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高次高調波を用いたコヒーレントな水の窓 X 線の発生

Generation of coherent water window X-rays using high-order harmonics

Objectives

超短パルスレーザーを希ガス媒質に集光照射して得られる高次高調波は、テーブルトップサイズの新しいコヒーレント軟 X 線光源として注目されている．我々は高次高調波を高効率で発生させ，且つ短波長化する研究に取り組んでいる．具体的には水の窓と呼ばれる生体イメージングに有用な波長域(0.28 - 0.54 keV)の高次高調波光源を実現し，さらに新しい励起レーザー光源を開発することで，その高出力化を目指している．

Achievements

励起光に赤外波長域の超短パルスレーザーを用い，中性媒質ガスによる分散で位相整合条件を実現する事で，水の窓域において高効率で高調波発生を行う手法の開発に成功した．開発した発生手法は，レーザー光から X 線への変換効率を従来法と比較して 100 倍以上も改善し，かつ高品質な X 線ビームを得ることができる．さらに本手法は高い変換効率を保ったまま，高調波の出力エネルギーを増加できるといった優れた特徴を持つ．

High-order harmonic generation (HHG) using an ultrashort high-peak power laser pulse is a powerful method for the generation of extreme-ultraviolet and soft X-ray light. We are researching the efficient generation of HHG with the aim of generating coherent water window soft X-rays (0.28 – 0.54 keV), which are attractive for high-contrast biological imaging. In addition, we are developing a high-power IR laser system in order to perform energy scaling of water window harmonic beams.

We have demonstrated the generation of coherent water window X-rays by extending the plateau region of high-order harmonics under neutral-medium conditions. Our proposed procedure for generating water window X-rays is efficient and scalable in output yield. By using our concept, we successfully obtained high conversion efficiency and good beam quality of harmonic beams in the water window. We believe that the method presented here paves the way for the generation and application of intense ultrafast coherent water window X-rays.

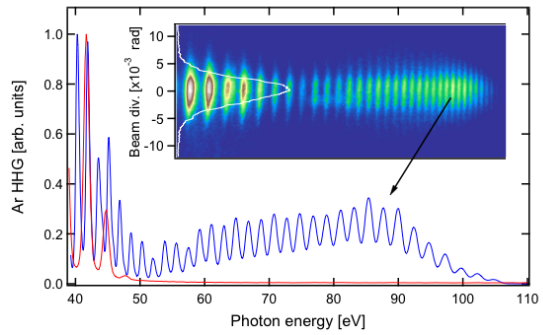

Fig.1: Experimentally obtained harmonic spectra in Ar. The red and blue profiles depict the spectra using a 0.8 μm pump and 1.4 μm pump, respectively. The inset shows an image of the measured two dimensional harmonic spectrum driven by the 1.4 μm pump.

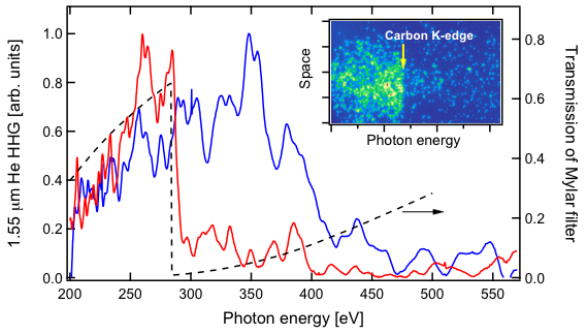

Fig.2: Measured He harmonic spectra driven by a 1.55 um pulse with a focused intensity of 5.5 x 10^{14} W/cm^2. The red line and the blue line correspond to the spectra with and without a 1-um-thick Mylar filter ($C_{10}H_8O_4$), respectively. The inset depicts a 2D HH spectrum image with a Mylar filter placed in front of the MCP.

References

1) E. J. Takahashi *et al.*, “10-mJ class femtosecond optical parametric amplifier for generating soft x-ray harmonics” Appl. Phys. Lett. 93, 041111 (2008).
2) E. J. Takahashi *et al.*, “Coherent water window x ray by phase-matched high-order harmonic generation in neutral media” Phys. Rev. Lett. 101, 253901 (2008).