Advanced Research Center for Beam Science
- Laser Matter Interaction Science -

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Dr KOFLER, Heinrich	Vienna University of Technology, 2 February 2008
Prof SHIMIZU, Hirohiko	High Energy Accelerator Research Organization, 10 October 2008

Scope of Research

Recent remarkable progress of ultra-intense ultra-shot lasers has opened the new field of intense laser science. The interaction of femtosecond laser pulses with matters involves interesting physics, which does not appear in that of nanosecond laser pulses. Investigating the interaction physics, potential of intense femtosecond lasers for new applications is being developed (such as laser produced radiations and laser processing). Ultra-intense lasers can produce intense radiations (electrons, x-ray, ions, THz, and so on), which have the features of point, pulse, intense, compact, and perfect synchronized sources with different radiations. The radiations can be expected as the next-generation radiation sources. Ultra-short lasers are available to process any matters without thermal dissociation. The femtosecond laser processing of soft matter, molecules, nano-scale matter, and so on is also the next-generation laser processing. In our laboratory ultra intense femtosecond laser named T^6-laser is equipped, and the physics of intense laser matter interactions and its applications are researched.

Research Activities (Year 2008)

Publications

Hashida M, Sakabe S: Carbon Nanotubes Cathode Modified by Femtosecond Laser Ablation, *O pluse E*, **30**, 461-464 (2008) (in Japanese).

Tokita S, Hashida M, Masuno S, Namba S, Sakabe S: 0.3% Energy Stability, 100-Millijoule-Class, Ti:Sapphire Chirped-Pulse Eight-Pass Amplification System, *Optics Express*, **16**, 14875-14881 (2008).

Presentations

Femtosecond Laser Ablation of Carbon Nanotubes Cathode, Hashida M, Shimizu S, Sakabe S, 28th Annual Meeting of The Laser Society of Japan, Nagoya, 30 January 2008 (invited).

Sapphire-Conductive End-Cooling of High Power Cryogenic Yb:YAG Lasers, Tokita S, Kawanaka J, Fujita M, Kawashima T, Izawa Y, 28th Annual Meeting of The Laser Society of Japan, Nagoya, 31 January 2008 (invited).

Basic of Ultrashort Pulse Laser Material Processing, Hashida M, Laser Expo 2008, Yokohama, 25 April 2008 (invited).

Self-Organization of Periodic Grating Structure on Metal Surface by Femtosecond Laser Pulses, Sakabe S, Hashida M, Tokita S, Namba D, Okamuro K, 4th Asian Symposium on Intense Laser Science 2008, Gwangju, Korea, 5 November 2008 (invited).

Application of Femtosecond Laser Material Processing, Hashida M, The 11th Optical Science Seminar, Miyazaki, 21 November 2008 (invited).

Grants

Sakabe S, et al., Time Resolved Electron Microscope with Intense Femtosecond Laser Produced Electrons, Grant-in-Aid for Scientific Research (A), 1 April 2006–31 March 2010.

Femtosecond Laser Nano-ablation of Metal

Nano-ablation of copper has been demonstrated with an intense femtosecond laser. In order to investigate the mechanism of nano-ablation of metal, the emitted ions were measured by a time-of-flight mass spectrometer. For ion measurement the laser was irradiated with an incidence angle of 60° relative to the surface normal. The distance from the cupper sample to a MCP ion detector was 1.45 m and the pressure was maintained to ~3×10^{-7} Pa. By laser matter interactions, high-energy Cu^+ ions are emitted, which cannot be produced by thermal ablation of metal. The ion energy shows contribution of ion Coulomb explosion rather than that of thermal expansion to generate high energy ions.

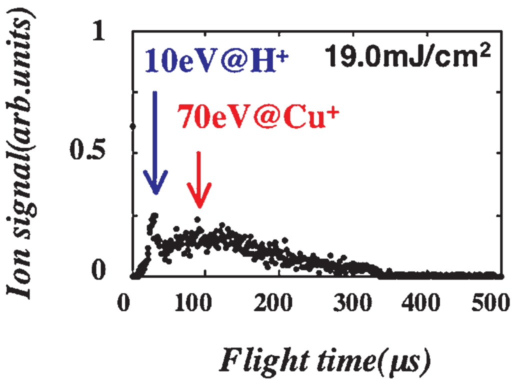

Figure 1. TOF spectrum of copper ablated by femtosecond laser (λ = 800 nm, τ = 130 fs, F = 19 mJ/cm^2, s-polarization).

A Novel Method for Ultrafast Time -Resolved Electron Diffraction

Observation of atomic motions on ultrafast time scales (less than 1 ps) is a very attractive approach to acquire new knowledge about the evolution of new phases in solids, the kinetic pathways of chemical reactions, and the biological functioning processes. The ultrafast electron diffraction (UED) with electrons field-emitted from a photocathode is a very promising method for the direct observation of non-equilibrium chemical structures at the atomic-level space and femtosecond time scales. This method, however, has an inevitable problem of broadening of the electron-pulse duration due to space-charge (Coulomb repulsion) effects. On the ground of this pulse broadening, the temporal resolution of the UED method is easily and seriously reduced when the number of electrons per pulse increases. Some proposals and experiments to overcome this problem have been recently introduced, but are not yet demonstrated or have significant defects. Our idea to solve this problem is to use laser acceleration of electrons in plasma. The laser acceleration provides an extremely strong acceleration field in plasma compared with electro-static or RF accelerations. This allows the space-charge effects to be minimized. We have started the development of this novel UED method and succeeded in the demonstration of getting the picture of electron diffraction patterns using the laser accelerated electron pulses (Figure 2). This achievement strongly indicates the high feasibility of the new present method.

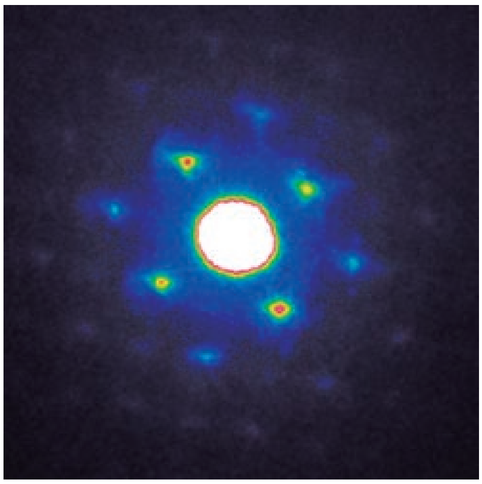

Figure 2. Electron diffraction pattern of a gold single crystal obtained using the laser accelerated electron pulses.

Hashida M, Advanced Material Processing with Femtosecond Lasers, Iketani Science and Technology Foundation, 20 July 2007–31 March 2008.

Hashida M, Improvement of Ablation Rate for Femtosecond Laser Processing, Amada Foundation for Metal Work Technology, 20 December 2007–31 March 2009.

Hashida M, Study on Mechanism of Metal Ablation by Short Pulse Laser, The Murata Science Foundation, 25 July 2008–31 March 2009.

Tokita S, Development of Mid-Infrared High-Power Ultrashort-Pulse Fiber Laser, Grant-in-Aid for Young Scientists (B), 1 April 2008–31 March 2010.

Tokita S, Development of Ultrafast Time-Resolved Electron Diffraction Method for Dynamic Structure Analysis in Femtosecond Time Scale, Iketani Science and Technology Foundation, 1 April 2008–31 March 2009.

Tokita S, Development of Mid-Infrared Femtosecond Fiber Laser using Fluoride Grass Fibers, Amada Foundation for Metal Work Technology, 15 December 2008–31 March 2010.