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Abstracts of Express Letters

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Domain Structure of a Magnetic Head Observed by Strain Imaging

Keiji TAKATA
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Magnetic domain structures in a magnetic head of a hard disk drive were observed by strain imaging. When a magnetic material is subjected to an external magnetic field, a strain is generated in the material. We can observe domain structures by imaging the strain using a scanning probe microscope. We proved by strain imaging of the magnetic head that magnetic structures in the top pole tip of the writing head were divided into two domains by the center axis, and the boundary was split in the interface between the sputtering and plating layers. The structures in the deep portions of the pole appeared in the images. These images were formed by the strains caused by magnetic forces. [DOI : 10.1143/JJAP.43.L608]

Keywords: strain imaging, magnetostriction, scanning probe microscopy, magnetic head, HDD, atomic force microscopy, magnetic force

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Self-Assembled Growth of GaSb Type II Quantum Ring Structures

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(Received March 22, 2004; accepted March 24, 2004; published April 23, 2004)

We demonstrate the self-assembled growth of GaSb quantum ring structures by molecular beam epitaxy. GaSb rings with the internal and external diameters of about 20 nm and 60 nm are successfully formed on GaAs by a growth procedure different from that for InAs rings reported earlier. The shape of GaSb structures can be controlled from a ring-like to an elongated disk-like geometry by changing the amount of deposited GaSb. A possible growth mechanism of GaSb rings is discussed. Photoluminescence spectra of the rings are presented and their features are discussed in terms of the type II band alignment, in which only holes are confined in the ring. [DOI : 10.1143/JJAP.43.L662]

Keywords: GaSb, GaAs, self-assembled quantum dots, quantum rings, MBE

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Giant Ferroelectric Polarization Beyond 150 μC/cm^2 in $BiFeO_3$ Thin Film

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(Received March 16, 2004; accepted March 18, 2004; published April 16, 2004)

Ferroelectric $BiFeO_3$ thin films have been deposited on Pt/TiO_2/SiO_2/Si substrate by pulsed-laser deposition. From the X-ray diffraction analysis, the $BiFeO_3$ thin film consists of perovskite single-phase, and the crystal structure shows the tetragonal structure (c/a = 1.018) with a space group P4mm. It is obtained that the $BiFeO_3$ thin film shows a well-saturated remarkably giant saturation polarization of 158 μC/cm^2 and a remanent polarization of 146 μC/cm^2 for a maximum applied voltage of 20 V at 90 K. These values of polarization are largest evermeasured in ferroelectrics. [DOI : 10.1143/JJAP.43.L647]

Keywords: $BiFeO_3$ thin film, giant ferroelectric polarization (GFP), multiferroic, PLD

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Tunable Exchange Interaction in Quantum Dot Devices

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(Received March 30, 2004; accepted April 5, 2004; published April 28, 2004)

We theoretically discuss the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction between semiconductor quantum dots (QDs). When each QD having a local spin is coupled to the conduction electrons in semiconductors, an indirect exchange interaction, i.e., the RKKY interaction, is induced between two local spins. The RKKY interaction between QDs, which is mediated by the Fermi sea in semiconductors, is modulated by changing the Fermi energy, and the magnitude or even the sign of the exchange interaction can be tuned, which leads to a tunable magnetic transition in QD devices. We estimate the magnitude of the RKKY interaction in QDs as a function of the electron density and the inter-dot distance. [DOI : 10.1143/JJAP.43.L691]

Keywords: quantum dot, RKKY interaction, ferromagnetism, spintronics, magnetic device

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Ultra-Low-Threshold Field Electron Emission from Pillar Array of Aligned Carbon Nanotube Bundles

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We observed the field electron emission of the technologically useful current density of 10 mA/cm^2 at an extremely low threshold electric field (E_{th}) of 1.0 V/μm, from an array of pillars of aligned carbon nanotube bundles, which were grown on a Si substrate by thermal chemical vapor deposition. Adjusting the distance between the neighboring pillars (R) and the pillar height (H) to the optimal condition (R/H = 2) can effectually enhance the field concentration, resulting in a highly efficient electron emission. The obtained E_{th} is 1/2-1/3 times lower than the best values that have been reported to date. [DOI : 10.1143/JJAP.43.L774]

Keywords: carbon nanotube, thermal chemical vapor deposition, field electron emission, field concentration, Fowler-Nordheim law

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Al_2O_3 Insulated-Gate Structure for AlGaN/GaN Heterostructure Field Effect Transistors Having Thin AlGaN Barrier Layers

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An Al_2O_3 insulated-gate (IG) structure was utilized for controlling the surface potential and suppressing the gate eakage in $Al_{0.2}Ga_{0.8}N$/GaN heterostructure field effect transistors (HFETs) having thin AlGaN barrier layers (less than 10 nm). In comparison with the Schottky-gate devices, the Al_2O_3 IG device showed successful gate control of drain current up to V_{GS} = +4 V without leakage problems. The threshold voltage in the Al_2O_3 IG HFET was about -0.3 V, resulting in the quasi-normally-off mode operation. [DOI : 10.1143/JJAP.43.L777]

Keywords: AlGaN, GaN, Al_2O_3, HFET, insulated gate, normally-off

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Unprecedented Imaging Capability Hard X-ray Detector Employing Scintillator-Deposited Charge-Coupled Device

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(Received April 9, 2004; accepted May 11, 2004; published June 4, 2004)

We report on a new photon-counting detector possessing an unprecedented spatial resolution, a moderate spectral resolution and a high background-rejection capability for 0.1-100 keV X-rays. The detector consists of an X-ray charge-coupled device (CCD) and a scintillator. We coupled the scintillator to the surface of the back-illuminated (BI) CCD. Hard X-rays absorbed in the scintillator create hundreds or thousands of visible lights whose number is proportional to the incident X-ray energy. Since the quantum efficiencies of BI CCDs for visible lights are high, the charge collection efficiency for visible lights emitted from the scintillator becomes high. We investigate the spatial resolution of our device by measuring the contrast transfer function for 17.4 keV X-rays and find almost unity up to 10 line pairs per mm in the photon-counting mode. We thus perform a demonstrative experiment with a sharp edge and determine the spatial resolution to be (10± 3) μm which is twofold that of the CCD pixel size. [DOI : 10.1143/JJAP.43.L808]

Keywords: charge-coupled device, hard X-ray imaging, scintillator, photon-counting detector, high spatial resolution

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Surface-modified Diamond Field-effect Transistors for Enzyme-immobilized Biosensors

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(Received April 15, 2004; accepted May 11, 2004; published June 4, 2004)

The enzyme sensors using electrolyte-solution-gate diamond field effect transistors (SGFETs) have been developed for the first time. The hydrogen-terminated surface channel of the FETs was modified into partially aminated and oxygen-terminated (H-A-O-terminated) with irradiation of ultraviolet in an ammonia environment. The pH response of that is obtained about 50 mV/pH at pH 2-10. The concentration of substrates (urea or glucose) in the electrolyte solution has been detected by the pH change due to the bio-catalyzed effect of enzyme (urease or glucose oxidase), which is immobilized on the channel of SGFETs. The sensitivity of urea and glucose is approximately 30 mV/decade and 20 mV/decade respectively. [DOI : 10.1143/JJAP.43.L814]

Keywords: Diamond SGFETs, H-A-O-terminated, Enzyme, urea, glucose

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Minimal Phase-Change Marks Produced in Amorphous $Ge_2Sb_2Te_5$ Films

Tamihiro GOTOH*, Kentaro SUGAWARA and Keiji TANAKA
(Received April 16, 2004; accepted April 28, 2004; published June 4, 2004)

The smallest mark which can be produced in phase-change recordings has been explored using an atomic force microscope. Electrical pulses applied to amorphous $Ge_2Sb_2Te_5$ films through conducting cantilevers can produce crystalline marks, the size decreasing with decreases in input power, pulse duration, and film thickness. The smallest mark obtained is ~10 nm in diameter in a film with thickness of ~1 nm. Formation mechanism of the mark is discussed. [DOI : 10.1143/JJAP.43.L818]

Keywords: AFM, Joule heat, phase change, nanoscale crystallization, Ge-Sb-Te

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Current-Induced Magnetization Reversal in a (Ga,Mn)As-Based Magnetic Tunnel Junction

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(Received April 28, 2004; accepted May 12, 2004; published June 4, 2004)

We report current-induced magnetization reversal in a ferromagnetic semiconductor-based magnetic tunnel junction (Ga,Mn)As/AlAs/(Ga,Mn)As prepared by molecular beam epitaxy on a p-GaAs(001) substrate. A change in magneto-resistance that is asymmetric with respect to the current direction is found with the excitation current of 10^6A/cm^2. Contributions of both unpolarized and spin-polarized components are examined, and we conclude that the partial magnetization reversal occurs in the (Ga,Mn)As layer of smaller magnetization with the spin-polarized tunneling current of 10^5A/cm^2. [DOI : 10.1143/JJAP.43.L825]

Keywords: III-V magnetic alloy semiconductors, spintronics, (Ga,Mn)As, magnetic tunnel junction, MBE

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Stiffness of Step Bunches on Si(111)

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Configurations of atomic steps on vicinal Si(111) miscut toward the [11\bar2] direction after homoepitaxial step-flow growth were studied as a function of growth thickness by *ex situ* atomic force microscopy. We found that step bunches coarsen via the zipping-up of single, double, triple, and quadruple bilayer steps during the growth, and that the zipping steps contact neighboring step bunches at characteristic angles depending on their heights. The new finding of the step-height-dependence enabled us to evaluate step bunch stiffness. The step bunches are shown to be significantly stabilized compared with a simple summation of stiffness of individual single bilayer steps. [DOI : 10.1143/JJAP.43.L822]

Keywords: Si(111), atomic step, stiffness, step bunch, molecular beam epitaxy, surface reconstruction, atomic force microscopy

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X-Rays Beam Condensation by Confinement in a Thin Crystal

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(Received April 12, 2004; accepted April 19, 2004; published June 11, 2004)

We have observed condensation of X-rays emitted from an edge of a thin Ge parallel crystal, using X-rays from synchrotron radiation. When highly parallel X-rays with the energy near an absorption edge of an atom or a nucleus are incident on a thin crystal in the Bragg case, a part of X-rays is confined in the crystal and do not come out either from the top or the bottom surface. The density of confined beam increases as the width of the incident beam is increased. The confined beam can come out from an edge of a thin crystal with higher density than the incident beam. [DOI : 10.1143/JJAP.43.L865]

Keywords: X-ray beam condensation, X-ray beam confinement, X-ray wave-guide, X-ray laser, Borrmann effect, X-ray splitter

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A Low Threshold Current Density InAs/AlGaSb Superlattice Quantum Cascade Laser Operating at 14 μm

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(Received May 7, 2004; accepted May 13, 2004; published June 11, 2004)

We report a low threshold current density InAs/AlGaSb superlattice quantum cascade laser operating at 14 μm. In order to reduce the threshold current density, InAs/AlGaSb superlattice is 0.92 kA/cm^2, which is about 5 times lower than that of the first InAs/AlSb quantum cascade laser reported earlier. This is among lowest threshold current density of quantum cascade lasers operating in the mid-infrared spectrum region. [DOI : 10.1143/JJAP.43.L879]

Keywords: quantum cascade laser, superlattice, molecular beam epitaxy, InAs, AlGaSb

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New Class of Diluted Ferromagnetic Semiconductors based on CaO without Transition Metal Elements

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(Received April 26, 2004; accepted May 25, 2004; published June 18, 2004)

We propose a new class of diluted magnetic semiconductors based on CaO without transition metal elements. The electronic structure and the magnetic properties of B-, C- or N-doped CaO are calculated by using the Korringa- Kohn-Rostoker method within the local spin density approximation. The substitutional and magnetic disorder is taken into account by the coherent potential approximation. It is found that B, C and N impurities show finite local magnetic moments in CaO at the oxygen-substitutional site. Moreover, these C- and N-doped CaO show the roomtemperature ferromagnetism with half-metallic density of states. [DOI : 10.1143/JJAP.43.L934]

Keywords: materials design, *ab initio* calculation, calcium oxide, p-impurity band, ferromagnetism without transition metal elements

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Unusual Phosphorescence Characteristics of Ir(ppy)$_3$ in a Solid Matrix at Low Temperatures

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We observed unusual radiative decay characteristics of a (*fac*-tris(2-phenylpyridine)iridium [Ir(ppy)$_3$]) tripletexcited state doped into 4, 4′-N, N′-dicarbazole-biphenyl (CBP) and polymethylmethacrylate (PMMA) host matrices. From a measurement of the temperature dependence on the phosphorescence intensity and the lifetime of Ir(ppy)$_3$ in these hosts, we observed that phosphorescence intensities are independent of temperature, while the lifetimes significantly increase at temperatures below T ~ 50 K. These results lead us to conclude that the non-radiative transition rate (k_{nr}) from the triplet excited state is very small compared with the radiative transition rate (k_r) and that the phosphorescence quantum yield (ϕ_{PH}) is nearly 100% even at room temperature. Based on our experimental results, we propose a possible decay mechanism to rationalize the characteristic temperature dependence on the transient phosphorescence. [DOI : 10.1143/JJAP.43.L937]

Keywords: phosphorescence, Ir(ppy)$_3$, OLED, electroluminescence, MLCT, triplet, lifetime

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Characteristic of the Si(100) Surface Low-Temperature Phase with Two Competing Structures Investigated by Rare Gas Adsorption

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The change of the Si(100) surface, exposed to Kr gas at 10 K with the scanning tunneling microscopy (STM) tip being extracted, was observed by STM. For a n-type sample, a p(2 × 2)/c(4 × 2) coexisting structure was stably observed even at low Kr coverage, and the amount of the c(4 × 2) area increased with increasing the coverage. These results clearly show the appearance of the p(2 × 2) phase at 10 K. The Kr growth process was observed by low-energy electron diffraction measurement for both n- and p-type samples, suggesting the influence of the STM measurement on the c(4 × 2) structure observed for the p-type sample at 10 K. [DOI : 10.1143/JJAP.43.L990]

Keywords: STM, Si(100), rare gas adsorption, LEED, ground state, low temperature phase, dimer

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Non-classical Photon Emission from a Single InAs/InP Quantum Dot in the 1.3-μm Optical-Fiber Band

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We report the first observation of single-photon emission from a single InAs/InP quantum dot at a telecommunication wavelength. The single quantum dot was developed through a 'double-cap' growth method using metalorganic chemical vapor deposition, and its emission covers a wide spectral range of the optical telecommunication band. Using a pulsed excitation source and gated single-photon detection modules, we observed a photon antibunching behavior through a single-mode optical fiber for an isolated exciton emission line at 1277.1 nm in the O-band (1.3 μm). [DOI : 10.1143/JJAP.43.L993]

Keywords: InAs/InP, single quantum dots, photon antibunching, single photon emission, O-band

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Optical "NOT" Operation in a Light Transducer in which a High-gain Photoresponsive Organic Heterojunction Device is Combined with an Organic Electroluminescent Diode

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A multilayered device combining an organic electroluminescent (EL) diode with a high-gain organic photoresponsive heterojunction between phthalocyanine and perylene pigments was fabricated. The EL output under red light irradiation was reversibly erased by superimposing blue light irradiation, due to the photosuppression of the photocurrent multiplication phenomenon at the organic/organic heterojunction. The spatial resolution for image conversion was confirmed to be finer than 280 μm. The present function can be regarded as an optical "NOT" operation. [DOI : 10.1143/JJAP.43.L1041]

Keywords: organic EL, photocurrent multiplication phenomenon, organic/organic junction, optical "NOT" operation, spatial resolution

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Ion Production Enhancement by Rear-Focusing and Prepulse in Ultrashort-Pulse Laser Interaction with Foil Targets

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It was found that the maximum ion energy produced in ultrashort-pulse laser interaction with foil targets is enhanced by a factor of five when the target is positioned before the focal point of the laser and the laser is accompanied by prepulses. A model is proposed in which the prepulse ablates the surface of the target. The resultant neutral gas guides the head of the main pulse by the Kerr effect. This finding opens up the possibility of MeV proton production by a TW-class laser. [DOI : 10.1143/JJAP.43.L996]

Keywords: ion generation, laser-matter interaction, tabletop terawatt laser, nonlinear self-focusing

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Temperature-Insensitive Eye-Opening under 10-Gb/s Modulation of 1.3-μm P-Doped Quantum-Dot Lasers without Current Adjustments

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We demonstrate temperature-insensitive eye-opening under 10-Gb/s direct modulation of 1.3-μm p-doped quantum-dot lasers without using any current adjustments. The lasers show a 6.5-dB extinction ratio between 20°C and 70°C. An active region consisting of ten quantum-dot layers with p-type doping enabled this highly temperature-stable dynamic performance, which was much superior to conventional 1.3-μm quantum-well lasers. These results make it possible to use uncooled 1.3-μm quantum-dot lasers without any current adjustments. [DOI : 10.1143/JJAP.43.L1124]

Keywords: quantum-dot lasers, p-doped layers, characteristic temperature, direct modulation

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Metallic $LaTiO_3/SrTiO_3$ Superlattice Films on the $SrTiO_3$ (100) Surface

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Metallic epitaxial $LaTiO_3/SrTiO_3$ superlattice films were fabricated on $SrTiO_3$ (100) substrates. The superlattice structure maintained compressive epitaxial strain on $LaTiO_3$ and stabilized the perovskite $LaTiO_3$ crystal phase, which is not thermodynamically stable in thick films on $SrTiO_3$. The superlattice films had very smooth surfaces and grew coherently on the substrates. The lowest resistivity was obtained in a $(LaTiO_3)_2/(SrTiO_3)_3$ superlattice film, reaching 200$\mu\Omega$·cm at 300 K. These superlattice films can be applied as epitaxial electrodes in n-type $SrTiO_3$ epitaxial heterodevices such as field-effect transistors. [DOI : 10.1143/JJAP.43.L1178]

Keywords: $LaTiO_3$, $SrTiO_3$, superlattice, conducting oxides, titanate, epitaxial electrodes

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Electronic Transition of Cobalt Monoxide under High-Pressure

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Pressure and temperature dependence of electrical resistance of cobalt monoxide (CoO) was examined using a diamond anvil cell to 133 GPa and 20-300 K. At room temperature, drastic decrease in the electrical resistance (eight orders of magnitude) was observed in the pressure range of 43 to 63 GPa. Another small decrease in the electrical resistance was also observed at about 90 GPa. These results were consistent with the phase transitions at 43 GPa and 80-90 GPa previously observed by in situ X-ray diffraction experiments. Temperature dependence of the electrical resistance showed metallic behavior at 133 GPa, indicating that the physical properties of the cobalt monoxide was completely altered under extreme pressure of 100 GPa region. [DOI : 10.1143/JJAP.43.L1281]

Keywords: transition metal oxide, cobalt monoxide, phase transition, electronic transition, electrical resistance, high pressure, diamond anvil cell

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Freestanding Individual Single-walled Carbon Nanotube Synthesis Based on Plasma Sheath Effects

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We report the successful synthesis of vertically aligned single-walled carbon nanotubes (SWNTs) at relatively low temperatures below 650°C using very short-time (30 s) plasma-enhanced chemical vapor deposition (PECVD) process. Based on the detailed transmission electron microscopy observation, it is revealed that all of the shortlength SWNTs growing from catalysts which are fixed by zeolites form individual shapes. According to the comparison between general PECVD and our PECVD, several requirements for the SWNT growth under PECVD are claimed. [DOI : 10.1143/JJAP.43.L1278]

Keywords: single-walled carbon nanotube, plasma-enhanced chemical vapor deposition, zeolite, freestanding, low-temperature synthesis

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Continuous-Wave Deep Blue Generation in a Periodically Poled $MgO:LiNbO_3$ Crystal by Single-Pass Frequency Doubling of a 912-nm $Nd:GdVO_4$ Laser

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Continuous-wave blue light generation at 456 nm is reported in bulk periodically poled $MgO:LiNbO_3$ by single-pass frequency doubling of a $Nd:GdVO_4$ laser operating at 912 nm. The $Nd:GdVO_4$ laser had a maximum output power of 2.6 W for 15.7 W pump power, with a beam M^2 factor of 1.4. $MgO:LiNbO_3$ samples of 1.0-mm thickness and 4.2 μm domain period were fabricated by using a high-voltage multipulse poling method. A maximum blue power of 167 mW with 8.3% infrared-to-blue conversion efficiency and 4.2%/W normalized conversion efficiency was obtained. To the best of our knowledge, this is the first report on continuous-wave deep blue (below 460 nm) generation by quasi-phase matching in periodically poled $MgO:LiNbO_3$. [DOI : 10.1143/JJAP.43.L1293]

Keywords: second-harmonic generation, blue light, quasi-phase matching, periodically poled $MgO:LiNbO_3$, $Nd:GdVO_4$ laser

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Development of Ultra-Fast Semiconducting Scintillators Using Quantum Confinement Effect

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The concept of a "quantum scintillator", satisfying both a large light output and a quick response, is proposed. The temporal behavior of scintillation from $(n\text{-}C_6H_{13}NH_3)_2PbI_4$, a natural multiple quantum well structure provided by the lead-halide-based perovskite-type organic-inorganic hybrid compound, was investigated using a short-pulsed electron beam and a streak camera. A decay component of 390 ps was efficiently observed even at room temperature. This response is notably quicker than conventional Ce^{3+}-activated scintillators because of a quantum confinement effect that increases the overlapping region of electron and hole wavefunctions in the lowdimensional system. This achievement would be the next breakthrough in the development of ultra-fast inorganic scintillators. [DOI : 10.1143/JJAP.43.L1333]

Keywords: pure semiconducting scintillator, low-dimensional quantum confinement system, C_6PbI_4, C_3PbBr_4, excitonic luminescence, thermal quenching, microchannel-plate photomultiplier tube (MCP-PMT), electron linac, nanotechnology

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Diameter-Controlled Carbon Nanotubes Grown from Lithographically Defined Nanoparticles

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We report the novel synthesis method of iron nanoparticles that can easily control both position and diameter significantly smaller than the lithography limit, and also demonstrate diameter- and position-controlled carbon nanotube (CNT) growth from the nanoparticles. We patterned iron particles having a 1.7 ± 0.6 nm diameter distribution within a positioning accuracy of ± 5 nm by means of the "lithographically-anchored nanoparticle synthesis (LANS)" method. CNTs were grown by chemical vapor deposition using ethanol. A catalyst activity of ~10% and a CNT diameter distribution of 1.3 ± 0.4 nm were obtained. Raman spectroscopy revealed the presence of single-walled CNTs. [DOI : 10.1143/JJAP.43.L1356]

Keywords: carbon nanotube, nanoparticle, chemical vapor deposition, Raman spectroscopy, electron beam lithography, electron beam resist

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