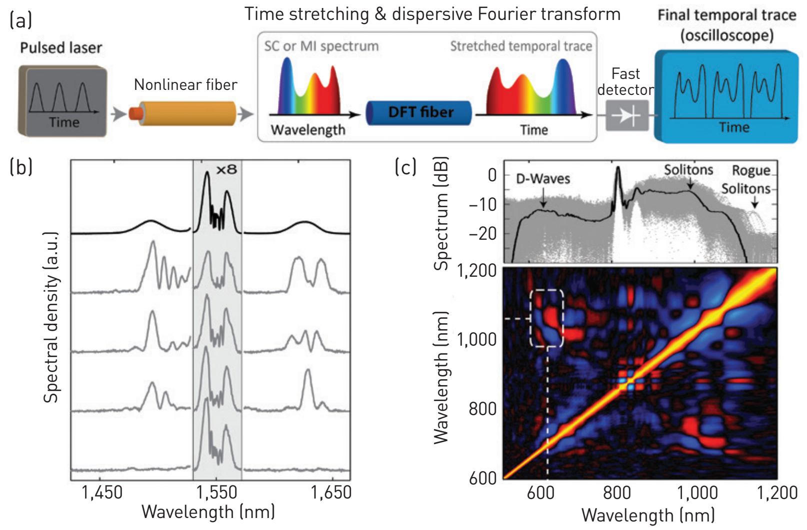
Ultrafast Single-Shot Measurements in Modulation Instability and Supercontinuum

The real-time measurement of ultrafast noisy processes is challenging because it requires single-shot resolution, broadband fidelity and long-record length. It is especially difficult to measure fluctuations in the optical supercontinuum, a white light source that can span over an octave in bandwidth. Yet, understanding noise in supercontinuum light and the intertwined process of modulation instability (MI) is critical. MI itself is one of the most fundamental processes in nonlinear physics, while supercontinuum noise studies yield new insights into the emergence of rogue wave events in settings from hydrodynamics to cold atoms.[1]

We studied shot-to-shot variations in both MI and supercontinuum generation using the time-stretch dispersive Fourier transform (TS-DFT) technique.[2–5] In TS-DFT, the intensity of a temporal field evolves into its Fourier transform with sufficient linear dispersive propagation, analogous to spatial far-field diffraction. Pulses from a mode-locked laser injected into a high-dispersion optical fiber are ultimately stretched such that their intensity profile matches their spectral envelope. Since this waveform is slow enough to be within the bandwidth of a real-time digitizer, it is possible to directly measure a series of single-shot spectra at the full laser repetition rate.

These measurements have uncovered new physics since access to large times-series permits detailed statistical analysis.[2,3,5] Experiments have shown that MI amplifies individual modes normally unseen in time-averaged experiments, lending insight into how patterns arise in other systems such as sand dunes.[2] Studies have also characterized supercontinuum noise around 1,550 nm and over an octave of bandwidth from 600–1,200 nm.[3,4] Extending TS-DFT to work across an octave required custom-fiber fabrication for the time-stretching step.[4] The correlation functions we calculated from experimental data revealed direct evidence of physical coupling between separated wavelength components, and the nature of the coupling was readily inferred from the correlation structure.[2,3]

Real-time measurements can expose hidden phenomena and yield insight into noise-driven nonlinear systems. More information remains to be unearthed from the libraries of single-shot spectra acquired by these means. OPN



(a) Experimental setup. (b) Single-shot (gray) and average (black) MI spectra.[2] (c) Top: single-shot (gray) and average (black) supercontinuum spectra;[4] Bottom: correlation between solitons and dispersive waves 400 nm apart. Red (+), blue (-) and black (uncorrelated).

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