PhD Thesis Defense STEPHAN TEICHMANN 'Ponderomotively Scaled High Harmonics Generation for Attoscience in the Water Window'

STEPHAN TEICHMANN

July 24, 2015

Friday, July 24, 14:30. ICFO Auditorium

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Attoscience and Ultrafast Optics

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During the past two decades, high-order harmonic generation (HHG) has benn established as the primary source for table-top radiation in the extreme ultraviolet (XUV). Considerable progress in the physics of atomic and molecular physics could be achieved with HHG, owing to its excellent coherence properties and attosecond time structure. In this thesis we present our efforts to efficiently extend the generated photon energies to the soft X-ray spectral region (beyond 120 eV) while maintaining the capability of generating isolated attosecond pulses.

We report on two experiments with the practical target geometry of a semiinfinite gas cell (SIGC) using typical femtosecond pulses at 800 nm. A typical high harmonic spectrum is presented and the generated photon flux estimated based on a measurement with an XUV photo diode. In the second study, one harmonic order exhibits an interesting far-field structure in the spectral-spatial domain. Based on a phase matching analysis, we attribute the harmonic shape to quantum path interference in the exit plane of the SIGC.

The attosecond Beamline at ICFO is introduced as the main experimental apparatus for the thesis work and high harmonic spectra generated in argon and neon at different target pressures are analysed with respect to phase matching conditions. In order to extend the characterisation of the high harmonics to the temporal domain, we employ the technique of Reconstruction of attosecond harmonic beating by interference of two-photon transitions (RABBITT) which allows for an estimation of the average pulse
duration of our attosecond pulse trains generated with multi-cycle pulses at 800 nm.
We discuss the phase matching requirements to efficiently extend the generated photon energies to the water window spectral range between 284 eV and 543 eV with driving wavelengths longer than 800 nm, i.e. by ponderomotive scaling. Experimentally, the fundamental wavelength is increased to 2.1 m in an optical parametric amplifier, resulting i
photon energies of up to ~560 eV by implementation of multi-atmosphere HHG gas targets
Exploiting a reliable pulse compression scheme at 1.85 m, we then generate water wind
w high harmonics with few-cycle pulses with a record photon flu
. Three measurements are presented with the water window HHG source: One of the first ev
r water window X-ray absorption near-edge structure experiments with a HHG source
s demonstrated on the carbon and nitrogen K-edges of a thin film of boron subphthalocyani
e chloride. For the other two experiments, the carrier-envelope phase (CEP) of the few-cyc
e laser pulses is controlled, facilitating the detection of half-cycle cutoff (HCO) traces. Wi
h neon as the generation gas and recording HCO traces at different target pressures, we c
n identify a CEP-slip inside the gas target, induced predominantly by free electrons. H
O traces generated in helium are reproduced well with three-dimensional numerical simulatio
s which suggest that attosecond pulses isolated at ~500 eV can be produced with our source.

HCOs generated in neon are the basis for a parameter estimation of a pulse duration measurement of attosecond pulses centred at 350 eV. Using the experimentally determined photon flux and the parameters of a realistic probe field, a possible configuration of a measurement is presented and a FROG-CRAB trace is calculated. Lastly, recent developments of laser sources are summarised with respect to their possible impact on future progress of water window high harmonic sources.

We also present the results of a project in which the transition from multiphoton to field ionisation of a gold surface with mid-IR femtosecond pulses is analysed. By exploiting surface plasmon excitation at 3.1   m, we show that the tunnelling regime can be accessed a unprecedentedly low focuse

intensities.

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