitated sea. Specifically, by considering real-rime spectral analysis of the wave envelope, the appearance of characteristic triangular spectral decay of the wings could provide valuable advance and immediate warning of nonlinear amplification conditions and the emergence of rogue waves. If such spectral signatures were apparent before visual observation, then this could be extremely important in allowing appropriate evasive action to be taken.

Here, we review the properties of the characteristic triangular spectrum for rational soliton solutions of the NLSE and demonstrate that such characteristics are universal, also being observed for higher order rogue wave solutions. By showing how these spectral characteristics appear at an early stage of evolution, our analysis supports the idea that analyzing the shape of propagating waves in the frequency domain may provide important information about the emergence phase of nonlinear wave shaping mechanisms. One of the solutions is the Peregrine soliton, suggested as a prototype of rogue wave in [3]. A second order rogue wave solution was first presented in [4]. This solution can be considered as a nonlinear superposition of two Peregrine solitons. The spectrum initially has a shape close to being triangular. Within an oceanographic context, our results suggest the potentially extremely important prospect of identifying spectral signatures of the early emergence of rogue waves resulting from nonlinear wave shaping.

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