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

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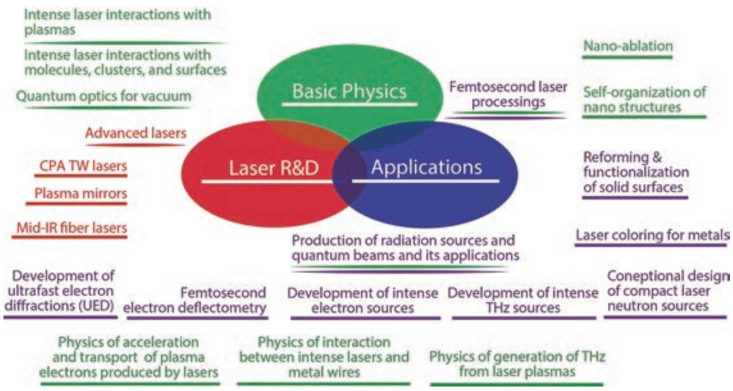
Scope of Research

The interaction of femtosecond laser pulses with matter involves interesting physics not seen with nanosecond laser pulses. Through investigations 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

Inoue, S.; Nakamiya, Y.; Teramoto, K.; Hashida, M.; Sakabe, S., Highly Intensified Emission of Laser-accelerated Electrons from a Foil Target through an Additional Rear Laser Plasma, *Phyiscal Review Accelerators and Beams*, **21,** 41302 (2018).
Teramoto, K.; Tokita, S.; Terao, T.; Inoue, S.; Yasuhara, R.; Nagashima, T.; Kojima, S.; Kawanaka, J.; Mori, K.; Hashida, M.; Sakabe, S., Half-Cycle Terahertz Surface Waves with MV/cm Field Strengths Generated on Metal Wires, *Appl. Phys. Lett.*, **113,** 51101 (2018).
Teramoto, K.; Inoue, S.; Tokita, S.; Yasuhara, R.; Nakamiya, Y.; Nagashima, T.; Mori, K.; Hashida, M.; Sakabe, S., Induction of Subterahertz Surface Waves on a Metal Wire by Intense Laser Interaction with a Foil, *Phys. Rev. E*, **97,** 23204 (2018).
Arikawa, Y.; Kato, Y.; Abe, Y.; Matsubara, S.; Kishimoto, H.; Nakajima, N.; Morace1, A.; Yogo, A.; Nishimura, H.; Nakai, M.; Fujioka, S.; Azechi, H.; Mima, K.; Inoue, S.; Nakamiya, Y.; Teramoto, K.; Hashida, M.; Sakabe, S., Efficient and Repetitive Neutron Generation by Double-laser-pulse Driven Photonuclear Reaction, *Plasma and Fusion Research*, **13,** 2404009 (2018).
Irizawa, A.; Suga, S.; Nagashima, T.; Higashiya, A.; Hashida, M.; Sakabe, S., Laser-induced Fine Structures on Silicon Exposed to THz-FEL, *Appl. Phys. Lett.*, **111,** 251602 (2017).

Ablation Suppression of Titanium Surface with Two Color Double-pulse Beam of Femtosecond Laser

An experiment of an ablation rate on a titanium surface irradiated by a double-pulse beam with two-color laser was demonstrated in time delays of Δt = 0–700 ps. The double pulse beam consists of 800 nm with 150 fs pulse and 400 nm with > 150 fs pulse. The fundamental-pulse fluence F_{800} is kept below ablation threshold ($F_{800\ th}$ = 0.108 J/cm^2) while the second harmonic pulse fluence F_{400} are kept above the ablation threshold ($F_{400\ th}$ = 0.090 J/cm^2). The ablation rate of titanium is clearly suppressed to 2.39 nm per pair at delay times of Δt = 200 ps. This ablation rate corresponds to one-third of 7.3 nm/pulse for only first pulse beam, while it corresponds to about one-half for one-color double pulse irradiation. We found that the ablation suppression with two-color double pulse beam was more enhanced than that for one-color double pulse beam. The shorting optical penetration length of the first pulse possibly related to suppression of the ablation rate.

Dot Coloring for Metal Surface by Femtosecond Laser Irradiation

Dot colorings to blue and brown have been demonstrated on the metal surface irradiated by the beam consisting of two-color femtosecond laser pulses with an appropriate time interval. Surface observation using an Electron Probe Micro Analyzer (EPMA) suggests that the dot coloring area is colored due to the formation of a uniform oxide layer on the irradiated area. The appropriate time interval for coloring is consistent with the time scale at which suppression of ablation by the double pulse irradiation is observed.

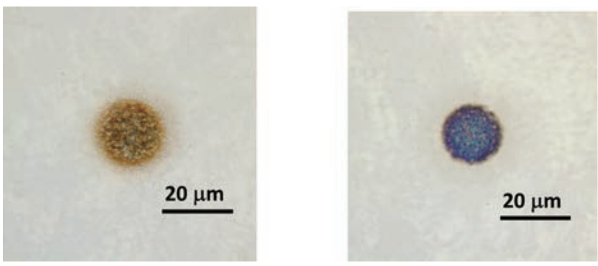


Figure 1. Double pulse irradiation (left) Brown, (right) Blue.

Highly Intensified Emission of Laser-accelerated Electrons from a Plasma-solid Hybrid Cathode

Intense ultrashort electron pulses are driven by the interaction of intense short laser pulses with solid targets. Ultrashort electron pulses are accelerated in the intense laser produced plasma. Laser-accelerated fast electrons have many possible applications, because of their higher absorptance of the laser pulse. For some applications, such as 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. Only a small fraction of electrons accelerated by intense short-pulse laser radiation escapes from the laser plasma, and most of the 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 escaping electrons with an energy of 380 keV released into vacuum 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. These results show that over 10% of the accelerated electrons will be converted to escaping electrons by controlling the expanding plasma. These results show that the intense laser-irradiated foil could be used as a plasma-attached cathode, with great potential for high-brightness electron guns.

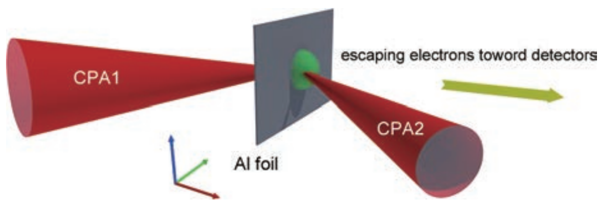


Figure 2. Schematic of the experimental setup. Two laser pulses (CPA1 and CPA2) are focused on the Al target (thickness: 11 μm).