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

Broad Section D

Title of Project : Evolution of Attosecond Science by Next-generation Ultrashort-pulse Lasers

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Keyword : Attosecond science, Soft-X-ray spectroscopy, Ultrashort-pulse laser, Frequency conversion

【Purpose and Background of the Research】

The advancement of Ti:sapphire lasers in the past two decades has realized the generation of attosecond pulses, and opened a new field called "attosecond science." However, the limitations of Ti:sapphire lasers such as fixed laser wavelength and thermally-limited output power, is becoming a barrier to make further progress of attosecond science. In this project, we will develop intense ultrashort-pulse light sources of new generation, which consist of optical parametric chirped pulse amplifiers (OPCPAs) pumped by a high-average-power Yb-based solid-state laser. These novel light sources will transform attosecond science from the stage of proof-of-principle to a new optical technology that is applicable to a broad range of materials science. We aim to realize attosecond sources that cover vacuum ultraviolet (VUV), extreme ultraviolet (XUV), and soft-X-ray (SX) regions, with sufficient photon flux for ultrafast spectroscopy. We will also develop an attosecond beamline for advanced attosecond measurements.

【Research Methods】

There are two important scaling laws in attosecond pulse generation. With λ as a drive laser's wavelength, the cut-off photon energy of high harmonics is proportional to λ^2, while the conversion efficiency is proportional to $\lambda^{-(5\text{-}6)}$. Because of this trade-off, we will develop three OPCPA systems that are operated at different wavelength to cover the VUV, XUV, and SX regions. Advantages of the OPCPA over Ti:sapphire lasers are that (i) selection of nonlinear crystals and phase matching conditions allow us to design an ultrabroad parametric gain in various wavelength, and (ii) transparent nonlinear crystals are used as gain media that are free from thermal problems. We will also develop high-average-power Yb-based solid-stage lasers as a pump source for the OPCPAs. An attosecond beamline will also be developed to use high-photon-flux attosecond pulses for various advanced spectroscopy and imaging as shown in Fig. 1.

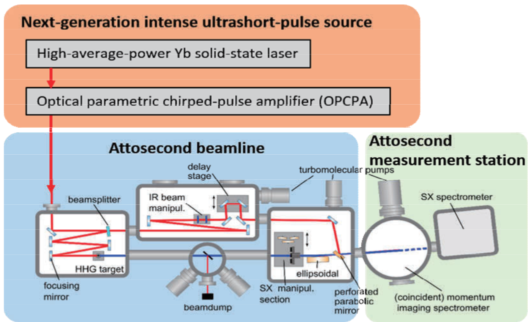

Figure 1 Schematic of an attosecond sources and an ultrafast measurement system.

【Expected Research Achievements and Scientific Significance】

We expect a significant increase of photon flux of attosecond pulses in VUV, XUV, and SX regions, which will enable a wide range of ultrafast spectroscopy of solids on the attosecond time scale. This will give us an opportunity to merge attosecond science and materials science, which leads to a new framework to understand the dynamics of non-equilibrium or highly-excited states of matters

【Publications Relevant to the Project】

N. Saito, N. Ishii, T. Kanai, S. Watanabe, and J. Itatani, "Attosecond streaking measurement of extreme ultraviolet pulses using a long-wavelength electric field," Scientific Reports, 6:35594, 1-5 (2016).

N. Ishii, K. Kaneshima, K. Kitano, T. Kanai, S. Watanabe, and J. Itatani, "Carrier-envelope phase-dependent high harmonic generation in the water window using few-cycle infrared pulses," Nature Commun. 5:3331, 1-6 (2014).

【Term of Project】 FY2018-2022

【Budget Allocation】 150,300 Thousand Yen

【Homepage Address and Other Contact Information】

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