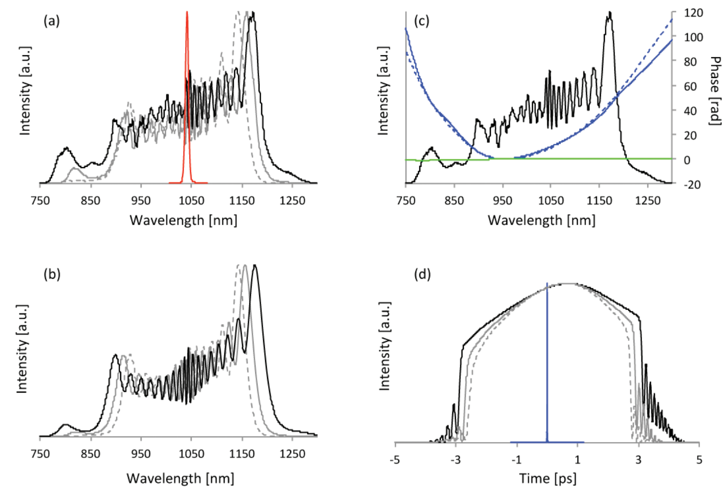
ULTRAFAST OPTICS

Wave-Breaking Extended Coherent Fiber **Supercontinuum Pulse Compression**

Like surface water wave breaking, optical wave breaking (WB) is a phenomenon that occurs when an optical pulse propagates in a normally dispersive nonlinear fiber.[1,2] It is often avoided in fiber continuum compression experiments by using lower coupling power or shorter fiber length, because the WB-extended continuum has higher-order spectral phase distortions that cannot be compensated by a quadratic compressor, a prism pair or a grating pair. This issue can be resolved when an ideal compressor such as a 4f pulse shaper is used. Linear and nonlinear chirps can be removed by arbitrary phase shaping toward transform-limited pulse compression.

In our experiment, the onset of a spectral tail at lower coupling power and the development of the tail into sidelobes at higher coupling power at both ends of the spectrum suggest the occurrence of WB.[3] With the WB-extended spectrum at the highest power, we compressed the supercontinuum to a pulse width of 6.4 fs using a 4f pulse shaper. We achieved the pulse measurement and compression by performing a multiphoton intrapulse interference phase scan.[3,4]

Our work included the theoretical modeling of the pulse progression by the scalar generalized nonlinear Schrödinger equation. The simulated spectra at different powers reproduced the fringe-like spectra and the evolution of WB. In the time domain, the trailing edge experienced self-steepening, creating an optical shock followed by temporal oscillations from the interference of the generated high-frequency (short-wavelength) components and unshifted light. At elevated power, the oscillations strengthened as the spectral tail developed into a side lobe, and the oscillations at the leading edge were simultaneously initiated. Also, the predicted spectral phase resembled the measured one except for the spectral ranges where the intensity of the supercontinuum is low. The agreement between simulations and experiments confirms the occurrence of WB and explains its non-symmetric development at both ends of the spectrum.



(a-b) Experimental and theoretical supercontinuum spectra at three coupling powers. (dashed gray: 0.17W; gray: 0.21W; black: 0.27W). WB emergence is seen at both ends. The red spectrum in (a) is the pump laser spectrum. (c) The WB-extended supercontinuum spectrum (black), spectral phase predicted by the S-GNLSE (dashed blue), measured by MIIPS (blue), and residual phase after compression (green). (d) Temporal profiles of the pulses corresponding to three coupling powers in (a) and (b). The blue profile is of the pulses compressed from the WB extended supercontinuum.

The combination of the WB-extended supercontinuum and arbitrary phase compensation allows us to generate 0.1 W, 80 MHz, near-transform-limited 6.4-fs (FWHM) pulses at a high compression ratio (28×). A broader bandwidth and higher compression ratio could be attained by overcoming nonlinear depolarization at higher coupling power or longer fiber length. The ultrabroad bandwidth and high coherence of the fiber light source could be appealing to nonlinear optical microscopy and spectroscopy using coherent control methods, especially for nonlinear interferometric vibrational imaging and other types of interferometric coherent anti-Stokes Raman scattering imaging.[5] OPN

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