1.3 Octave Supercontinuum Generation in Highly Ge-doped Photonic Crystal Fiber

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Abstract: We present a flat, visible 1.3-octave supercontinuum generated in a GeO₂-doped photonic crystal fiber owing to an overlap of the modulation instability and Raman gain regions resulting in efficient energy transfer to new frequency components.

OCIS codes: (320.0320) Ultrafast optics; (320.6629) Supercontinuum generation; (060.2280) Fiber design and fabrication

Supercontinua are of interest for numerous industrial applications including sensing, imaging, and frequency comb generation as well as in optical device characterization. Recently, Q-switched lasers were found to be compelling candidates for supercontinuum generation in the long-pulse regime [1–3]. Here we present supercontinuum generation between 620 – 1552 nm in a highly doped photonic crystal fiber (PCF) pumped with a passively Q-switched sub-ns microchip laser at 1064nm. Efficient generation is enabled even at low pump powers owing to overlapping modulation instability (MI) and Raman gain regions.

We designed a hexagonal lattice, solid-core silica matrix PCF with a 20% mol. GeO₂ doped, 3μm core and strong index contrast (Δn= 30x10⁻³) between the core and the cladding (Fig.1a, inset) fabricated by PERFOS. The PCF has n² = 4.709 x 10⁻²⁰ m²/W and a Raman gain of gR = 7.07x10⁻¹⁴ m/W. We measured the zero dispersion wavelengths to be λZDW=1047 nm and 1050 nm for the two principal polarization axes. Dispersion is 6.44 ps/km-nm at 1064nm, the attenuation 0.17dB/m and γ=50 (W-km)⁻¹. In Fig.1a the supercontinuum is generated after 1m of fiber for various input powers: a flatness of <6 dB over 820 nm extending from 620 nm to 1440 nm (Fig. 1a), and <15 dB over 932 nm between 620 nm - 1552 nm is observed for Pave=7.8mW (Ppeak=670W). This result is competitive with similar sources using longer fibers (1.8 – 20 m) and higher peak powers [4–6] in the same ns pulse regime. Notably, in Fig. 1a we start seeing supercontinuum in 1m of fiber (bandwidth >250nm) at markedly low peak powers of 98W (Pave=1.1mW) with a 0.8ns, 14 kHz laser, lowest reported to our knowledge.

![Fig. 1: (a) Experimental supercontinuum in 1m PCF, 0.8ns pulse duration at 14 kHz; (b) Simulations showing spectrum evolution as a function of fiber length and experiment in 1m fiber for Pave=7.8mW, overlaid with experimental result. Traces are offset for visibility.](image)

The generating mechanisms of this supercontinuum are studied using the generalized nonlinear Schrodinger Equation (GNLSE) solver [7], modified to include measured attenuation and quantum noise. Simulation results (Fig. 1b) show an evolution starting from MI. Raman response of GeO₂ reaches its maximum at 13.2THz extending from 10–15THz. Accordingly, MI and Raman peaks overlap, producing a highly efficient energy transfer from pump to shorter and longer wavelengths. This effect is primarily responsible for the extremely wideband spectrum competitive with current research-grade and commercial sources operating in the nanosecond pulse regime.

5. NKT Photonics, NKT Supercontinuum Application Note V2.0 July 2009 (2009).