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

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

Prof
SAKABE, Shuji
(D Eng)

Assoc Prof
HASHIDA, Masaki
(D Eng)

Assist Prof
INOUE, Shunsuke
(D Sc)

PD
HATA, Masayasu
(D Sc)

Students

MIYASAKA, Yasuhiro (D3)
IKEDA, Daiki (M2)
KAWAMOTO, Mao (M2)
MAEDA, Kazuya (M2)
MORI, Kazuaki (M2)
TERAMOTO, Kensuke (M1)
NAKASHIMA, Yuto (M1)
NISHII, Takaya (M1)

Visiting Researcher

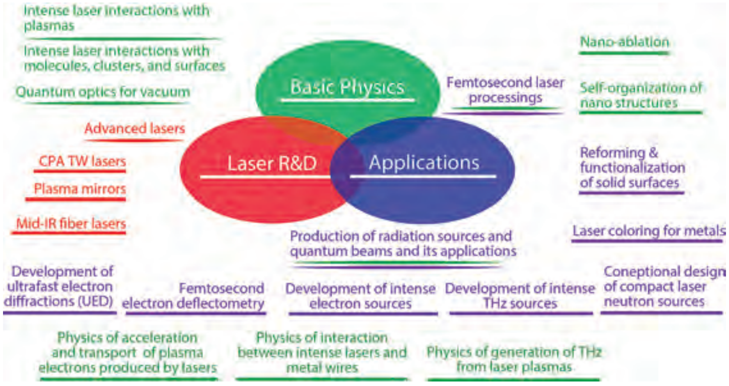
Ms. GEMINI, Laura Czech Technical University, Czech R., 15 April–16 September

Scope of Research

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, ions, THz, and so on), which 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 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.

KEYWORDS

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



Selected Publications

Gemini, L.; Hashida, M.; Shimizu, M.; Miyasaka, Y.; Inoue, S.; Tokita, S.; Limpouch, J.; Mocek, T.; Sakabe, S., Metal-like Self-organization of Periodic Nanostructures on Silicon and Silicon Carbide under Femtosecond Laser Pulses, *J. Appl. Phys.*, **114,** 194903 (2013).

Shimizu, S.; Hashida, M.; Miyasaka, Y.; Tokita, S.; Sakabe S., Unidirectionally Oriented Nanocracks on Metal Surfaces Irradiated by Low-fluence Femtosecond Laser Pulses, *Appl. Phys. Lett.*, **103,** 174106 (2013).

Nakajima, H.; Tokita, S.; Inoue, S.; Hashida, M.; Sakabe, S., Divergence-Free Transport of Laser-Produced Fast Electrons Along a Meter-Long Wire Target, *Phys. Rev. Lett.*, **110,** 155001 (2013).

Hashida, M.; Ikuta, Y.; Miyasaka, Y.; Tokita, S.; Sakabe, S., Simple Formula for the Interspaces of Periodic Grating Structures Self-organized on Metal Surfaces by Femtosecond Laser Ablation, *Appl. Phys. Lett.*, **102,** 174106 (2013).

Jahangiri, F.; Hashida, M.; Tokita, S.; Nagashima, T.; Hangyo, M.; Sakabe, S., Enhancing the Energy of Terahertz Radiation from Plasma Produced by Intense Femtosecond Laser Pulses, *Appl. Phys. Lett.*, **102,** 191106 (2013).

Divergence-Free Transport of Laser-Produced Fast Electrons Along a Meter-Long Wire Target

The development of ultraintense lasers has facilitated the generation of high-current charged particle beams; however, the control of such beams (collimation, transport, and focusing) remains a challenge. We report the observation that a metal wire can act as a guiding device for an electron beam. We have observed that a significant number of fast electrons can be guided over 1 m along a metal wire, without a change in beam size. The experimental results for the transverse distribution of the electron beam are well reproduced by numerical simulations of electron trajectories based on a simplified model. Numerical simulations suggest that a relatively weak steady electric field (~10^6 V/m), which does not decay for several nanoseconds, is generated around the wire and plays a key role in the long-distance guidance.

Figure 1 (a) shows the experimetnal setup for spatial distribtuion measurement of electrons. The electrons produced by irradiation of an ultraintense laser pulse on a metal wire target are detecded by stacked imaging plates (IPs). On the first layer and second of the stacked IPs, electrons with energies higher than ~40 and ~400 keV can be deteced, respectively. Figure 1 (b) shows typical single-shot images at L = 150, 400, and 1050 mm, where L is the distance from the laser irradiated spot to the end of the wire. On the first layer IP, the signal is saturated near the center to a maximum electron density of the order of 4×10^{-9} C/cm^2. The full width at half-maximum (FWHM) of the central part of the images on the second layer IP is 3 to 4 mm, at each L. The beam patterns for each wire length were highly reproducible; however, the beam size showed slight shot-to-shot fluctuation of less than ±1 mm. Assuming a typical electron energy to be 100 keV, the total charge of detected electrons was estimated to be at least 3 nC by integrating the signals below the saturation level. The total charge and diameter of the electron beam are maintained over a propagation distance of 1 m.

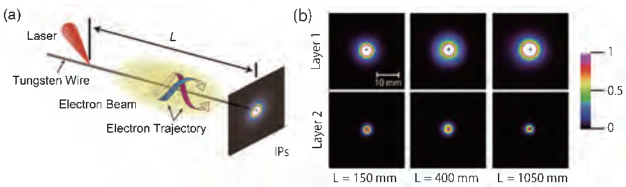


Figure 1. (a) Experimetnal setup for the observation of the spatial distributions of electrons generated from ametal wire. (b) Typical single shot images detected by IP at L = 150, 400, and 1050 mm generated from the setup in (a).

Unidirectionally Oriented Nanocracks on Metal Surfaces Irradiated by Lowfluence Femtosecond Laser Pulses

We have observed the generation of nanocracks oriented perpendicular to the incident laser polarization at fluence below ablation threshold F_{th} for W, Mo, and Cu metal targets. The number density of nanocracks increased with incident pulse number (Figure 2), but their length distributions were independent of it. From the experimental and simulation results, we proposed that an initial tiny crack on the metal surface grows to a nanocrack through local field enhancement. The enhanced field near the hole edge in longitudinal direction of the nanocrack makes the crack longer, and the low intensity field near the edge on short direction governs the space to the next crack.

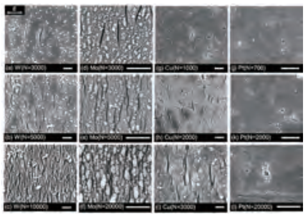


Figure 2. FESEM images of surface nanostructures on (a)-(c) W, (d)-(f) Mo, (g)-(i)Cu, and (j)-(l)Pt. The arrow in (a) shows the direction of polarization of the incident laser field, which is applied to all images. *N* is the number of incident pulses. The white bar in each image corresponds to 500 nm.

Metal-Like Self-Organization of Periodic Nanostructures on Silicon and Silicon Carbide under Femtosecond Laser Pulses

Periodic structures were generated on Si and SiC surfaces by irradiation with femtosecond laser pulses. Self-organized structures with spatial periodicity of approximately 600 nm appear on silicon and silicon carbide in the laser fluence range just above the ablation threshold and upon irradiation with a large number of pulses. As in the case of metals, the dependence of the spatial periodicity on laser fluence can be explained by the parametric decay of laser light into surface plasma waves (Figure 3). The results show that the proposed model might be universally applicable to any solid material.

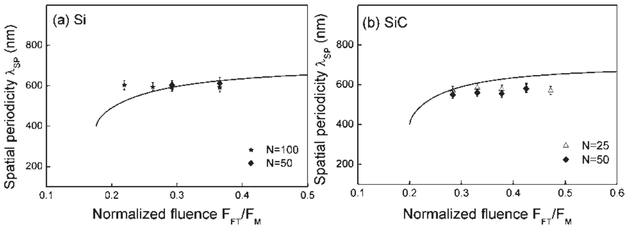


Figure 3. Evolution of spatial periodicity λ_{SP} for classical ripples with respect to normalized laser fluence for (a) Si and (b) SiC. Solid lines indicate the evolution of the spatial periodicity of ripples predicted by the parametric decay model.