High harmonic generation in gas-filled photonic crystal fibers

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High harmonic generation (HHG) is a promising tabletop source of coherent short wavelength radiation, with applications spanning science and engineering [1]. However, the low conversion efficiency and low average power of conventional few-kHz near-infrared (NIR) driving lasers limits the photon flux of such sources. Scaling this technique to MHz driving lasers requires strong focusing due to the limited pulse energy, and as a result the interaction volume is greatly reduced. It has been shown that this may be mitigated by restricting HHG to a photonic crystal fiber (PCF) [2, 3]. Here, we explore HHG in the latest generation of negative curvature PCFs [4] and achieve the highest photon energies to date.

Our experiment is shown in Fig. 1b. Here, 30 fs pulses from a high energy Ti:Sa laser system, operating at a 1 kHz repetition rate are attenuated, spatially filtered and launched into a 10.5 mm long section of a PCF with a 22.5 µm core diameter. The PCF is mounted between two chambers. The first of these is filled with 800 mbar of gas, and high-vacuum is maintained throughout the second. The extreme ultraviolet (XUV) output of the PCF is analyzed using a flat field XUV spectrometer. Additionally, a fiber coupled NIR spectrometer is used to characterize the residual driving laser. In argon we observe HHG at launched pulse energies of approximately 5 µJ. Using neon this threshold shifts to 10µJ, and increasing the pulse energy to 15 µJ yields harmonics with energies up to 66 eV (43rd harmonic order, Fig. 1a). These are, to our knowledge the highest photon energies recorded from a PCF to date. In addition, we have observed ionization-induced reshaping of the driving laser as it passes through the PCF. The fundamental spectrum of the driving laser at the output of an argon-filled PCF is shown in Fig. 1d for a range of pulse energies. When the XUV output is analyzed under identical conditions (Fig. 1c) this behavior is shown to map onto the harmonic spectrum, towards a continuum like regime. We believe this mechanism may lead to the realization of compact, high average power sources of XUV supercontinuum.

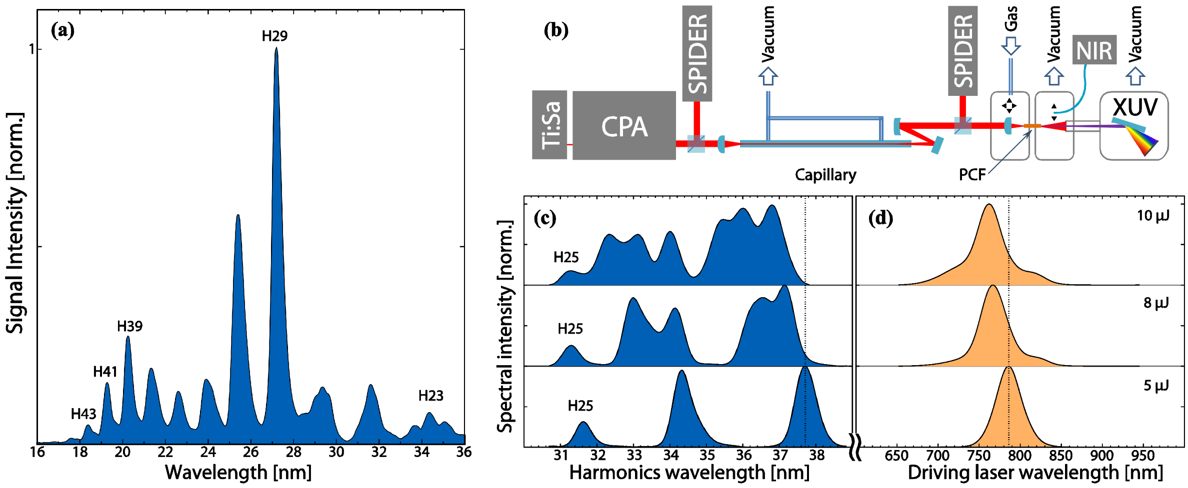

Fig. 1. (a) Harmonic spectrum from a neon-filled PCF driven by 15 µJ pulses. (b) Optical setup. Ti:Sa oscillator; CPA, chirped pulse amplifier; SPIDER, spectral phase interferometry for direct electric-field reconstruction; PCF, photonic crystal fiber; NIR, near-infrared spectrometer; XUV, extreme ultraviolet spectrometer. (c) Harmonic spectrum from an argon-filled PCF at a range of pulse energies. (d) The corresponding fundamental spectrum.

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