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Towards efficient second-order nonlinear optical processes in hollow-core photonic crystal fibres

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Second-order solid-state nonlinear crystals are used for a wide variety of parametric frequency-conversion processes including the generation of second harmonic, degenerate entangled photon pairs and phase-locked terahertz transients. These crystals can have a high $\chi^{(2)}$ coefficient enabling efficient nonlinear effects, but their spectral range of operation is limited because of their strong linear dispersion properties and their relatively narrow transmission window. Gas-filled hollow-core photonic crystal fibres (PCFs) are efficient nonlinear optical platforms featuring low-loss broadband guidance and tunable dispersion (via an adjustable gas pressure) [1]. However, both the gas and the glass are amorphous materials with a vanishingly small $\chi^{(2)}$. Here we rely on a strong dc electric field E_{dc}, which breaks the centrosymmetry of the gas inside the fibre and induces an effective $\chi^{(2)} \propto \chi^{(3)} E_{dc}$, to enable a new design of second-order nonlinear medium with highly tunable linear properties [2]. We demonstrate the concept by monitoring the electric-field-induced second harmonic generation (EFISH) when pumping a xenon-filled kagomé PCF with nanosecond and femtosecond pulses at $\lambda \sim 1$ μm. A second harmonic (SH) signal is detected at Xe pressures where intermodal phase-matching is satisfied. For example, SH can be generated in the LP02 mode when the Xe pressure is 3.85 bar and the pump beam is launched into the fundamental LP01 mode. Also, by means of quasi-phase-matching (QPM) using a periodic electrode, we demonstrate generation of SH in the low-loss LP01 mode. We observe a maximum conversion efficiency of 2.5×10^{-3} % with a non-optimized electrode configuration and we discuss modified designs that will lead to larger electric-field-induced optical nonlinearities.

[1] P. St.J. Russell et al. Hollow-core photonic crystal fibres for gas-based nonlinear optics. Nature Photonics 8, 278 (2014).

[2] J.-M. Ménard and P. St.J. Russell. Phase-matched electric-field-induced second-harmonic generation in Xe-filled hollow-core photonic crystal fiber. Optics Letters 40, 3679 (2015).

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