RESEARCH ACTIVITIES VIII
Laser Research Center for Molecular Science

VIII-A Developments and Researches of New Laser Materials

Although development of lasers is remarkable, there are no lasers which lase in ultraviolet and far infrared regions. However, it is expected that these kinds of lasers break out a great revolution in not only the molecular science but also in the industrial world.

In this project we research characters of new materials for ultraviolet and far infrared lasers, and develop new lasers by using these laser materials.

VIII-A-1 High-Energy, All-Solid-State, Ultraviolet Laser Power-Amplifier Module Design and Its Output-Energy Scaling Principle

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[*Appl. Opt.* **41**, 7556 (2002)]

We demonstrated that a coaxially pumped, large-aperture ultraviolet power-amplifier module using solid-state tunable laser medium Ce^{3+}:$LiCaAlF_6$ has 98-mJ, 290-nm, and 3-ns output pulses with sufficient extraction efficiency of 25%. The detailed information of design parameters, including the gain-coefficient dependence on pump condition, is successfully accumulated for further energy scaling for a terawatt-class ultraviolet chirped pulse amplification laser system or a high-pulse-energy laser system.

VIII-A-2 Generation of Intense 25-fs Pulses at 290 nm by Use of a Hollow Fiber Filled with High-Pressure Argon Gas

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[*Jpn. J. Appl. Phys.* **41**, L986 (2002)]

Frequency-tripled pulses at 290 nm from a 100-fs, 1-kHz Ti:sapphire regenerative amplifier system are spectrally broadened in hollow fiber filled with high-pressure argon gas. The self-phase-modulated pulses are compressed to 25 fs through a prism pair. The compressed pulse has an energy of 15 μJ.

VIII-A-3 Anomalous Power and Spectrum Dependence of THz Radiation from Femtosecond-Laser-Irradiated InAs in a High Magnetic Field of 14 T

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[*Appl. Phys. Lett.* **82**, 1164 (2003)]

We report on the THz radiation from femtosecond-laser-irradiated InAs in a high magnetic field up to 14 T. It is found that the radiation power exhibits anomalous magnetic-field dependence, including saturation, decrease, and recovery up to 14 T. Moreover, the radiation spectrum possesses a clear periodic structure over 6 T, possibly due to differently phased radiation from holes with different masses.

VIII-A-4 Significant Enhancement of Terahertz Radiation from InSb by Use of a Compact Fiber Laser and an External Magnetic Field

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[*Appl. Phys. Lett.* **82**, 2005 (2003)]

We investigated the magnetic-field dependence of terahertz (THz) radiation power from InSb. Significant enhancement of THz-radiation power is observed by using a compact fiber laser that delivered 100 fs optical pulses at a center wavelength of 1560 nm. Additionally, applying external magnetic fields dramatically enhanced the THz-radiation power. THz-radiation power reaches a maximum value at around 1.2 T, and its enhancement factor exceeds 100. From an applications viewpoint, this is a significant finding for practical light source design, since it is easily achieved by using a compact fiber laser and a conventional magnet.

VIII-A-5 Micro-Character Printing on a Diamond Plate by Femtosecond Infrared Optical Pulses

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[*Jpn. J. Appl. Phys.* **42**, 4613 (2003)]

Processing of less than 400 nm has been performed on the surface of a diamond plate by means of a femtosecond infrared pulse laser. Various characters with a size of about 1 μm were drawn by the femtosecond pulse laser system in conjunction with a microscope equipped with a precisely controlled piezo-stage. The tightly focused laser light on the flat surface of the diamond made it possible to minimize the light-induced graphitization. The surface of the diamond plate after laser machining was analyzed by micro-Raman measurements to estimate the graphitization effect induced by laser irradiation. The obtained results indicate that graphitization increased with the number of irradiated laser pulses.

VIII-A-6 Mode-Locking Stability Adjustment of a Kerr-Lens Mode-Locked Ti:sapphire Laser, Analyzed by a Recently Developed Real-Time Spectrum Analyzer

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[*Jpn. J. Appl. Phys.* **42**, 4330 (2003)]

This is a report on the mode-locking stability of a Kerr-lens mode-locked Ti:sapphire, measured by a newly developed noise measurement method. Mode-locking stability is monitored *via* a power spectrum, which is obtained by irradiating optical pulses onto a fast photodiode, and by processing the detected signal using a recently developed real-time spectrum analyzer. The mode-locking stability of the Ti:sapphire laser strongly depends on pump power and becomes unstable as pump power decreases from an optimum power level. Amplitude fluctuation and Q-switched mode-locking are notably observed as the main causes for a break in a continuous-wave (CW) mode-locking operation. Moreover, chaotic frequency hopping is observed in a Q-switched mode-locking operation. A real-time spectrum analyzer provides a time-varying power spectrum, which enables easy adjustment for stable CW mode-locking operation of ultra-fast solid state lasers.

VIII-A-7 Magnetic-Field-Induced Enhancement of THz-Radiation Power from Femtosecond-Laser-Irradiated InAs up to 27 T

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[*Jpn. J. Appl. Phys.* **42**, L532 (2003)]

Magnetic-field dependence of THz-radiation power from InAs surface is investigated by using a hybrid magnet, which is capable of providing a magnetic field up to 28 T. It is found that THz-radiation power saturates at around 3 T and also at 13 T. Maximum THz-radiation power with high-frequency component spectrum is observed at 3-T. This result leads to the conclusion that a magnetic field of 3 T is optimum for the enhancement of THz-radiation power. Additionally, THz-radiation spectrum exhibits periodic structure at magnetic fields above 12 T. This can be attributed to the change of dielectric constant induced by the strong magnetic field resulting in the interference of THz-radiation pulses from the front and back surfaces of the InAs substrate.

VIII-A-8 Optical Properties of Ce^{3+} Ion Doped $LiCaAlF_6$ Crystal in Vacuum Ultraviolet Region

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[*Jpn. J. Appl. Phys.* **42**, L660 (2003)]

The optical properties of Ce^{3+} ion doped $LiCaAlF_6$ (Ce:LiCAF) crystal is investigated in vacuum ultraviolet (VUV) region. It is found that the optical excitation from the valence band of LiCAF crystal to the highest ^2D excited state of Ce^{3+} can be utilized as an efficient excitation channel to obtain the ultraviolet emission due to $4f$–$5d$ transition of Ce^{3+}. Furthermore, the energy level of ^2D state is found to be located near the conduction band of LiCAF crystal, which leads to the electron transfer from the LiCAF crystal to the active Ce^{3+} ion.

VIII-A-9 Identification of Potential Estrogenic Environmental Pollutants by Terahertz Transmission Spectroscopy

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[*Jpn. J. Appl. Phys.* **42**, L932 (2003)]

Using magnetically enhanced terahertz radiation from InAs, various naphthols, which exhibits estrogenic like activity and are potentially mimic natural hormones, are studied. The experimental results show that the naphthols, depicted by the position of the hydroxyl (-OH) component at different carbon atom sites of the naphthalene compound, are distinguishable based on the absorption of THz radiation. It is found that the THz radiation absorption is strongly related to the crystal symmetry and dipole moment of these isomers.

VIII-A-10 Excitation Fluence Dependence of Terahertz Radiation Mechanism from Femtosecond-Laser-Irradiated InAs under Magnetic Field

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([1]GUAS)

[*Appl. Phys. Lett.* **83**, 1068 (2003)]

The excitation fluence and magnetic field dependence of terahertz (THz) radiation power from InAs is investigated. At low excitation fluence, an enhancement of the THz-radiation power is observed independent of the magnetic-field direction. As the excitation fluence is increased, a crossover of terahertz radiation mechanism is observed. At excitation fluence above this crossover, the radiation power is either enhanced or reduced depending on the magnetic-field direction. These results are explained by considering the different THz-radiation mechanisms from the InAs surface with or without photoexcited carrier screening.