Contribution ID: **280** Contribution code: **FT-02** Type: **Invited talk (virtual)**

On the nature of optical rogue waves

Thursday, 1 September 2022 12:30 (30 minutes)

We present rogue wave solutions to the standard cubic nonlinear Schrődinger equation that models many propagation phenomena in nonlinear optics. We propose the method of mode pruning for suppressing the modulation instability of rogue waves. We point to instances when rogue waves appear as numerical artefacts, due to inadequate numerical treatment of modulation instability and homoclinic chaos of rogue waves. In the end, we display how statistical analysis based on different numerical procedures can lead to misleading conclusions on the nature of rogue waves. Thus, we will discuss the nature of optical rogue waves in view of conflicting opinions expressed in the literature. In particular, we address three pairs of opposing suppositions on their nature: Linear vs. nonlinear [1]; random vs. deterministic [2]; and numerical vs. physical [3]. In our opinion, a short answer to the three suppositions is that rogue waves in optics are essentially nonlinear, deterministic, and physical. They are nonlinear because the major cause of rogue waves is the modulation or Benjamin-Feir instability, which by its nature is the basic nonlinear optical process. Rogue waves are deterministic because modulation instability (MI) leads to deterministic chaos; random phenomena are probabilistic and may look chaotic but are not deterministic. Rogue waves are physical because they appear in many experiments and media, with similar statistics. Our opinion is supported by extensive numerical simulations of the nonlinear Schrődinger equation in different regimes that touch upon the aspects of all three conflicting suppositions.

Unfortunately, in numerical simulations optical rogue waves may appear fictitiously, as numerical artefacts. Different numerical algorithms represent different dynamical systems and in chaotic regimes may provide different evolution pictures for exactly the same inputs, leading – distressingly – to significantly different statistics [4]. The statistics appear similar, but the number of peaks, the maximum of intensity, and the slope of distributions, among other things, are different. Hence, in the chaos produced by modulation instability, optical rogue waves and their statistics may appear as numerical artefacts. Owing to a vague definition of rogue waves and exponential amplification of numerical errors, there are situations in which optical rogue waves may appear as linear, random, and numerical. In the very end, we demonstrate how to produce stable Talbot carpets – recurrent images of light and plasma waves – by rogue waves, for possible use in nanolithography.

References

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Session Classification: Frontiers

Track Classification: Frontiers