Isolated Attosecond Pulse Generation Driven by Spatio-Temporal Pulse Reshaping in a Semi-infinite Gas Cell

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High-order Harmonic Generation (HHG) is a non-linear optical phenomenon in which an intense ($\approx 10^{14}$ W/cm^2) infrared (IR) laser pulse interacts with a noble gas target, resulting in a train of attosecond pulses in the eXtreme UltraViolet (XUV) spectral region. By implementing proper strategies and customized geometries, an Isolated Attosecond Pulse (IAP) can be generated. In this work, we demonstrate the generation of an IAP by spatio-temporal reshaping of few-cycle IR driving pulses within a semi-infinite gas cell. Through numerical simulations, we investigate the interplay between the spatio-temporal nonlinear reshaping of the driving field affecting the generation and the isolation of the attosecond pulses.

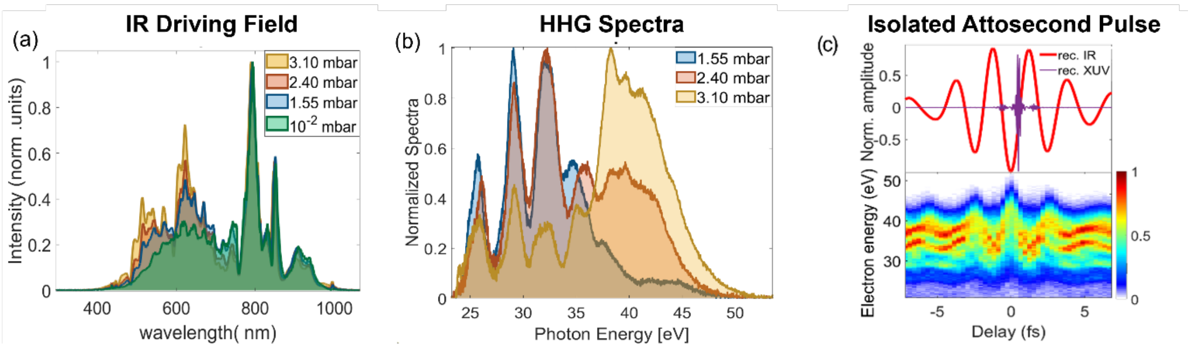

Figure 1: a) IR spectra driving pulse at the output of the cell as a function of different gas pressures. b) XUV spectra generated in Ar, same pressures as in (a). c) Lower panel: Streaking trace of the IAP at 3.1-mbar Ar pressure. Upper panel: reconstructed XUV and IR fields.

The experiments were performed using 3.8-fs driving pulses, centered at 730 nm, generated by the hollow-fiber compression technique, injected in a semi-infinite cell, filled with Argon [2,3]. Figures 1(a) and (b) show the spectra of the driving pulses transmitted by the semi-infinite cell at different Ar pressures and the corresponding HHG spectra. A clear correlation can be observed between the level of blue shifting and the spectral properties of the resulting XUV radiation: increasing gas pressure from 10^{-2} mbar to 3.10 mbar (green and yellow curves in Fig. 1(a), respectively), enhances the short-wavelength content the driving pulse spectrum. Simultaneously, the generated XUV spectrum becomes progressively more continuous, ultimately meeting the conditions necessary for the generation of an IAP (yellow line in Fig. 1(b)). To validate this phenomenon, we performed numerical simulations including nonlinear IR propagation and full quantum calculations of HHG emissions and propagation. Our results show the relevance of ionization around the beam focus and the spatio-temporal coupling in the HHG process. Temporal characterization of the XUV pulses, generated at 3.10 mbar in Ar, has been achieved by measuring the Streaking trace in an Ar gas target (Fig. 1(c), lower panel). Isolated pulses with a duration of 140±23 as were reconstructed (Fig. 1(c), upper panel). These results highlight the role of spatio-temporal reshaping in HHG, providing insights for the development of more robust techniques for the generation of IAPs.

References

[1] R. Borrego-Varillas et al 2022 Rep. Prog. Phys. 85 066401
[2] A. von Conta, et. Al 2016 Rev. Sci. Instrum. 87, 073102
[3] J. R. Sutherland et al. 2004 Opt. Express, 12, 4430-4436