【Grant-in-Aid for Scientific Research (S)】

Broad Section D

Title of Project： Attosecond Science in the sub-keV region

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Research Project Number：19H05628　Researcher Number：40166070
Keyword：Quantum Electronics, Attosecond Science, Ultrafast Optics, Nonlinear Optics, Laser Engineering

【Purpose and Background of the Research】

Attosecond science has carved out one important research branch of ultrafast optics for the last two decades. The success had given us many important knowledges for fundamental science of the interaction between electrons and photons. However, an output energy of isolated attosecond pulses above 100 eV is still not sufficient, though the pulse duration attained is sub-100 as. Thus, applications of attosecond pulses has been limited to a photon energy region of less than 100 eV and the extension of available photon energy of an isolated attosecond pulse to the sub-keV region is desired eagerly.

In this research, in order to bring a breakthrough in attosecond science, we will extend the cut-off wavelength of an isolated attosecond pulse to the sub-keV region and develop a novel method to control polarization of attosecond pulses by combining a high energy mid-infrared pulse source and a loose focusing method.

【Research Methods】

(1) Compression of high energy 3μm pulses
A 2.5 μm idler pulse generated with optical parametric amplifier (OPA) pumped by a fs Ti:S laser is introduced to a gas cell filled with rare gases to increase the bandwidth to 1.8 – 4.0 μm by self-phase modulation. This broadband pulse is used as a seed of dual-chirped pulse OPA (DC-OPA). Then, the chirp and pulse duration are adjusted with a AOPDF to suppress spectral narrowing during amplification. After the amplification, the 3 μm pulse is compress to a few cycle duration with a combination of bulk silica glasses and chip mirrors.
(2) Generation of sub-keV attosecond high harmonics
The continuum harmonics having a cutoff energy near keV is generated by focusing a few cycle 3 μm high energy pulse to a rare gas cell. Although generation efficiency of high harmonics is rapidly decreasing with increasing the pump wavelength, an efficiency of 10^{-7} is expected by compensating absorption loss and phase mismatch in the sub-keV region.
(3) Observation of sub-femtosecond structural dynamics by x-ray transient absorption spectroscopy
A 50 nm thick graphite on a Al thin film is irradiated with 25 fs Ti:S pulses to induce its structural change. Then, ultrafast transient x-ray absorption spectrum is measured to obtain an information of the rearrangement of C atoms with attosecond harmonics covering the C K-edge to 700 eV.
(4) Generation of circularly polarized high harmonics
Novel two-stage co-axial pumping geometry which can generate circularly polarized high harmonics is investigated. The polarization of high harmonics is arbitrary controlled by precisely adjusting the delay between two orthogonally polarized harmonics with linear polarization which are generated two different position and propagated colinearly.

【Expected Research Achievements and Scientific Significance】

Since the demonstration of “water window” high harmonics generation by using fs 1.6 μm pulses, a pumping source of attosecond pulses is being changed to from a conventional 800 nm Ti:S laser to mid-infrared OPA. An intense attosecond pulse in the sub-keV region which is generated with DC-OPA developed in my laboratory will provide attosecond temporal resolution in x-ray absorption spectroscopy. Circularly polarized attosecond pulses also would revolutionize x-ray magnetic circular dichroism measurements. Those new attosecond pulse technologies are expected to bring the remarkable progress in materials and chemical science. Furthermore, the advent of fs high-energy mid-infrared lasers has a potential to explore the horizon of strong field physics as well as attosecond science.

【Publications Relevant to the Project】

・Y. Fu, K. Midorikawa, and E. J. Takahashi, “Towards a petawatt-class few cycle infrared laser system via dual-chirped optical parametric amplification,” Sci. Reports. 8, 7629 (2018).
・E. J. Takahashi, T. Kanai, K. L. Ishikawa, Y. Nabekawa, and K. Midorikawa, “Coherent water window x-ray by phase-matched high-order harmonics,” Phys. Rev. Lett. 101, 253901 (2008).

【Term of Project】FY2019-2023

【Budget Allocation】152,400 Thousand Yen

【Homepage Address and Other Contact Information】

https://rap.riken.jp/en/labs/eprg/asrt/