Optical tsunami

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Abstract:

Extreme or rogue waves have received a great deal of attention recently for their emergence in a variety of applications [1]. The most popular manifestation of a rogue wave is the sudden build-up and subsequent rapid disapperance in the open sea of an isolated giant wave, whose height and steepness are much larger than the corresponding average values of other waves in the ocean. On the other hand, the occurrence of rogue waves in shallow waters has been comparatively much less explored, in particular in the context of nonlinear optics [2]. In this presentation we will point out that extreme waves may be generated in optical fibers in the normal GVD regime of pulse propagation [3-4]. The model linking hydrodynamics with nonlinear optics is provided by the semiclassical approximation to the NLSE, which is known as the nonlinear shallow water equation (NSWE) [5-6]. Although in the normal GVD regime a CW is modulationally stable, extreme waves may still be generated by imposing a suitable temporal pre-chirping or phase modulation [3-4,6], which is analogous to a nonuniform velocity distribution of the propagating water waves, eventually leading to tsunamis. We shall describe first the dynamics of the generation of an intense, flat-top, self-similar and chirp-free pulse as a result of the initial step-wise frequency modulation of a CW laser. The intriguing property of such pulses is their stable merging upon mutual collision into either a steady or transient high-intensity wave. This effect may lead to extreme intensity peaks in optical communication systems whenever various wavelength channels are transported on the same fiber, and to the generation of highly temporally compressed periodic optical pulse trains [3]. Next we will discuss the otical analogy with the shoaling of ocean waves as they run-up to the beach. We consider the propagation of special, input temporally pre-chirped optical pulses with different power profiles. These pulses represent nonlinear invariant solutions of the NSWE (Riemann waves). For such type of chirped pulses, we obtain exact solutions of the optical NSWE, and demonstrate their good agreement with numerical solutions of the NLSE, at least up to the point where a vertical front develops in the power profile. Finally, we discuss how third-order dispersion leads to the occurrence of extreme waves whenever a dispersion tapered fiber is used, in analogy with the dramatic run-up and wave height amplification of a tsunami towards the coast [4].

References:

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