Experimental Signature of Riemann Wave Shoaling in Optical Fiber

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Over the last decade, optical pulse propagation in optical fibers has provided a convenient and controlled environment to study and establish intriguing analogies with hydrodynamic phenomena. Beside the study of optical rogue waves occurrence in the context of supercontinuum generation [1], nonlinear fiber optics has allowed the first experimental observations of several peculiar solutions of the nonlinear Schrödinger equation (NLSE) predicted more than 50 years ago [2]. In the particular case where nonlinearity is predominant compared to dispersion, optical pulse propagation dynamics can be efficiently described by a semi-classical approximation to the NLSE [3], known as the nonlinear shallow water equation (NSWE). In such a context, where optical pulses propagate in the regime of normal dispersion, direct analogies with hydrodynamics can also be established as attested, among others, by the numerical demonstration of an optical tsunamis analog through the shoaling of a Riemann wave [4] as well as the experimental observation of optical undular bores generated by cascaded four-wave mixing in a quasi-periodic pulse train [5]. Here we report on the shoaling of Riemann waves, whose signatures are observed experimentally in a context of nonlinear fiber optics propagation. These pulse dynamics are associated with nonlinear invariant solutions of the NSWE, given by a pulse that exhibits a chirp profile proportional to its amplitude. Assuming a 4.5 ps (FWHM) input Gaussian pulse, we calculate the ideal chirp and power parameters to be used so that the pulse will experience a maximal steepening of its trailing edge after 500m propagation in a highly nonlinear fiber (HNLF), as illustrated in Fig.1(a). The appropriately pre-chirped pulse is generated experimentally through spectral reshaping of a broadband transform-limited pulse (300fs FWHM), and characterized at both the input and output ends of the fiber. As seen in Fig. 1(b), the simulation results obtained by numerical integration of the generalized nonlinear Schrödinger equation (GNLSE) exhibit a good agreement with analytical predictions. We further provide experimental measurements of the pulse properties that are consistent with those expected from numerical simulations (Fig. 1(c)).

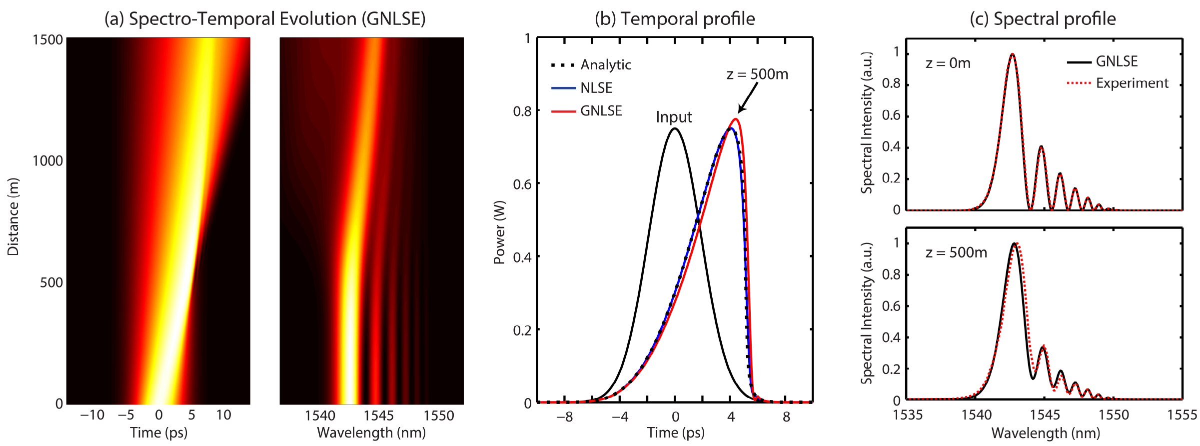

Fig. 1 a) Temporal and spectral evolution of the ideal Riemann pulse propagating in HNLF obtained by numerical simulations (GNLSE). b) Comparison of the temporal profiles at the input and output of the fiber obtained analytically and numerically. c) Input and output spectra measured experimentally (red) compared with numerical predictions (black).

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