Generation of Dispersive VUV Pulse Carrying Orbital Angular Momentum

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Bright and ultrashort VUV and DUV pulses generation is of prime interest for chemistry applications since this spectral range strongly interacts with atoms and molecules and thus can be used as a unique tool for time-resolved spectroscopy. Travers *et al.* [1] experimentally demonstrated the possibility of generating tunable VUV-DUV pulses (from 122 to 350 nm) in gas-filled hollow core fiber with μJ energy and sub-10-fs pulse duration with different spin states.

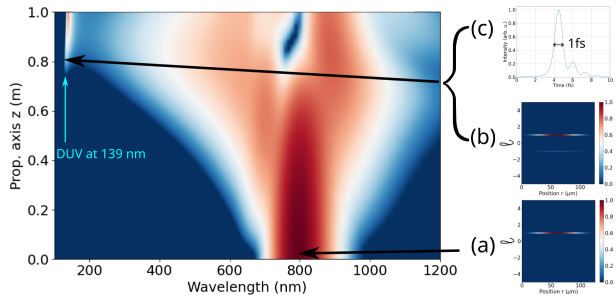

Figure 1: Spectral evolution of the intense femtosecond pulse propagating in helium-filled hollow core fiber in linear scale from 0 to 1 as for the inset. The input beam characteristics are: 400 μJ, 10 fs, $w_0 = 70$ μm and a central wavelength of 800 nm carrying an OAM $\ell = 1$. The insets plot the OAM of the light for (a) 800 nm at distance 0 m, (b) 139 nm at 0.8 m. The inset (c) represents the intensity temporal profile of the VUV (in the range $100 - 200$ nm) spatially integrated at z = 0.8 m

In this theoretical work, we demonstrate that the orbital angular momentum of the pulse can also be preserved and transferred to the VUV-DUV dispersive waves resulting from soliton dynamics. Our home-made pulse propagation code is based on the UPPE model [2] including *ad-hoc* nonlinear source terms, namely Kerr effect, plasma dispersion and absorption by ionization. Pulse propagation in the gas-filled hollow core fiber is achieved by the use of a vectorial orthonormal basis of fiber modes including large number of OAM. To illustrate OAM transfer in the VUV range, we calculate the soliton dynamics of an initial pulse of 400 μJ - 10 fs centered at 800 nm propagating in a 1 meter-long, 250 μm of inner diameter capillary filled with 1.2 bar of helium pressure. The input beam is described by Laguerre-Gauss beam carrying the angular orbital momentum (OAM) $\ell = 1$ (LG_{10}). The waist of the beam is defined as $w_0 = 0.56a$ with a being the capillary radius [3]. The input beam is decomposed on the canonical basis defined by the hollow-core fiber modes EH_{21}, $EH_{21}^{\pi/2}$, TE_{01} and TM_{01} [4].

Fig. 1 presents the results of nonlinear propagation of the LG_{10} input pulse with insets showing the OAM purity (obtained by angular Fourier transform of the electric field for different r values) at different propagation distances and different wavelengths. As the initial ultrashort pulse propagates through the fiber presenting an anomalous dispersion, Kerr and ionization effects broaden the spectrum resulting in a shorter pulse (self-compression). At the 0.8 m propagation distance, the soliton fission appears with the generation of a VUV dispersive wave at 139 nm forming a pulse as short as 1 fs. The analysis of the angular momentum of the generated VUV pulse indicates a rather good purity with 77% in $\ell = 1$ and 23% in $\ell = -1$. This behavior is different from the one obtained for High-order Harmonic Generation for which the transfer of OAM to the XUV pulse results in a value of $q\ell$ where q is the harmonic order and ℓ the OAM of the driving beam [5,6]. We will demonstrate in this theoretical work that the orbital angular momentum of an ultrashort pulse can be fully preserved in the dispersive wave by using a specific field configuration. A discussion on the physics underlying the purity of the OAM of the VUV pulse will be done and we will consider also the coupling with spin state of light in particular for generating entangled state of OAM and spin.

References

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