A new scheme for time-resolved X-ray spectroscopy based on soliton self-compression of pump and driving pulses

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Table-top high-harmonic-generation (HHG) based soft X-ray sources offer the best temporal resolution to study biologically relevant elements (C, N, S) in the so-called water window [1]. Since the HHG spectrum cut-off is proportional to λ^2, optical parametric amplification (OPA) is often used to extend it; however, due to the drop of the generation efficiency at longer wavelengths ($\eta \propto \lambda^{-6}$ [2]), there have been efforts in development of short-wave IR (1-1.4 µm) sources [3]: such possibility is given by the signal pulses obtained by a Ti:Sa laser-pumped OPA, but the further shortening of the pulses is hindered by the lack of sufficiently broadband chirped mirrors. This limitation can be overcome by pulse self-compression: under optimal conditions, for a pulse propagating through a gas-filled hollow-core fiber (HCF), the negative dispersion and the positive nonlinearity compensate each other, yielding pulses characterized by a super-continuum spectrum and a duration of a few femtoseconds without any need for additional dispersive optics [4]. In this contribution we propose a pump-probe scheme for time-resolved X-ray absorption spectroscopy (TR-XAS) where both the pump and the probe pulses are obtained by self-compression in a waveguide. The probe is obtained from the signal emerging from the OPA, centered at 1450 nm, propagating through a 3.45 m HCF with a core diameter of 536 µm in the same pressure gradient scheme, and it is then delivered directly to a HHG beamline under vacuum. The 800 nm driving laser depleted in the OPA is driven through a 2.80 m HCF with a core diameter of 250 µm filled with He at the input and evacuated at the output, to be used as an optical pump. A simulation of both signal and depleted pump propagating through a HCF in optimal conditions as well as measured HHG spectra is shown in Fig. 1. The pump self-compression offers the possibility of a tunable UV source via resonant dispersive wave (RDW) emission. Detailed systematic studies of the spectral broadening and relative temporal self-compression of pump and probe will be presented together with an experimental scheme for TR-XAS.

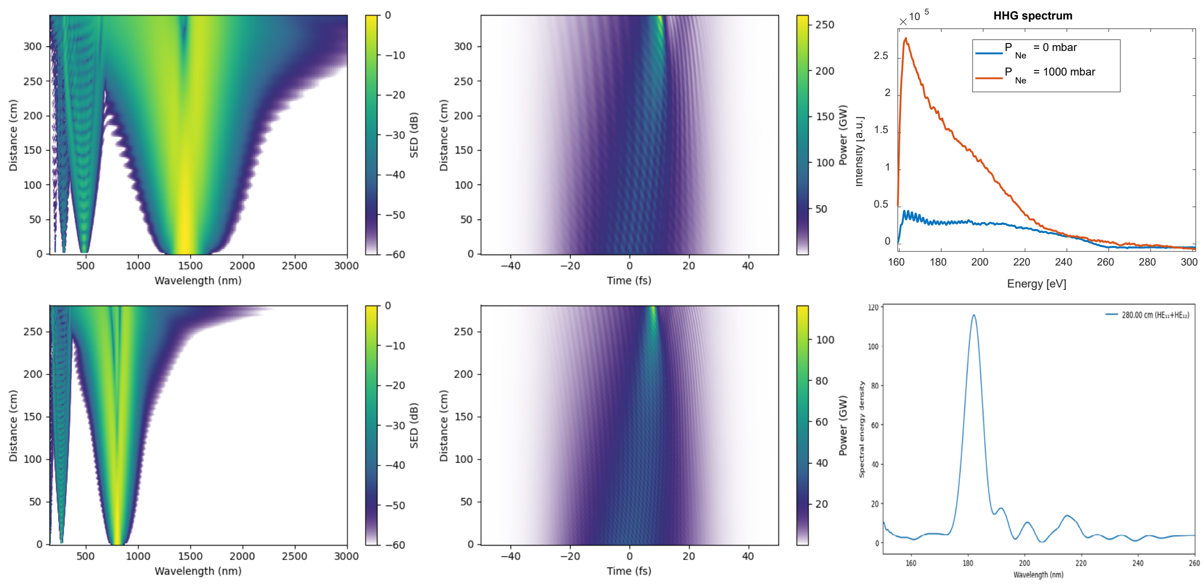

Fig.1 Top, from left to right: spectral broadening of the signal (1450 nm, 2 mJ) in a HCF (3.45 m long, 536 µm in diameter) filled with 1.3 bar of Ne; relative temporal compression from 30 fs to 2 fs; comparison of HHG efficiency driven by the beam propagating in vacuum (blue line) and self-compressed soliton (red line). Bottom, from left to right: spectral broadening of the depleted pump (800 nm, 1 mJ) in a 2.8 m long HCF with a diameter of 250 µm; relative temporal compression from 30 fs to sub- 2 fs; zooming in the high-energy region highlights the RDW in the UV at the output.

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