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

http://laser.kuicr.kyoto-u.ac.jp/e-index.html

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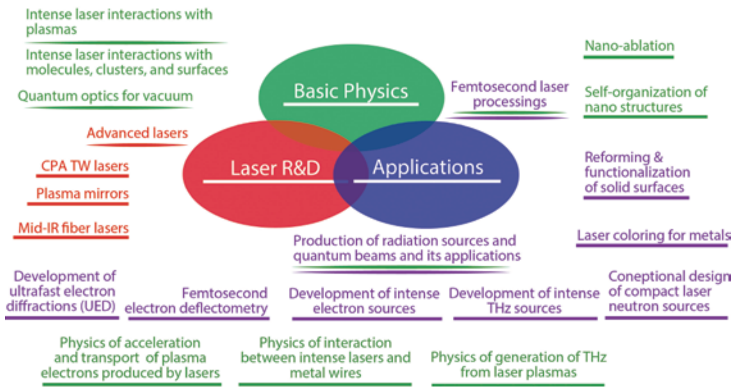
Scope of Research

The interaction of femtosecond laser pulses with matter involves interesting physics not seen with nanosecond laser pulses. Through investigation of the interaction physics, the potential of intense femtosecond lasers for new applications is being developed (e.g., laser-produced radiation and laser processing). Ultra-intense lasers can produce intense radiations (e.g., electrons, ions, and THz), which are promising as next-generation radiation sources. Ultra-short lasers can process any matter without thermal dissociation. Femtosecond laser processing is also the next-generation of laser processing. Our laboratory is equipped with an ultra-intense femtosecond laser named T6, to study the physics of intense laser–matter interactions and its applications.



KEYWORDS
Intense Laser Science
Laser Plasma Radiations (electrons, ions, and THz)
Ultrafast Electron Diffraction (UED)
Laser Nano-ablation Physics
Femtosecond Laser Processing

Selected Publications

Gouda, A. M.; Sakagami, H.; Ogata, T.; Hashida, M.; Sakabe, S., The Formation Mechanism of the Periodic Nanograting Structure by the Weibel Instability, *Appl. Phys. A*, **122,** 454-1-454-6 (2016).

Hashida, M.; Nishii, T.; Miyasaka, Y.; Sakagami, H.; Shimizu, M.; Inoue, S.; Sakabe, S., Orientation of Periodic Grating Structures Controlled by Double-pulse Irradiation, *Appl. Phys. A*, **122,** 484-1-484-5 (2016).

Furukawa, Y.; Sakata, R.; Konishi, K.; Ono, K.; Matsuoka, S.; Watanabe, K.; Inoue, S.; Hashida, M.; Sakabe, S., Demonstration of Periodic Nanostructure Formation with Less Ablation by Double-pulse Laser Irradiation on Titanium, *Appl. Phys. Lett.*, **108,** 264101(2016).

Hashida, M.; Nishii, T.; Miyasaka, Y.; Sakagami, H.; Shimizu, M.; Inoue, S.; Sakabe, S., Threshold Fluence for Femtosecond Laser Nanoablation for Metals, *Electr. Communi. Jpn*, **99,** 88-95 (2016).

Inoue, S.; Maeda, K.; Tokita, S.; Mori, K.; Teramoto, K.; Hashida, M.; Sakabe, S., Single Plasma Mirror Providing 104 Contrast Enhancement and 70% Reflectivity for Intense Femtosecond Lasers, *Appl. Opt.*, **55,** 5647-5651 (2016).

Highly Intensified Emission of the Laser Accelerated Fast Electrons by Using Solid-plasma Composite Target

Intense ultrashort electrons pulses are driven by the interaction of intense short laser pulses with solid targets. These laser-accelerated fast electrons have many possible applications such as fast ignition for inertial confinement fusion, ultrafast electron diffraction measurement, and ultrafast transient field measurement. For these applications using fast electrons as probe pulses with high temporal resolution, it is desirable for a greater number of electrons to be emitted from the laser plasma. However, most laser-accelerated electrons cannot escape from the laser plasma because they are trapped by a strong quasi-static electric field, called the sheath field, produced around the steep density gradient boundary between the solid/plasma and the vacuum. Almost all electrons are bound within the solid target, and only about 1% of the hot electrons can escape. Therefore, only a small fraction of electrons accelerated by intense short-pulse laser escapes from the laser plasma, and the most of electrons expend their energy heating the target or producing other types of radiation.

We demonstrate the intensification of electrons escaping from an intense laser plasma by using double femtosecond laser pulses. An intense pulse from a chirped pulse amplification laser (CPA1) for driving fast electrons is used to irradiate a foil target, the rear of which is pre-irradiated with another laser pulse (CPA2). Pre-irradiation with CPA2 controls the electron density distributions in the target to suppress sheath field growth and expand the target plasma into which the fast electrons are released. The number of escaping electrons increases greatly when the target is irradiated with CPA2 540 ps prior to CPA1. The number of electrons released is 7 times that for single pulse irradiation. These results are supported by two-dimensional (2D) particle-in-cell (PIC) simulations of plasma produced by CPA2 and analytical evaluation considering the expansion of the plasma.

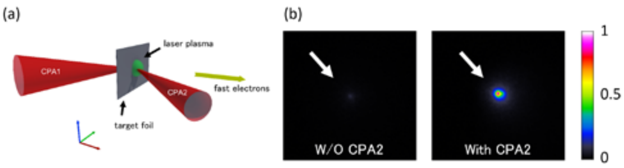


Figure 1. (a) schematic of the experimental setup. (b) Images of fast electrons emitted from laser plasma.

Threshold Fluence of Femtosecond Laser Nano-Ablation for Metals

Femtosecond laser nano-ablation of Ti by short-pulse laser irradiation (800 nm/40 fs) is studied in the laser fluence range of 0.07 – 0.5 J/cm^2. To determine the ablation threshold, the ablation rate dependence on laser fluence is precisely measured. Multi-shot ablation threshold of titanium is found to be 0.074 J/cm^2 in which value is good agreement with that reported previously by other group. To discuss the ablation mechanism, all the ablation thresholds for metals previously published are plotted as a function of work function and melting temperature. We found that the ablation thresholds correlated with work function of metals. Experimental data suggested that the femtosecond laser ablation is mainly due to multi-photon absorption and optical field ionization.

Reduction of Ablation Rate by Double-Pulse Laser Irradiation on Titanium

Reduction of ablation rate is demonstrated on a titanium surface irradiated by a double-pulse beam parallel-polarized at time delays from $\Delta t = 0.16 – 1280$ ps. The first-pulse fluence F_1 and the delayed pulse fluence F_2 are kept below or above the ablation threshold $F_{TH} \sim 100$ mJ/cm^2 of Ti. A pair of laser pulses with fluences of 70 and 140 mJ/cm^2 is used for ablation rate experiment. Figures 1 show the dependence of ablation rate on interval Δt for the fluences $(F_1, F_2) = (70, 140)$. The maximum and minimum ablation rates are 15.5 nm for $\Delta t = 0.16$ ps and 4.4 nm for $\Delta t = 80$ ps, respectively. The maximum is as much as that (17.1 nm) for a single pulse of 210 mJ/cm^2 ; the minimum (4.4 nm) is half of that for a 140 mJ/cm^2 single pulse. Thus, the first pulse modifies the surface to suppress ablation even if its fluence is below the ablation threshold. The experimental results suggest that the first pulse influences the surface, suppressing ablation by the following pulse even though no laser plasma is produced on the surface, and that this influence continues for rather a long time (several hundred picoseconds). Double-pulse irradiation certainly has significant potential for future applications of laser nano-processing.

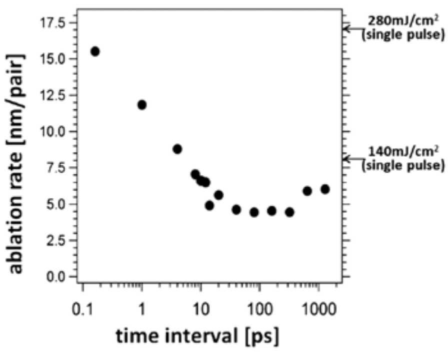


Figure 2. Dependence of ablation rate on time interval for fluences $(F_1, F_2) = (70,140)$.