Laser Research Center for Molecular Science

IX-R 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-R-1 Photonic-Crystal-Fiber Pigtail Device Integrated with Lens-Duct Optics for Terahertz Radiation Coupling

DIWA, Girbert; QUEMA, Alex; ESTACIO, Elmer; POBRE, Romeric[1]; MURAKAMI, Hidetoshi; ONO, Shingo; SARUKURA, Nobuhiko
([1]De La Salle Univ.)

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An integrated optics called terahertz (THz) pigtail, which is comprised of an emitter, an optically transparent launching media, and a waveguide, is devised and fabricated. The InAs emitter under a 1 T magnetic field is coupled to the launching media using silicone grease, an index matching liquid. The launching media, a lens duct made from a polymer based on poly 4-methyl pentene-1 (commonly known as TPX), is designed based on the concept of guiding THz radiation into Teflon photonic crystal fiber (PCF) waveguide by means of total internal reflection. It is found that the constructed THz lens duct is able to channel and couple the THz radiation into the PCF waveguide with a loss of < 1 dB. The results here show that the idea of using the THz pigtail can be a potential means of effectively directing THz radiation.

IX-R-2 Band-Structure Design of Fluoride Complex Materials for Deep-Ultraviolet Light-Emitting Diodes

ONO, Shingo; EL OUENZERFI, Riadh; QUEMA, Alex; MURAKAMI, Hidetoshi; SARUKURA, Nobuhiko; NISHIMATSU, Takeshi[1]; TERAKUBO, Noriaki[1]; MIZUSEKI, Hiroshi[1]; KAWAZOE, Yoshiyuki[1]; YOSHIKAWA, Akira[1]; FUKUDA, Tsuguo[1]
([1]Tohoku Univ.)

[*Jpn. J. Appl. Phys.* **44**, 7285 (2005)]

The design principle for fluoride-containing optical devices for applications in the deep ultraviolet range is discussed. Variations in band gap energy, band structure and lattice constant of $LiBa_xCa_ySr_{(1-x-y)}F_3$ and $Li_{(1-x)}K_xBa_{(1-y)}Mg_yF_3$ have been studied. The band structure and transition type of these fluorides are predicted by ab initio band calculations based on the local density approximation. The lattice-matched double-hetero structure of direct-band-gap compounds $LiBa_xCa_ySr_{(1-x-y)}F_3$ on $LiSrF_3$ and $Li_{(1-x)}K_xBa_{(1-y)}Mg_yF_3$ on either $LiBaF_3$ or $KMgF_3$ is sufficiently feasible to fabricate.

IX-R-3 Ce^{3+}-Doped $LiCaAlF_6$ Crystals as a Solid-State Ultraviolet Saturable Absorber and Role of Excited State Absorption

HAI, Le Hoang[1]; HUNG, Nguyen Dai[1]; QUEMA, Alex; DIWA, Girbert; MURAKAMI, Hidetoshi; ONO, Shingo; SARUKURA, Nobuhiko
([1]Inst. Phys. Elect.)

[*Jpn. J. Appl. Phys.* **44**, 7984 (2005)]

Nonlinear absorption properties of Ce^{3+}-doped $LiCaAlF_6$ (Ce:LiCAF) crystals at wavelength of 266 nm are studied using open-aperture Z-scan method and a Q-switch Nd:YAG laser. Saturable absorption of solid-state materials. in ultraviolet region is demonstrated for the first time.

IX-R-4 Generation of Terahertz Radiation Using Zinc Oxide as Photoconductive Material Excited by Ultraviolet Pulses

ONO, Shingo; MURAKAMI, Hidetoshi; QUEMA, Alex; DIWA, Girbert; SARUKURA, Nobuhiko; NAGASAKA, Ryujiro[1]; ICHIKAWA, Yo[1]; OGINO, Hiraku[2]; OHSHIMA, Eriko[2]; YOSHIKAWA, Akira[2]; FUKUDA, Tsuguo[2]
([1]Nagoya Inst. Tech.; [2]Tohoku Univ.)

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Terahertz (THz) radiation generated from photoconductive antenna fabricated on a single crystal zinc oxide (ZnO) is presented. The THz-radiation power is saturated at bias voltages above 800 V/cm and the obtained spectrum extends up to 1 THz. Moreover, ZnO is found to be highly transparent in the visible, near-infrared, mid-infrared and THz frequency regions. The results depicted here will categorically unravel the prospects of using ZnO as a material for integrated active optics.

IX-R-5 Ultraviolet Irradiation Effect of Ce^{3+}-Doped $BaMgF_4$ Crystals

HAYASHI, Eiji[1]; ITO, Kiyotaka[1]; YABASHI, Satoshi[1]; YAMAGA, Mitsuo[1]; KODAMA, Nobuhiro[2]; ONO, Shingo; SARUKURA, Nobuhiko

([1]Gifu Univ.; [2]Akita Univ.)

[*J. Alloys Compd.* **408**, 883 (2006)]

Ce^{3+}-doped $BaMgF_4$ (BMF) crystals have the absorption and luminescence spectra in the vacuum ultraviolet (VUV) and ultraviolet (UV) ranges. Strong excitation of the fourth harmonic (266 nm) of a pulsed Nd:YAG laser colours the BMF crystal brown and produces a new luminescence spectrum with double peaks at 445 and 500 nm and a lifetime of less than 10 ns. When the sample temperature is elevated up to 200 degrees C, the crystal colour is changed from brown to green. The colouration is due to localized electrons and holes created by the strong UV excitation, which are identified by the electron spin-resonance (ESR) technique. This new luminescence may be due to Ce^{3+} perturbed by the colour centres.

IX-R-6 Vacuum Ultraviolet and Ultraviolet Spectroscopy of $BaMgF_4$ Codoped with Ce^{3+} and Na^+

HAYASHI, Eiji[1]; ITO, Kiyotaka[1]; YABASHI, Satoshi[1]; YAMAGA, Mitsuo[1]; KODAMA, Nobuhiro[2]; ONO, Shingo; SARUKURA, Nobuhiko
([1]Gifu Univ.; [2]Akita Univ.)

[*J. Lumin.* **119**, 69 (2006)]

Ce^{3+}/Na^+-doped $BaMgF_4$ (BMF) crystals with a nonlinear property show strong absorption in the vacuum ultraviolet (VUV) and ultraviolet (UV) ranges. Three different fluorescence bands (A, B, C) at 300, 340, and 430 nm were observed when pumped at different wavelengths. Under excitation of the fourth harmonic (266 nm) from a pulsed Nd:YAG laser the BMF crystal changed its colour from transparent to brown due to formation of colour centres. The A, B and C bands are assigned to three different sites of Ce^{3+}: site A is Ce^{3+} substituting for perfect Ba^{2+} sites; site B is Ce^{3+} (Ba^{2+}) perturbed by Na^+ as a charge compensator; and site C is a complex composed of Ce^{3+} and F- vacancies, which trapped one or two electrons.

IX-R-7 Vacuum Ultraviolet Spectroscopy of Ce^{3+}-Doped $SrMgF_4$ with Superlattice Structure

YAMAGA, Mitsuo[1]; HAYASHI, Eiji[1]; KODAMA, Nobuhiro[2]; ITO, Kiyotaka[1]; YABASHI, Satoshi[1]; MASUI, Yuki[1]; ONO, Shingo; SARUKURA, Nobuhiko; HAN, T. P. J.[3]; GALLAGHER, H. G.[3]
([1]Gifu Univ.; [2]Akita Univ.; [3]Univ. Strathclyde)

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X-ray diffraction of Ce^{3+}-doped $SrMgF_4$ (SMF:Ce) crystals shows a superlattice structure, reflecting the distribution of Ce^{3+} polyhedra centres observed in optical experiments. Optical absorption bands and fluorescence bands from the Ce^{3+} polyhedra centres overlap in the vacuum ultraviolet (VUV) and ultraviolet (UV) regions, respectively, so that wide pumping and tuning ranges are expected for laser operation. The SMF: Ce crystals, as well as the isomorphous $BaMgF_4$, are candidates for a tunable laser gain material with nonlinear properties.

The optical absorption, excitation, and fluorescence bands observed in the SMF: Ce crystals at low temperatures are ascribed to five distinct fluorescent centres. Three centres have well-known Ce^{3+} optical characters, for example, fluorescence with double peaks separated by 2000 cm^{-1} and five resolved absorption/excitation bands. These centres are assigned to Ce^{3+}-polyhedra classified by weak and strong crystal fields as a consequence of the superlattice structure. The other two fluorescence bands observed in the visible region have 1.5–2 times larger linewidths than those of the former three bands. These bands are interpreted as optical transitions from complexes consisting of Ce^{3+} and one or two electrons trapped at a vacancy of the nearest neighbour F-ligand ions.