Generation of high-brightness vacuum and deep ultraviolet radiation through soliton self-compression in gas-filled hollow capillary fibers

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The development of ultrafast vacuum and deep ultraviolet sources has underpinned many spectroscopy techniques - for example, the study of time-resolved molecular dynamics and angle-resolved photoemission of superconductors. However, in some cases the available laboratory-based sources are incapable of delivering sufficient brightness and pulse durations and many experiments need to be performed at synchrotron or free electron laser facilities. Here, a route to improving the performance of laboratory-based sources by utilizing soliton effects in gas-filled hollow-core capillary fibers is presented.

Soliton-related effects have been extensively explored in hollow-core photonic crystal fibers with pump pulses at μJ energy levels. The observation of soliton formation is a result of the continuous compensation of self-phase modulation from the medium in the fiber core by the anomalous fiber dispersion. This leads to a self-compression of the pump pulse down to single-cycle duration, which is eventually perturbed by higher-order dispersion and can transfer part of its energy to a phase-matched wave in the ultraviolet region, know as dispersive-wave emission. We have found that the energy scaling of these soliton-effect self-compression and dispersive-wave emission dynamics to mJ levels is possible in large-core capillary fibers. Initial experimental results show high-energy dispersive-wave emission tunable from 110-300 nm with energies up to 20 μJ, with simulations suggesting that the dispersive-wave has sub-fs duration. Since these parameters present an improvement to the available small-scale ultraviolet sources, this makes such a system a viable alternative for many applications in spectroscopy and metrology.