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

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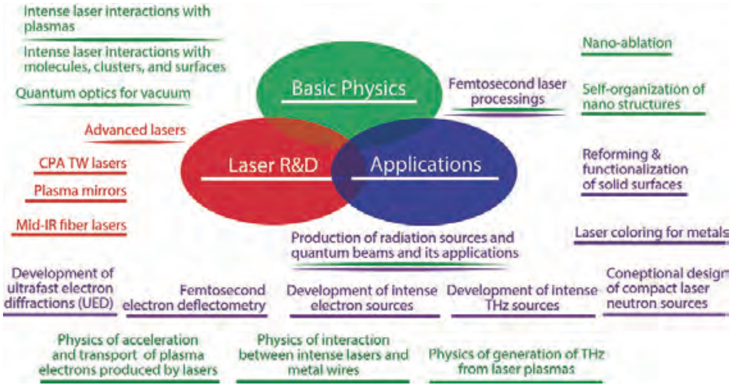
Scope of Research

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

Mori, K.; Hashida, M.; Nagashima, T.; Li, D.; Teramoto, K.; Nakamiya, Y.; Inoue, S.; Sakabe, S., Increased Energy of THz Waves from a Cluster Plasma by Optimizing Laser Pulse Duration, *AIP Advances*, **9,** [015134-1]-[015134-4] (2019).

Nishiura, Y.; Inoue, S.; Kojima, S.; Teramoto, K.; Furukawa, Y.; Hashida, M.; Sakabe, S., Detection of Alpha Particles from ^{7}Li(p, α)^{4}He and ^{19}F(p, α)^{16}O Reactions Induced by Laser-accelerated Protons Using CR-39 with Potassium Hydroxide–ethanol–water Etching Solution, *Rev. Sci. Instrum.*, **90,** 083307 (2019).

Takenaka, K.; Tsukamoto, M.; Hashida, M.; Masuno, S.; Sakagami, H.; Kusaba, M.; Sakabe, S.; Inoue, S.; Furukawa, Y.; Asai, S., Ablation Suppression of a Titanium Surface Interacting with a Two-color Double-pulse Femtosecond Laser Beam, *Appl. Surf. Sci.*, **478,** 882-886 (2019).

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, *Phys. Rev. Accel. Beams*, **21,** [041302-1]-[041302-6] (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,** 023204 (2018).

Development of Intense Terahertz Light Source for Forming Periodic Structures on Material Surface

When solid materials are irradiated with intense terahertz waves, periodic structures are formed on their surface. The inter space of these structures is about 1/20 of terahertz wavelength, and mechanism of structures formation has not been clarified yet. Getting clues of formation mechanism, we develop an intense terahertz light source to form structures and intend to observe the formation process by pump-probe method during a terahertz wave irradiation.

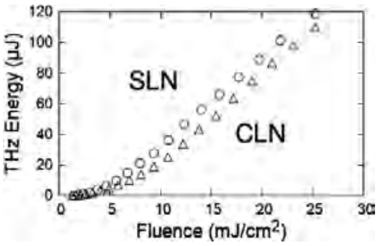


Figure 1. Terahertz energy dependence on laser fluence.

Uniform LIPSS on Titanium Irradiated by Two-color Double-pulse Beam of Femtosecond Laser

We produced the uniform LIPSS (Laser Induced Periodic Surface Structures) on titanium surfaces with using the use of two-color femtosecond double-pulse laser irradiation. The double-pulse beam consisted of 800 nm pulses with duration of 150 fs and 400 nm pulses with duration of > 150 fs. For double-pulse beam irradiation in which the laser fluence is close to the ablation threshold, it was found that the longer-wavelength laser pulse is responsible for LIPSS formation, while the shorter-wavelength laser pulse is responsible for improving LIPSS uniformity. Relatively uniform LIPSS characterized by the fundamental wavelength were obtained using a double-pulse beam with fluences of $1.5F_{400\ th} + 0.9F_{800\ th}$ and delay of Δt = 0–2 ps.

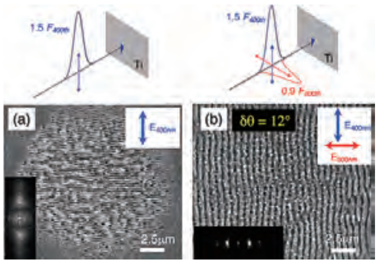


Figure 2. SEM images of titanium surfaces irradiated with (a) only the fundamental wavelength pulse with N = 60 pulses and (b) the two-color double-pulse beam with delay of Δt = 0 and N = 60 pairs of pulses. The LIPSS uniformity (δθ) shows the LIPSS characterized by the 800 nm pulse.

Detection of Alpha Particles from ^{7}Li(p,α)^{4}He and ^{19}F(p,α)^{16}O Reactions Induced by Laser-accelerated Protons Using CR-39 with PEW Etching Solution

With the development of high-intensity lasers in recent years, applied research on laser-accelerated ions has attracted considerable interest in fields where nuclear reactions are used or studied and in industrial applications. In studies of laser plasma and laser ion acceleration, electrostatic or magnetic ion analyzers such as the Thomson parabola spectrometer (TPS) are widely used to monitor the primary and secondary ions emitted from laser plasmas and nearby targets. The TPS is an effective instrument for measuring the energy spectra of laser plasma ions, but it has difficulty detecting small numbers of secondary ions, such as those generated by nuclear reactions with a small cross section, and this limitation is primarily attributable to the solid angle of the TPS entrance aperture from the ion source. Solid-state nuclear track detectors (SSNTDs) can be used to detect even a single ion and are insensitive to radiation other than ions. Furthermore, SSNTDs are easy to handle owing to their compact nature and can be cut into arbitrary sizes and shapes. These features of high sensitivity and easy handling allow for convenient measurements of high-intensity laser-produced ions with extremely large solid angles. However, SSNTDs exhibit high sensitivity for all ion species, making the fractionation of ion species a key issue for SSNTD. In particular, when CR-39 is used, one of the most popular SSNTD in laser plasma physics, the sensitivity must be controlled to be sufficiently high for the secondary ions and sufficiently low for the primary protons.

We have reported the control of the sensitivity of the CR-39 for radioactive particles, and the selectively detection of Alpha particles generated by ^{7}Li(p,α)^{4}He and ^{19}F(p,α)^{16}O reactions in the presence of abundant primary protons by reducing the proton sensitivity of CR-39 using potassium hydroxide–ethanol–water (PEW) etching solution. These nuclear reactions are induced in a LiF crystal using the laser-accelerated protons (4×10^{11} protons/pulse with a maximum energy of 3.3 MeV) generated and accelerated by the interaction of a 40-fs laser pulse with a polyethylene thin film target at a peak intensity of 5×10^{19} W/cm^2. Subsequent etching of the CR-39 in PEW solution (KOH: 17 wt %; C_2H_5OH: 25 wt %; H_2O: 58 wt %) permits the selective detection of 4.0 MeV alpha particles, which is independently confirmed by an experiment using alpha particles from an ^{241}Am source. The described method is expected to be useful for research into nuclear reactions in laser plasma.