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

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Scope of Research

By making the physics of interaction between femto-second laser and matters clear, possibility for new applications is being developed in such as laser processing and laser nuclear science. The interaction of femto-second laser and matter differs from that of nanosecond laser in physics such as ionization and ablation process. Soft-ionization and ablation by the femto-second laser can be applied to mass spectrometry and nano-scale structural formation and matter reforming, respectively. In addition, with the progress of short pulse lasers, even a small-sized equipment can create ultra-high optical field. In this strong electromagnetic field the motion of an electron becomes relativistic, and the electron is accelerated easily above MeV, emitting high energy pulse x-ray and ions. Laser produced radiation has the feature such as impulse, a point source and high intensity, and its potential to the new radiation source is expected. In our laboratory physics of intense laser matter interactions and its application are researched.

Research Activities (Year 2006)

Presentations

High-average-power, High-efficient Operation of Q-switched Cryogenic Yb:YAG Laser, Tokita S, Kawanaka J, Fujita M, Kawashima T, Izawa Y, Advanced Solid-State Photonics 2006 (OSA), January, Nevada, USA.

High-energy Pico-second Regenerative Amplifier with Cryogenically Cooled Yb:YAG, Tokita S, Kawanaka J, Fujita M, Kawashima K, Izawa Y, The Conference on Lasers and Electro-Optics 2006 (IEEE and OSA), May, California, USA.

The Processing of Single Crystal Diamond by Ultra-short Pulse Laser, Harano K, Nakamae K, Toda N, Hashida M, Shimizu S, and Sakabe S, 4th International Congress on Laser Advanced Materials Processing, 16–19 May, Kyoto, Japan.

Nano-ablation with an Intense Femto-second Laser, Hashida M, Shimizu S, Sakabe S, Canada-Japan SRO-COAST Symposium on Ultrafast Intense Laser Science 1, 7–8 July, Tokyo, Japan.

Terahertz Radiation from Argon Gas Jet Excited with Intense Femto-second Laser Pulses, Nagashima N, Shibuya K, Hangyo M, Hashida M, Sakabe S, Joint 31st International Conference on Infrared and Millimeter Waves and 14th International Conference on Terahertz Electronics (IRMMW-THz2006), 18–22 September, Shanghai, China.

Femto-second Laser Ablation of Carbon-nanotube Cathode, Hashida M, Shimizu S, Sakabe S, 5th Asia Pacific Laser Symposium (APLS2006), 23–27 November, Guilin, China (Invited).

Intense Femto-second Laser-Cluster Interaction, Sakabe S, Hashida M, Shimizu S, Masuno S, 5th Asia Pacific Laser Symposium (APLS2006), 23–27 November, Guilin, China (Invited).

Terahertz Radiation from Argon Clusters Irradiated by Intense Femto-second Laser Pulses, Nagashima N, Shibuya K, Hangyo M, Hashida M, Sakabe S, 5th Asia Pacific Laser Symposium (APLS2006), 23–27 November, Guilin, China.

Grants

Sakabe S, Fundamental Research on γ-ray Laser with Intense Femto-second Lasers, Grant-in-Aid for Scientific Research (A), 1 April 2006–31 March 2009.

Hashida M, Advanced Material Processing with Femto-second Lasers, Grant-in-Aid for Young Scientists (B), 1 April 2005–31 March 2006.

Awards

Tokita S, The Best Oral Presentation Award: High-average-power, High-efficient Operation of Q-Switched Cryogenic Yb:YAG Laser, The Review of Laser Engi-

Skinning of Argon Clusters by Coulomb Explosion Induced with an Intense Femto-second Laser Pulse

The energy distributions of ions emitted from argon clusters Coulomb exploded at an intensity of < 10^{17} W/cm^2 with an intense femto-second laser have been experimentally studied. The power m of energy E of the ion energy distribution ($dN/dE \sim E^m$) is expected to be 1/2 for spherical ion clusters, but it is in fact reduced smaller than 1/2 as the laser intensity is decreased. This reduction can be well interpreted as resulting from the instantaneous ionization of the surface of the cluster. The validity of this interpretation was confirmed by experiments with double pulse irradiation. A cluster irradiated by the first pulse survives as a skinned cluster, and remaining core part is Coulomb exploded by the second pulse. It is shown that a cluster can be skinned by an intense short laser pulse, and the laser-intensity dependence of the skinned layer thickness can be reasonably explained by the laser-induced space charge field created in the cluster.

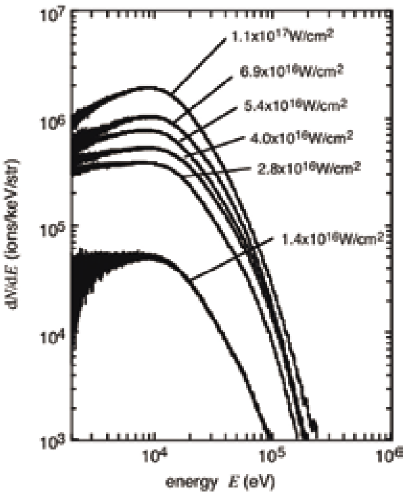
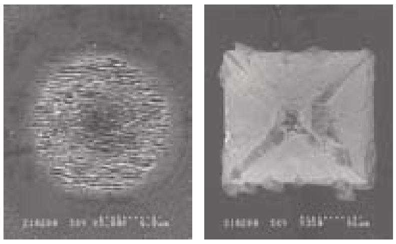


Figure 1. Energy distributions of Ar ions emitted from Coulomb-exploded Ar clusters, depending laser intensity. Backing pressure is 6 MPa.

Ultrashort Pulse Laser Ablation of Single Crystal Diamond

The laser ablation experiments on a single crystal diamond were carried out with a T6 laser (800 nm wavelength, 130 fs–400 ps pulse width). The ablation rate and the ablation threshold dependence on laser pulse width were investigated. The ablation threshold was found to be approximately proportional to pulse width to the power 0.34. It was suggested that the multi photon absorption was not predominated at this range of pulse width (166 fs–2 ps). The released ions upon the ablation process were studied by time-of-flight mass spectrometer (TOF-mass) with a 130 fs pulse laser. The TOF-mass spectra analysis revealed that the multi photon ionization is occurred, and the ablation mechanism are different at near the ionizing threshold energy from at the higher energy regime where thermal affect is predominant. These results indicate that the thermal effect is negligible at near the threshold energy, arising with laser energy at 130 fs laser ablation. The results of Raman spectra measurement suggested the possibility of the laser processing without thermal damage.



(a) 1.18ps, 0.97 J/cm^2 (b) 400ps, 0.7 J/cm^2

Figure 2. SEM photographs of diamond surface ablated by 1000 pulses.

Development of High-average-power Pico-second Lasers with Cryogenically-Cooled Yb:YAG Crystal

Compact picosecond lasers with high average power are in high demand for precision micromachining. Cryogenically-cooled Yb:YAG crystal is one of the promising laser materials for the high-average-power picosecond lasers, because the cryogenically cooling takes advantage of significant improvement of the crystal's thermal properties at low temperatures such as higher thermal conductivity, lower thermo-optic coefficient, and lower thermal expansion coefficient. We have developed a diode-pumped picosecond 8-pass amplifier with a liquid-nitrogen-cooled Yb:YAG crystal. An average output power of 23.7 W with a near-diffraction-limited beam quality was obtained at a pulse repetition rate of 80 kHz and a pulse duration of 11.7 ps. This is the highest average power, to the best of our knowledge, obtained by single-stage diode-pumped ultrafast amplifiers with pulse energies above multi-hundreds of micro-joules. Average powers above 20 W were also obtained in the 30–80 kHz repetition rate range. The pulse energy reached almost 1 mJ at the 20 kHz repetition rate.

neering, May 2006.

Tokita S, Encouragement Prize for Oral Presentation, Research, High-energy Pico-second Regenerative Amplifier with Cryogenically Cooled Yb:YAG, The Japan Society of Applied Physics, August 2006.