Dispersive wave emission from self-phase modulation with normal dispersion regime pumping in photonic crystal fibers

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Abstract: We provide a detailed numerical and experimental investigation of dispersive wave (DW) emission from femtosecond pulses propagating in the normal dispersion regime of a polarization-maintaining photonic crystal fiber.

The generation of dispersive waves (DWs) from solitons, also known as resonant or Cherenkov-like radiation, has been extensively studied in nonlinear optics, particularly within the framework of supercontinuum generation (SCG) [1]. Recent studies have however expanded the understanding of DW emission, showing that it is not restricted only to soliton pulses in the anomalous dispersion (AD) regime [1]. Notably, power transfer from a pump in the normal dispersion (ND) regime to a DW in the AD regime has also been observed, with the frequency detuning influenced by the pump self-phase modulation (SPM) [2]. This concept has been theoretically extended to include fourth-order dispersion, demonstrating the possibility of generating multiple DWs under normal dispersion pumping [3].

In this work, we present a comprehensive numerical and experimental study of DW emission from femtosecond pulses propagating in the weak normal dispersion regime of a polarization-maintaining photonic crystal fiber (PCF). Results from numerical simulations shown in Fig 1(a)-(d) highlight the critical role of higher-order dispersion in leading to typical spectral characteristics of self-phase modulation (SPM), optical wave breaking (OWB), and DW generation. The output profile in Fig. 1(d) shows how a strong oscillation appears on the temporal intensity envelope, arising rather from the coherent beating between the DW and SPM spectral components that temporally overlap (this is seen in the spectrogram in Fig. 1(b). Experimental results shown in Fig. 1(e) show excellent agreement with numerical simulations (Fig. 1(f)), further validating our numerical model. Additionally, we evaluated the relative intensity noise (RIN) of the output spectra using the dispersive Fourier transform (DFT) technique, confirming the stability of the DW generated near 1130 nm (See Fig 1g). Note that experimental RIN measurements (blue) in regions of low measured spectral intensity are higher than those seen in simulations, but this is an artifact arising from the contribution of instrumental noise in the DFT. In addition to these results shown here, we will also discuss additional simulation and experimental studies which give further insights into these novel normal-dispersion regime dynamics.

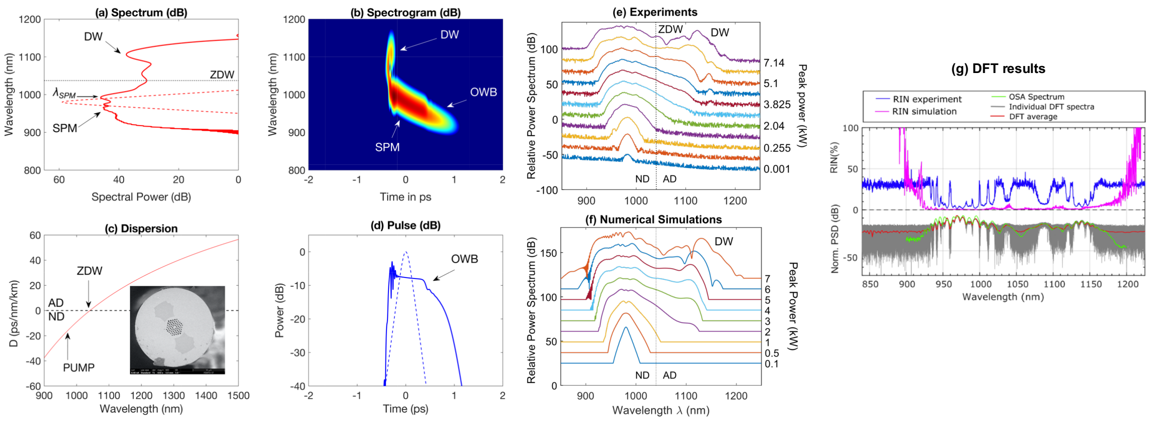

Figure 1: (a) Fiber input (dashed) and output (solid) simulated spectra, showing DW emission at 1130 nm under normal dispersion pumping at 980 nm. (b) Time-frequency spectrogram showing DW emission driven by SPM. (c) Dispersion of the experimentally used PCF shown in inset. (d) Fiber input (dashed) and output (solid) pulse simulated profiles. The input conditions are a 140 fs (FWHM) Gaussian pulse at 980 nm with peak power of P = 7 kW, and propagation distance of 80 cm. (e) Experimental and (f) numerical output spectra as a function of input peak power, showing the progressive DW generation near 1130 nm in the anomalous dispersion regime. (g) DFT results and SC relative intensity noise (RIN) measurements.

References

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