RESEARCH ACTIVITIES IX
Laser Research Center for Molecular Science

IX-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.

IX-A-1 Terahertz Radiation Mechanism from Femtosecond-Laser-Irradiated InAs (100) Surface

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[*Jpn. J. Appl. Phys.* **42**, L1259 (2003)]

Terahertz (THz) radiation mechanism from femtosecond-laser-irradiated InAs surface is investigated by measuring the excitation-fluence dependence of THz-radiation power. It is found that the THz-radiation is mainly generated by the surge-current, which originates from the different diffusion velocities between photo-excited electrons and holes. Furthermore, it is also found that the excitation fluence dependence of THz-radiation is categorized into two regions depending on the excitation fluence. At low excitation fluence, a quadratic-dependent enhancement of the THz-radiation power is observed with increasing excitation fluence. In contrast, at high excitation fluence, the enhancement factor is gradually reduced, and the radiation power becomes proportional to a logarithm function of the excitation fluence. These results are explained by considering the photo-Dember field as the THz-radiation source.

IX-A-2 Broadband Terahertz Radiation Emitter Using Femtosecond-Laser-Irradiated *n*-Type InAs under Magnetic Field

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[*Jpn. J. Appl. Phys.* **43**, L221 (2004)]

We present the generation of broadband terahertz (THz) radiation using *n*-type InAs irradiated by ultrafast laser pulses. It is found that the high-frequency component of the THz-radiation spectrum originates from the hybrid modes of the plasmons and the longitudinal optical (LO) phonons, whose peak frequency shifts toward higher frequency with increasing doping density. For *n*-type InAs with a doping density of 3.1×10^{17} cm^{-3}, the high-frequency components of THz-radiation spectrum are observed at around 5.5 and 9 THz. Furthermore, the enhancement of THz-radiation power from these hybrid modes is achieved by applying an external magnetic field.

IX-A-3 Teflon Photonic Crystal Fiber as Terahertz Waveguide

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[*Jpn. J. Appl. Phys.* **43**, L317 (2004)]

We demonstrate the construction of reasonably long and non-polarization changing photonic fiber waveguide using Teflon which is a readily available and highly flexible material. Due to its relatively low loss coefficient, the possibility of preparing longer photonic fiber waveguide,which has the potential of guiding intense THz radiation, can be easily attained.

IX-A-4 Growth and Charge Transfer Luminescence of Yb^{3+}-Doped $YAlO_3$ Single Crystals

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[*J. Appl. Phys.* **95**, 3063 (2004)]

Yb^{3+}-doped $YAlO_3$ single crystals have been grown by the Czochralski method with a radio-frequency heating system. Starting melt compositions of $Y_{1-x}Yb_x$ AlO_3 were varied with x = 0.02, 0.1, 0.2, 0.3, and 0.45. The best Yb^{3+}-doped $YAlO_3$ single crystals were obtained for a growth rate of 1.0 mm/h. The grown crystals were transparent and almost colorless. To investigate the homogeneity, the effective segregation coefficient of the Yb ion was estimated. The absorption, photoluminescence, and luminescence decay kinetics of Yb^{3+}-doped $YAlO_3$ were investigated for the temperature range 4–300 K. Very fast charge transfer luminescence of Yb^{3+} from the near ultraviolet to visible spectral range and the high density of the Yb-rich $YAlO_3$ makes this material a promising candidate for fast scintillators.

IX-A-5 Terahertz Radiation from InAs with Various Surface Orientations under Magnetic Field Irradiated with Femtosecond Optical Pulses at Different Wavelengths

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[*J. Appl. Phys.* **95**, 4545 (2004)]

We present the magnetic-field dependence of terahertz (THz)-radiation power from femtosecond-laser-irradiated InAs with various surface orientations. Under 800 nm optical excitation, the magnetic field that provides the maximum THz-radiation power is found to be affected by the surface orientation, and InAs(111) exhibits it at lower magnetic fields than that of the other surfaces. In contrast, under 1560 nm excitation, the dependence on the surface orientation almost disappeared, and saturation is observed at a much smaller magnetic field than that in the 800 nm excitation case. Additionally, from the results of magnetic-field dependence up to 14 T, the shift of the peak in the THz-radiation spectrum toward lower frequency is confirmed, depending on the magnetic field applied, which is possibly induced by the emergence of a magneto-plasma effect.

IX-A-6 Optical, Infrared and EPR Spectroscopy of CaF_2:Ce^{3+} Crystals Co-Doped with Li^+ or Na^+

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[*J. Lumin.* **108**, 307 (2004)]

Interconfigurational 4f ↔ 5d VUV absorption and luminescence, intra-$4f^1$ IR absorption and X-band EPR measurements have been carried out on CaF_2:Ce^{3+} crystals co-doped with Na^+ and Li^+ ions. For both Li^+ and Na^+ co-doping, cubic, new tetragonal and rhombic-symmetry centres are observed. Cubic centres, which are readily observable by their infrared transitions, could not be identified and remain elusive in the EPR spectra.

IX-A-7 Effect of Ultrafast Optical Pulses with Different Pulse Duration on the Terahertz Radiation Spectrum of *n*-Type InAs

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[*Jpn. J. Appl. Phys.* **43**, L746 (2004)]

Terahertz (THz) radiation from *n*-type InAs irradiated by ultrafast laser pulses is investigated under the existence of the magnetic field. It is found that the high-frequency component of the THz-radiation spectrum originates from the hybrid modes of the plasmons and the longitudinal optical (LO) phonons, and its intensity can be drastically enhanced by using the laser pulses with duration shorter than the oscillation period of the hybrid modes. Additionally, it is also found that the ratio of THz-radiation power from these two modes can be controlled by adjusting the pulse duration and the magnetic field strength.

IX-A-8 Physical Origin of Magnetically Induced Periodic Structure Observed in Terahertz Radiation Spectrum Emitted from InAs

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[*Jpn. J. Appl. Phys.* **43**, L1017 (2004)]

Terahertz (THz) radiation from femtosecond-laser-irradiated InAs(100) surface is investigated. It is found that THz-radiation spectrum exhibits two inter-related phenomena in a strong magnetic field under the Voigt configuration. The peak shift of THz-radiation spectrum toward lower frequency is observed with increasing magnetic field. Additionally, THz-radiation spectrum is found to posses a periodic structure owing to the interference of THz-radiation pulses from the front and back surfaces of the InAs substrate. The physical origin of the latter phenomenon is discussed by considering the magneto-plasma effect, which affects both real and imaginary parts of refractive index for THz-radiation propagating in a direction perpendicular to the magnetic field.

IX-A-9 Design Proposal of Light Emitting Diode in Vacuum Ultraviolet Based on Perovskite-Like Fluoride Crystals

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[*Jpn. J. Appl. Phys.* **43**, L1140 (2004)]

The variation of band gap energy, band structure and lattice constant of mixed $LiBaF_3$, $LiCaF_3$ and $LiSrF_3$ perovskites is studied. The band structure and transition type of these fluorides is predicted by *ab initio* band calculation based on the local density approximation. The design principle of vacuum ultraviolet light emitting diode is proposed. The lattice-matched double-hetero structure of different perovskite-like fluorides is found to be sufficiently feasible to fabricate with direct-band-gap compounds $LiBa_xCa_ySr_{(1-x-y)}F_3$ on $LiSrF_3$.