Canadian Association of Physicists
Association canadienne des physiciens et physiciennes

Contribution ID: **293** Type: **Oral not-in-competition (Graduate Student) / Orale non-compétitive (Étudiant(e) du 2e ou 3e cycle)**

Multidimensional Raman Solitons as Drivers of the High Harmonic Generation Process

Monday, 7 June 2021 16:08 (4 minutes)

High harmonic generation (HHG) in gasses has become a method of choice among table-top extreme ultraviolet (XUV) sources. In order to generate higher photon energies from this process, many strategies can be implemented, including red-shifting and compressing the driver pulses. Here, we propose a new approach for inducing a red-shift to driver pulses and compressing them to few-cycle durations in a single stage. This method uses the recently discovered multidimensional solitary states (MDSS) pulses that result from the nonlinear Raman process in gas-filled hollow-core fibers. It has a few key advantages: 1) MDSS are created from relatively long pulses, making this method suitable for any laser source offering sub-picosecond pulses. 2) The MDSS pulses can be compressed by simple propagation through glass. 3) In contrast with commonly-used optical parametric amplifiers, the induced red-shift can be modest, allowing to reach a target XUV photon energy while minimizing the detrimental effects of long driver wavelengths on HHG efficiency.
To produce MDSS pulses, the output pulses of a Titanium-Sapphire system are stretched to 400 fs and coupled to a hollow-core fiber filled with nitrogen. In the fiber, intermodal nonlinear processes occur which lead to the red-shifted MDSS pulses. Then, CaF2 plates inserted into the beam path compress the pulses down to 12 fs and these are sent to an argon-filled cell where HHG occurs. From this simple apparatus, the HHG spectrum is expanded to cover the $M_{2,3}$ edge of cobalt and 10^9 photons/second are generated at 60 eV. This significant XUV photon flux allows for the implementation of X-ray resonant magnetic scattering measurements on a cobalt/platinum ferromagnet, an example of photon-hungry application. Although such flux has previously been generated in a different gas from the direct output of the same laser system, the conversion efficiency of our approach is one order of magnitude higher as it allows to reach the target photon energy by generating harmonics in argon, a gas that offers a large generation efficiency. Due to its simplicity and versatility, our approach can readily be adapted to different applications and could be particularly interesting for high power Ytterbium laser systems offering sub-picosecond pulses.

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Session Classification: M3-1 Nonlinear and Quantum Optics (DAMOPC) / Optique non linéaire et optique quantique (DPAMPC)

Track Classification: Atomic, Molecular and Optical Physics, Canada / Physique atomique, moléculaire et photonique, Canada (DAMOPC-DPAMPC)