Experimental demonstration of a high-flux capillary based XUV source in the high ionisation regime

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Summary

High harmonic generation (HHG) has proven to be a fascinating and incredibly useful nonlinear optical phenomenon and has led to the realisation of tabletop sources of coherent extreme ultraviolet (XUV) radiation. Capillary based geometries in particular have attracted a great deal of attention due to their lengthy interaction regions and the potential to phase-match the HHG process leading to a large increase in XUV flux. Unfortunately due to plasma induced nonlinear and dispersive effects the simple phase-matching mechanism detailed in [1] cannot be scaled to high energy pump pulses and high gas pressures. In this work we have used a computational model [2] to design a capillary that can support a broad interaction region well-suited to quasi-phase-matching (QPM) while simultaneously reducing the effect that XUV reabsorption has on the output flux of the source. This modelling work has involved adjusting both the capillary length and gas density profile (figure 1a) in order to produce rapid oscillations in the radially integrated ionization fraction (figure 1b) coupled with a rapid decrease in gas pressure at the capillary exit. Our theory suggests that these oscillations are driven by a nonlinear self-compression process modulating the intensity of the pump pulse as it propagates through the plasma-filled waveguide [3]. Subsequent experimental work has shown an increase in XUV flux of almost 50 times over our previous capillary-based source (see figure 1c), and preliminary estimates suggest a photon flux of 10^{12} photons s^{-1} $harmonic^{-1}$ in the 45 eV spectral region.

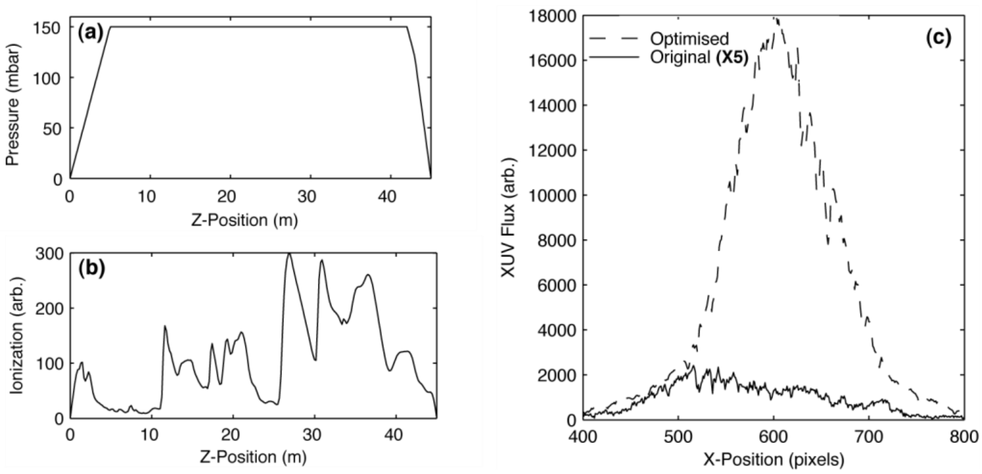

Fig. 1. The (simulated) pressure (a) and radially integrated ionization profiles (b) supported by our new capillary. (c) The cross-section of the XUV beam measured at the output of our optimized (dotted line) and original (solid line) capillary based sources for a peak Argon pressure of 150 mbar. Note that the cross-section data for the original source has been multiplied by a factor of five.

References

[1] A. Rundquist, C. Durfee, Z. Chang, C. Herne, S. Backus, M. Murnane, H. Kapteyn, “Phase-Matched Generation of Coherent Soft X-Rays,” Science **280**, 1412 (1998)
[2] R. T. Chapman, T. J. Butcher, P. Horak, F. Poletti, J. G. Frey, W. S. Brocklesby, “Modal effects on pump-pulse propagation in an Ar-filled capillary” Optics Express **18**, 13279 (2010)
[3] N. L.Wagner, E. A. Gibson, T. Popmintchev, I. P. Christov, M. Murnane, H. C. Kapteyn, “Self-Compression of Ultrashort Pulses through Ionization-Induced Spatiotemporal Reshaping” PRL 93(**17**) (2004)