Power Dependent Noise Performance of fs Supercontinuum Generation in Normal Dispersion Fibers with a Long Zero-dispersion Wavelength

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One of the requirements for generating a low noise supercontinuum (SC) in a normal dispersion fiber using a femtosecond (fs) pump is to have the minimum absolute dispersion wavelength to be close to zero in order to avoid parametric Raman noise [1]. SC generation in all-normal dispersion fibers can under certain requirements provide a highly coherent spectrum [2, 3], which is of key importance to a large range of imaging and spectroscopy applications. Key requirements to avoid Raman noise and noise from polarization mode instability (PMI) is to have a sufficiently low peak power (P_0), short pulse length (T_0), short fiber length, and high fiber birefringence [4].

Silica microstructured fibers (MSFs) pumped with 1550 nm fs lasers is an attractive platform to generate a low noise SC due to their technological maturity. We therefore fabricated a low-loss silica MSF (using 2 cladding sections with different hole sizes) with weak dispersion at 1500 nm and experimentally studied SC generation at low peak powers using a 1550 nm, 125 fs pump [5]. The group velocity dispersion (β_2) profile of the fiber is shown in Fig. 1(a). Since the dispersion at the pump is weak, a low P_0 can be used to generate a broad SC. A further advantage of using low peak powers is the possibility of avoiding PMI. The requirement of weak dispersion at 1550 nm leads to a fiber design with a zero dispersion wavelength (ZDW) at 1.8 μm . The SC generated with up to $P_0 = 9$ kW does not cross the ZDW and has low relative intensity noise (RIN) as was demonstrated numerically and experimentally [see Fig. 1(b)].

Fig. 1. (a) Numerically calculated (red) dispersion and the dispersion measured experimentally (blue) using a white light interferometry set up. (b) Numerically calculated spectrum (green) and RIN (blue) after $z=3$ m and $P_0 = 9$ kW and the experimentally measured spectrum (red) and the RIN (dots) measured using 12 nm bandwidth bandpass filters. (c) Numerically calculated spectrum (red) and RIN (blue) after $z=3$ m and $P_0 = 45$ kW. (d) Evolution of RIN along 3 m of the fiber with $P_0 = 45$ kW.

To study the effect of higher input power, where the SC crosses into the anomalous dispersion region (ADR), we performed numerical modelling, taking into account both quantum noise and laser amplitude noise by adding 1% fluctuation in P_0 with constant $P_0 T_0$ [4, 6]. At $P_0 = 45$ kW the broadening is initially from self-phase modulation and optical wave breaking in the normal dispersion region (NDR), but later the SC broadens into the ADR and develops into solitons. These solitons generate trapped dispersive waves that are very noisy and move through the low-noise spectrum in the NDR [see Fig. 1(c+d)]. Our results using the novel MSF for low-noise normal dispersion SC generation at 1550 nm, demonstrate that a long wavelength ZDW can be tolerated, as long as the peak power is sufficiently low to avoid power crossing into the ADR.

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