XUV generation with MPC and OPCPA drivers

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Bio:

Bastian Manschwetus received his Ph. D in physics at the Max Born Institute in Berlin (Germany) in 2010 in the field of atomic and molecular ionization dynamics in strong laser fields. From 2010 to 2015 he first worked with Pascal Salières at CEA Saclay and then with Per Johnsson and Anne L'Huillier at Lund University on development and applications of high harmonic generation sources and attosecond physics. In 2015 he became beamline scientist at the free electron laser FLASH in Hamburg, supporting the user operation at the facility. 2022 he moved to industry when he joined Class 5 Photonics, where he is responsible for the Moonlander HHG sources and EUV / Soft X-ray product portfolio.

Short abstract:

We measured the spectral flux of the Class 5 Moonlander high harmonic source for two driver systems using similar pulse parameters but different central wavelength: a solid state multipass cell compressed Yb laser and an optical parametric amplifier system.

Both laser systems provide 17 W average power at 100 kHz repetition rate at similar pulse durations, 29 fs vs 20 fs FWHM. Main difference is the central wavelength of 1030 nm for the MPC system versus the OPCPA system with a central wavelength of 800 nm. We performed high harmonic generation in with both laser systems in Argon and Krypton gas media producing broad band XUV radiation ranging from 20 to 60 eV photon energy. Using a spectrometer and an XUV diode the spectral photon flux after filtering was determined. For both systems we could reach state of the art performance with photon flux of 10^11 photons/s/eV to 10^13 photons/s/eV after filtering at the output of the light source.

We will discuss the advantages and disadvantages of the different drivers for the high harmonic generation.

Long abstract:

We performed high harmonic generation in with both laser systems in Argon and Krypton gas media producing broad band XUV radiation ranging from 20 to 60 eV photon energy. Using a spectrometer and an XUV diode the spectral photon flux after filtering was determined reaching state of the art performance of up to 60 µW total output flux of the Moonlander light source.

In the recent years, multipass cell compression of industrial ytterbium-based pico- and femtosecond lasers has become popular for the generation of ultrashort laser pulses with pulse durations below 50 fs [1], complementing the widely used Ti:sapphire laser systems or high power optical parametric chirped-pulse amplifiers (OPCPAs). One application of these ultrashort laser systems is the coherent upconversion of the near-infrared pulses to extreme ultraviolet (XUV) pulses by high harmonic generation (HHG) in noble gases [2] for gas phase and condensed matter spectroscopy as well as nanoscale imaging.

In this contribution we compare the high harmonic generation process for two different driver systems, using either a solid-state based multipass cell compression of an Yb:YAG laser system providing 17W at 100 kHz with a pulse duration of 29 fs (8 optical cycles), and a white-light seeded OPCPA system providing 17W at 100 kHz with a pulse duration of 20 fs (7 optical cycles), see Figure 1.

The laser pulses are coupled into a high harmonic generation system and focused onto a glass capillary connected to a noble gas supply, either argon or krypton for this experiment. When the high intensity pulses travel through the target gas XUV radiation is produced. Behind the focus inside capillary the driver beam diverges much stronger than the XUV beam, so the main part of the near-infrared (IR) beam can be blocked by a water-cooled beam dump. The remaining IR radiation on axis is blocked by a 200 nm thin aluminium metal foil, which has a transmission of 40-60% in the XUV spectral range from 20 to 78 eV. We use a calibrated XUV photodiode to measure the total generated XUV photon flux behind the Al filter. An XUV spectrometer is used to measure the spectral intensity of the generated XUV radiation. From the measured total flux and spectral intensity, we calculate the generated spectral flux. The target gas pressure, focal position and driver power were experimentally adjusted to optimize the measured flux and to achieve the highest photon energy. Total XUV flux measured for argon target gas behind the aluminium filter was 19 µW for the OPCPA system and 1.4 µW for the MPC system. For the krypton target we measured 61 µW for the OPCPA system and 2.8 µW for the MPC system. The brightest harmonics measured have photon flux of 2 x 10^{12} Ph/s/eV at 38.7 eV (OPCPA) and 1 x 10^{11} Ph/s/eV at 42 eV (MPC) in argon and photon flux of 7 x 10^{12} Ph/s/eV at 32.5 eV (OPCPA) and 2 x 10^{11} Ph/s/eV at 39.5 eV (MPC) in krypton.

The high harmonic generation process has a strong dependence on the driver wavelength, which originates from the electron wave packet propagation in the electric field of the laser pulse during the process. For the highest generated photon energy, the spectral cut-off scales with $\sim\lambda^2$, due to the highest energy the electron can gain during the sinusoidal electric field. Therefore, longer wavelength drivers are beneficial to reach high photon energies. The conversion efficiency on the other hand drops with $\sim\lambda^{5.5}$ due to the electron wavepacket diffusion occurring in the longer propagation at longer wavelengths [8].Thus, we expect an extension of the highest photon energy by a factor of 1.6 and simultaneously a drop of the conversion efficiency by a factor of 4 for the 1030 nm central wavelength of the MPC system compared to the OPCPA system with its central wavelength of 800 nm. Experimentally we could observe the higher cutoff for the MPC driver but the measured extension is only a factor of 1.1. The measured spectral flux within the Al filter transmission window drops strongly by a factor of 13 for argon and by a factor of 20 for krypton. The discussed scaling laws are derived from the electron wave packet dynamics, and therefore neglect phase matching effects in the gas medium or experimental conditions as non-perfect gaussian pulses.

These first measurements indicate that the used OPCPA driver provides highest conversion efficiency at lower photon energies compared to the used MPC driver. But on the other hand, the MPC driver system is significantly less complex, more cost effective and a more compact system.These first measurements indicate that the used OPCPA driver provides highest conversion efficiency at lower photon energies compared to the used MPC driver. But on the other hand, the MPC driver system is significantly less complex, more cost effective and a more compact system.

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