Title: Silicon carbide photonic crystal fibers for broadband supercontinuum generation: Design and optimization

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Abastact: Supercontinuum (SC) generation in photonic crystal fibers (PCFs) is pivotal for applications in spectroscopy, biomedical imaging, frequency metrology, and optical communications. Conventional silica-based PCFs demand megawatt-level input powers for effective broadband SC, prompting exploration of superior materials like silicon carbide (SiC), which provides an extended transparency window from 0.4 to 6 μm and a Kerr nonlinearity over three times higher than silica. In this study, we introduce and optimize novel SiC-based PCFs through precise engineering of structural parameters, including lattice pitch, air-hole diameters with radial variations (gradually increasing, uniform, and gradually decreasing configurations), and core properties. Employing finite-element simulations for modal and dispersion analysis, coupled with solutions of the Generalized Nonlinear Schrödinger Equation (GNLSE) for nonlinear dynamics, we evaluate mode confinement, dispersion tailoring, and spectral broadening under femtosecond pumping at 1.55 μm. Our results reveal that SiC PCFs deliver superior SC performance with significantly reduced confinement losses compared to silica counterparts. Notably, the optimized decreasing air-hole design achieves a broad spectral span from 0.8 to 3.0 μm at 5 kW peak power, extending to 3.7 μm at 10 kW—outperforming silica PCFs that require orders-of-magnitude higher powers for equivalent bandwidths. These advancements position SiC as a transformative material for efficient, low-power broadband SC sources in high-power optics, ultrafast lasers, and telecommunications.

Keywords: Supercontinuum generation Photonic crystal fiber Silicon carbide Nonlinear optics Dispersion engineering Numerical simulations

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