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Extreme Photonics Seminar

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Title : Mirrorless focusing of High Order Harmonics by XUV Wavefront Control

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A major goal in attoscience is to perform XUV/XUV pump/probe experiments to investigate attosecond-few femtosecond dynamics in molecules. A limited number of such experiments have been performed so far [1, 2] since it requires high enough XUV intensities isolated (or train with few) attosecond pulse(s) which is still challenging to achieve. The most suitable process to produce attosecond XUV pulses is high-order-harmonic generation in gases. Maximizing the XUV intensity depends not only on optimizing the XUV energy but also on simultaneously obtaining XUV spatial properties compatible with a tight focus.

Nevertheless, spatial properties of high-order harmonics appear more complex than previously considered [3, 4]. Moreover, even if harmonics can be produced in smoothed XUV beams with a high degree of spatial coherence, their divergence and their effective source waist position may substantially vary with the harmonic order [5]. Then as those harmonics produced over a broad bandwidth are focused it result in distinct foci, thus limiting the intensity and introducing spatio-temporal couplings. The understanding and the control of the spatial properties are then crucial for attosecond science.

Here we study, the impact of the macroscopic conditions of High-Order-Harmonic generation on the XUV beam wavefront and spatial profiles. As compared to previous studies, they are realized with a TW class laser system and a relatively long focal focusing mirror suitable for high XUV yield generation. Also, in contrast with other optimization strategies, we chose to use a thin gas jet and to move it to several Rayleigh ranges away from focus in order to increase the generating volume. This can be made while preserving XUV good spatial properties providing a high spatial mode quality of the generating laser is maintained far from focus. This is achieved by both spatial filtering and wavefront correction of the ECLIPSE Ti: Sapph. 10 HZ, 200 mJ, 40 fs laser at CELIA. But most importantly, moving the gas jet on both side of the focus allows us to finely control the divergence of the XUV beam. In contrast to current understanding, we demonstrate that harmonics can be generated in converging beams. We study how the converging properties vary with the harmonic order and the gas jet position. A simple Gaussian model developed to infer the XUV beam properties nicely reproduces the observed behavior. It shows that under specific conditions harmonics can be self-focused well after the IR focus and that the harmonic foci of successive orders can be separated by several XUV Rayleigh lengths.

Our studies opened up new perspectives. On one hand, the foci shift can be used to spectrally select several harmonics by locating a pinhole near the harmonic foci and tune the selected harmonic range by adjusting the generating condition. At the opposite, using tailored fundamental beams should enable mirrorless focusing with close foci over a large XUV spectral range compatible with broadband intense XUV irradiation as required for non-linear XUV attosecond science.

References :

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