Temporal Characterization of Sub-3-fs, µJ-level Deep UV Pulses Generated by Resonant Dispersive Wave Emission

Marta Pini[1,2], Lorenzo Mai[1], Federico Cappenberg[1], Lorenzo Colaizzi[1], Federico Vismarra[1,2], Matteo Lucchini[1,2], Aurora Crego[2,3], Christian Brahms[4], John Travers[4], Rocío Borrego Varillas[2], Maurizio Reduzzi[1], Mauro Nisoli[1,2]

[1]Department of Physics, Politecnico di Milano, 20133 Milano, Italy
[2]Institute for Photonics and Nanotechnologies, IFN-CNR, 20133 Milano, Italy
[3]Grupo de Investigación en Aplicaciones del Láser y Fotónica, Departamento de Física Aplicada, Universidad de Salamanca, E-37008 Salamanca, Spain
[4]School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, EH14 4AS, United Kingdom

marta.pini@polimi.it

The generation of few-femtoseconds (fs) laser pulses in the Deep Ultraviolet (DUV) spectral region (200-300 nm) is crucial to study ultrafast electron dynamics in molecules with biological and opto-electronic interest, absorbing in the DUV [1]. Resonant Dispersive Wave (RDW) emission in gas-filled Hollow Capillary Fibers (HCF) is a novel efficient way to generate µJ-level DUV few-fs pulses, continuously tunable with gas pressure [2]. Their ultrashort time duration is essential for high temporal resolution pump-probe spectroscopy applications, but their large bandwidth in this challenging spectral region render their temporal characterization particularly demanding. We report on the direct temporal characterization of few-cycle DUV pulses generated by RDW emission in HCF, demonstrating near transform-limited (TL) pulses in the DUV.

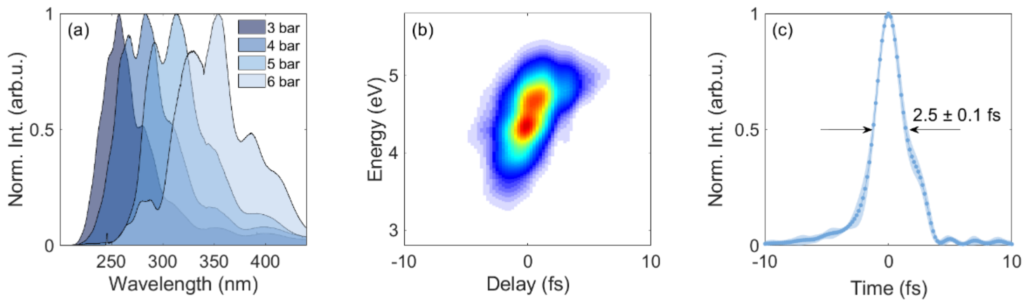

Figure 1: (a) Normalized measured RDW spectra as function of the gas pressure at fiber input. (b) Experimental SD-FROG trace of the pulse generated at 5 bar of Neon and (c) correspondent retrieved pulse temporal profile.

We developed an HCF setup for the RDW generation, working with a decreasing gas pressure gradient [3], directly connected to an all-in-vacuum Self-Diffraction FROG setup, to temporally measure the generated UV pulses without additional dispersion given by air propagation or through windows. RDW pulses tunable between 250 and 350 nm (Fig. 1(a)) were generated in a 150-µm diameter, 60-cm-long, Neon-filled HCF, driven by 10-fs input pulses at 800 nm. The driving pulse energy has been tuned to phase match RDW emission at different pressures, generating DUV pulses with measured energy exceeding 1 µJ and TL below 2 fs in the whole range. Fig. 1(b) shows the experimental spectrogram obtained at 5 bar input pressure: the retrieved [4] temporal duration is 2.5±0.1 fs (Fig. 1c)). Importantly, sub-3 fs pulse durations are measured in the entire range explored, confirming the existing results [5] on the temporal properties of RDW emission. The generated DUV pulses can be readily exploited for pump-probe experiments to investigate charge transfer and charge migration processes occurring in organic molecules on fs or sub-fs time domain.

References

[1] R. Borrego-Varillas, M. Lucchini, M. Nisoli, "Attosecond spectroscopy for the investigation of ultrafast dynamics in atomic, molecular and solid-state physic" Rep. Prog. Phys. 85, 066401 (2022)
[2] J.C. Travers, T.F. Grigorova, C. Brahms, Federico Belli ,"High-energy pulse self-compression and ultraviolet generation through soliton dynamics in hollow capillary fibres", Nat. Photonics 13, 547–554 (2019)
[3] C. Brahms, F. Belli, J.C. Travers, "Resonant dispersive wave emission in hollow capillary fibers filled with pressure gradients" Opt. Lett. 45, 4456-4459 (2020)
[4] E. Escoto, A. Tajalli, T. Nagy, and G. Steinmeyer, "Advanced phase retrieval for dispersion scan: a comparative study" J.Opt. Soc. Am. B 35, 8–19 (2018)
[5] C. Brahms, D. R. Austin, F. Tani, A. S. Johnson, D. Garratt, J. C. Travers, J. W. G. Tisch, P. St. J. Russell, J. P. Marangos, "Direct characterization of tuneable few-femtosecond dispersive-wave pulses in the deep UV," Opt. Lett. 44, 731-734 (2019)