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Optical Rogue Waves: Physics and Impact

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Abstract: We review our recent work in the field of optical rogue wave physics and applications. Beginning from a brief survey of the well-known instabilities in optical fiber supercontinuum generation, we trace the links to recent developments in studying the emergence of high contrast localized breather structures in both spontaneous and induced nonlinear instabilities. We also discuss the precise nature of optical rogue wave statistics and examine the dynamics leading to the formation of extreme events in the context of noise-driven supercontinuum generation.

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A central challenge in understanding extreme events in physics is to develop rigorous models linking the complex generation dynamics and the associated statistical behavior. Quantitative studies of extreme phenomena, however, are often hampered in two ways: (i) the intrinsic scarcity of the events under study and (ii) the fact that such events often appear in environments where measurements are difficult. A particular case of interest concerns the infamous oceanic rogue or freak waves that have been associated with many catastrophic maritime disasters. Studying rogue waves under controlled conditions is problematic, and the phenomenon remains a subject of intensive research. On the other hand, there are many qualitative and quantitative links between wave propagation in optics and in hydrodynamics, and it is thus natural to consider how insights from studying instability phenomena in optics can be applied to other systems. The field of "optical rogue wave physics" began in 2007 and has since become a major international research effort involving many international groups and consortia [1-3]. The purpose of this paper will be to discuss these results that have been obtained in optics, and to consider the precise nature of optical rogue wave statistics and to examine in detail the dynamics leading to the formation of extreme events in the context of noise-driven supercontinuum generation in highly nonlinear fibers. Specifically, we consider the statistical analysis of solitons generated in a noise-driven SC and revisit the original interpretation on the nature of optical rogue waves showing that the enhanced redshift of "rogue" solitons is associated with soliton collision dynamics. Using a full field analysis we further show that the statistical distribution of the amplitude of all solitons present in a noise-driven SC contains events that can be labelled "rogue" using standard hydrodynamic definitions. These events are found to correspond to the onset of a collision between two solitons with different frequencies. In addition, we will report on recent experimental results on the observation in a fiber-based system of novel classes of nonlinear structure predicted theoretically over 25 years ago. The particular structure that we study is the Peregrine soliton, a localized nonlinear wave which has not to date been experimentally observed in any physical system [4]. It is of fundamental significance because it is localized in both time and space, and because it defines the limit of a wide class of solutions to the nonlinear Schrödinger equation. In showing that Peregrine soliton characteristics appear with initial conditions that do not correspond to the mathematical ideal, our results may impact widely on studies of hydrodynamic wave instabilities where the Peregrine soliton is considered a freak wave prototype [5,6].

[1] D. R. Solli, C. Ropers, P. Koonath, & B. Jalali, "Optical rogue waves," Nature **450**, 1054-1057 (2007)

[2] N. Akhmediev, J. M. Soto-Crespo, & A. Ankiewicz, "Extreme waves that appear from nowhere: On the nature of rogue waves," Phys. Lett. A **373**, 2137-2145 (2009).

[3] G. Genty, C. M. de Sterke, O. Bang, F. Dias, N. Akhmediev, J. M. Dudley , "Collisions and turbulence in optical rogue wave formation," Phys. Lett. A, **374** 989-996 (2010)

[4] D. H. Peregrine, "Water waves, nonlinear Schrödinger equations and their solutions," J. Austral. Math. Soc. Ser. B **25**, 16-43 (1983)

[5] V. I. Shrira & V. V. Geoigjaev, "What makes the Peregrine soliton so special as a prototype of freak waves?," J. Eng. Math. **67**, 11-22 (2010)

[6] B. Kibler, J. Fatome, C. Finot, G. Millot, F. Dias, G. Genty, N. Akhmediev, J. M. Dudley, "The Peregrine soliton in nonlinear fibre optics," Nat. Phys. **6**, 790-795 (2010)