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

https://en.laser.kuicr.kyoto-u.ac.jp/

Prof
TOKITA, Shigeki
(D Eng)

Program-Specific Res
KANAI, Tsuneto
(D Sc)

Res (pt)
HASHIDA, Masaki
(D Eng)

Researcher (pt)

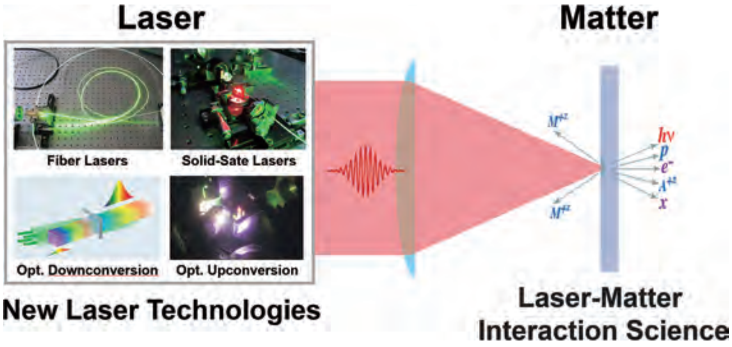
MURAKAMI, Masanao (D Sc)
MASUNO, Shin-ichiro

Scope of Research

We are developing cutting-edge high-intensity laser sources and studying experimental research on the laser interaction with matter by using the new laser sources. We are promoting cross-disciplinary research based on high-intensity laser technologies such as development of high-intensity mid-infrared solid-state lasers and fiber lasers, research on particle acceleration and wavelength conversion with plasmas produced by high-intensity ultrafast lasers, development of laser isotope separation method for neutrino research, and search for dark matter using high-intensity lasers.

KEYWORDS

High Power Laser Optics
Ultrafast Laser Physics
Laser Plasma Interaction Physics
Laser Nano-Ablation Physics
Femtosecond Laser Prosessing



Recent Selected Publications

Goya, K.; Koyama, Y.; Nishijima, Y.; Tokita, S.; Yasuhara, R.; Uehara, H., A Fluoride Fiber Optics in-Line Sensor for Mid-IR Spectroscopy Based on a Side-Polished Structure, *Sens. Actuators B Chem.*, **351,** 130904 (2022).

Ogino, J.; Tokita, S.; Kitajima, S.; Yoshida, H.; Li, Z.; Motokoshi, S.; Morio, N.; Tsubakimoto, K.; Fujioka, K.; Kodama, R.; Kawanaka, J., 10-J, 100-Hz Conduction-Cooled Active-Mirror Laser, *Opt. Contin.*, **1,** 1270-1277 (2022).

Yokoyama, N.; Morioka, Y.; Murata, T.; Honda, H.; Serita, K.; Murakami, H.; Tonouchi, M.; Tokita, S.; Ichikawa, S.; Fujiwara, Y.; Hikosaka, T.; Uemukai, M.; Tanikawa, T.; Katayama, R., Second Harmonic Generation in GaN Transverse Quasi-Phase-Matched Waveguide Pumped with Femtosecond Laser, *Appl. Phys. Express*, **15,** 112002 (2022).

Sekine, T.; Kurita, T.; Hatano, Y.; Muramatsu, Y.; Kurata, M.; Morita, T.; Watari, T.; Iguchi, T.; Yoshimura, R.; Tamaoki, Y.; Takeuchi, Y.; Kawai, K.; Zheng, Y.; Kato, Y.; Kurita, N.; Kawashima, T.; Tokita, S.; Kawanaka, J.; Kodama, R., 253 J at 0.2 Hz, LD Pumped Cryogenic Helium Gas Cooled Yb:YAG Ceramics Laser, *Opt. Express*, **30,** 44385-44394 (2022).

Takenaka, K.; Hashida, M.; Sakagami, H.; Masuno, S.; Kusaba, M.; Yamaguchi, S.; Iwamori, S.; Sato, Y.; Tsukamoto, M., Uniformity Evaluation of Laser-Induced Periodic Surface Structures Formed by Two-Color Double-Pulse Femtosecond Laser Irradiation, *Rev. Sci. Instrum.*, **93,** 093001 (2022).

Collaborative Development of Compact High-Power Femtosecond Lasers for Micromachining

In the recent industrial field of automobiles, semiconductors, medical equipment, etc., it is required to develop/supply products with higher performance and smaller sizes, and accordingly, downsizing their components is also required. For this purpose, one of the crucial technologies is microfabrication on the order of several tens of microns for metals, ceramics, resins, glass, and their composite materials. Recently, ultrafast lasers, which have extremely short pulse durations of picoseconds to femtoseconds, are expanding their use in a wide range of fields as crucial tools that enable high-speed and precise microfabrication. Currently, with the rapid growth of the laser microfabrication market, the global market size for ultrafast laser oscillators has reached 420 billion yen in 2018 and is expected to expand to more than 1.2 trillion yen. The presence of Japanese companies in the ultrafast laser market, however, is extremely low, and they are far behind European and American companies.

In the present project, to enhance the presence of Japan in this expanding industrial field, novel high-performance femtosecond lasers will be developed based on a collaboration by our laboratory, which is one of the centers of excellence in high-power laser studies, and Spectronics Co., Ltd., which is the only manufacturer/seller of picosecond laser oscillators for microfabrication in Japan. The existing femtosecond lasers have lower power efficiency and more complicated structures compared with general nanosecond/picosecond lasers, and therefore their sizes inevitably become large, and the prices are not competitive. By combining the state-of-the-art technologies in mode-locked fiber oscillators and chirp pulse amplification, and through optimizing the structure of the laser systems as well as the materials of their housing in detail, we have developed next-generation femtosecond, lasers that realize high power output, an ultra-compact size, and ultra-lightness in weight, simultaneously (Fig. 1).

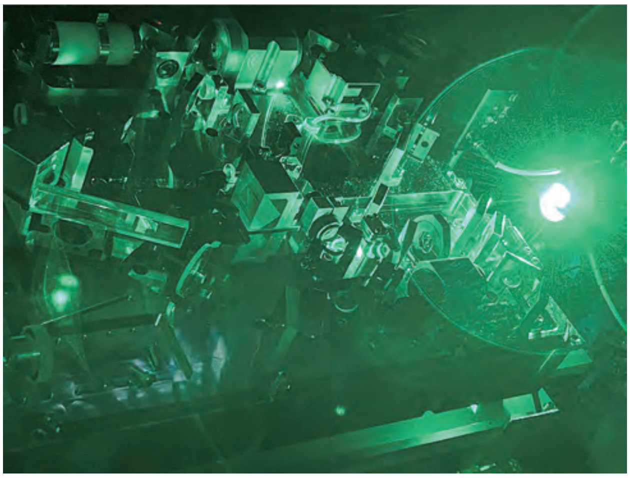


Figure 1. The developed high-power and compact laser emitting intense green femtosecond pulses for laser microfabrication.

Uniformity Evaluation of Laser-Induced Periodic Surface Structures Formed by Two-Color Double-Pulse Femtosecond Laser Irradiation

In order to evaluate the uniformity of a laser-induced periodic surface structure (LIPSS) we have proposed a Perpendicular Period and Phase Scanning (P^3S) method. P^3S assesses the uniformity of LIPSS using the standard deviation of the peak period and the average of the phase difference in the direction perpendicular to LIPSS. The P^3S method demonstrates that LIPSS formed by two-color double-pulse irradiation is reduced to a quarter of the period dispersion, and the average phase difference of LIPSS is also reduced compared to the single-pulse irradiation. In addition, a three-dimensional electromagnetic particle-in-cell simulation was performed to evaluate the possibility of an improved uniformity of LIPSS. The results confirm that the two-color double-pulse irradiation produces a uniform LIPSS and validates the effectiveness of the P^3S method to assess the uniformity of LIPSS.

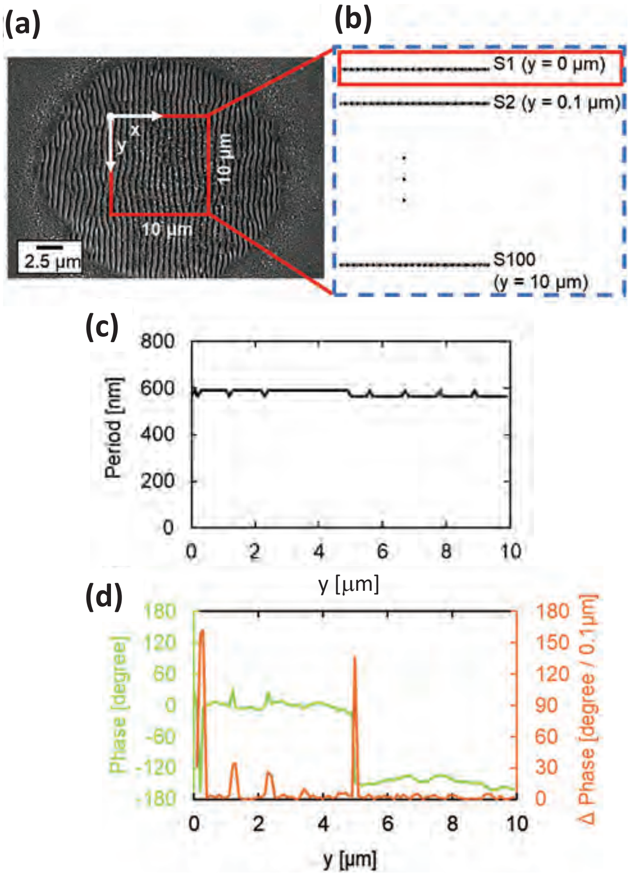


Figure 2. Schematic of P^3S method for evaluating the LIPSS uniformity. (a) SEM image is divided into (b) S1–S100 segments. Then segment of S1 is performed by 1-D Fast Fourier transform (FFT), and the peak period of 1-D FFT and the peak phase are evaluated. Standard deviation (SD) of the period and the average of the Δ phase are determined by calculating (c) the period, and (d) the phase, and the Δ phase for each y-coordinate, the SD of the period, and the average of the Δ phase.