【Grant-in-Aid for Scientific Research(S)】
Science and Engineering (Engineering Ⅰ)

Title of Project : Demonstration of ultrafast electron diffraction with fast electron pulse generated in plasma by intense femtosecond laser pulses

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Research Area : Eng., Applied Phys., Thin film/surface and interfacial physical properties
Keyword : Electron microscopy

【Purpose and Background of the Research】

As a technology to observe structural dynamics such as superfine state transition in matter directly in the temporal scale as short as vibration of a single atom (< several 100fs), time resolved electron diffraction (TRED) is promising. With the TRED phase transition in solid, transitional molecular structure in gas, and surface dynamics have been studied. However, the temporal resolution in the TRED experiments is not shorter than several ps up to now. To observe structural dynamics directly in femtosecond temporal resolution by electron diffraction, intense femtosecond electron pulses are absolutely necessary. In recent research the electron pulses are generated from a photo -cathode irradiated by a low power femtosecond laser. In this method electron pulses must be accelerated to several 100keV, which is suitable to electron diffraction in matter, in an external electric field, and during the acceleration the pulse expands much by space charge effect. By only one pulse in which the number of electrons is reduced to avoid pulse expansion due to the space charge effect, electron diffraction cannot be imaged and multiple pulses are required, consequently it is not available to the observation of irreversible phenomena.

Radiation emitted from plasma produced by an intense femetosecond laser pulse is in general featured by point, pulse, high bright -ness, and compactness. In this research, to avoid the space charge effect mentioned above, we use and control the electrons, which are accelerated instantaneously to several 100keV in plasmas by an intense femtosecond laser pulse light. The specification of electron source required for ultrafast electron diffraction (UED) is estimated to be several 100keV, shorter than several 100fs, and more than one million in number. The present laser accelerated electron pulse can image diffraction by a single pulse, which cannot be done by the conventional photocathode electron source.

Though it is known that high-energy electrons are generated from solid or gas irradiated by an intense femtosecond laser pulse, generation and control of high quality electron source of several 100keV suitable to UED is not studied in both foreign and domestic institutes. The purpose of the present research is generation and acceleration of high-energy (several 100keV), short pulse (<several 100fs), and intense (>1 million electrons) electron source by intense femtosecond laser pulse light, and demonstration of single pulse UED with temporal resolution as short as several 100fs.

【Research Methods】

With an intense femtosecond laser, high quality electron pulses are generated, controlled, and compressed. Short pulse light is irradiated in advance on an object sample, and with some delay the electron pulse is irradiated it on to see the dynamical change through the electron diffraction. We are aiming single shot UED. Major theme and methods are (1) high density electron source <- use of metal foil <- reduction of laser pre-pulse <- development of plasma mirror, (2) low emittance electron source <- use of isolated micro foil <- development of laser driven foil flying, (3) short pulse electron source <- self pulse compression by phase reversal, (4) construction of laser pump & electron probe system, (5) construction of UED system and demonstration of single shot UED. The team organized by professionals of laser, laser plasma physics, radiation science, electron microscopy, and crystal science perform the present research.

【Expected Research Achievements and Scientific Significance】

The present research is advanced in the world. The completeness of the UED will bring much innovation in the fields of material science and nano science. By the combination with advanced electron microscopy technologies, we can observe ultrafast phenomena under various environments. Additionally the research on interactions of intense femtosecond laser with isolated micro thin foil is available to other radiations, and will contribute on the development of the next generation radiation sources.

【Publications Relevant to the Project】

○S. Tokita, M. Hashida, S. Sakabe, *et al.*, "Single-Shot Femtosecond Electron Diffraction with Laser-Accelerated Electrons:Experimental Demonstration of Electron Pulse Compression," Physical Review Letters **105**, 215004(4) (2010).
○S. Tokita, M. Hashida, S. Sakabe, *et al.*, "Single -shot ultrafast electron diffraction with a laser-accelerated sub-MeV electron pulse," Applied Physics Letters, **95**, 111911(3) (2009).

【Term of Project】 FY2011-2015

【Budget Allocation】 129, 200 Thousand Yen

【Homepage Address and Other Contact Information】

http://laser.kuicr.kyoto-u.ac.jp