IX-S Development and Research of Advanced Tunable Solid State Lasers

Diode-pumped solid-state lasers can provide excellent spatial mode quality and narrow linewidths. The high spectral power brightness of these lasers has allowed high efficiency frequency extension by nonlinear frequency conversion. Moreover, the availability of new and improved nonlinear optical crystals makes these techniques more practical. Additionally, quasi phase matching (QPM) is a new technique instead of conventional birefringent phase matching for compensating phase velocity dispersion in frequency conversion. These kinds of advanced tunable solid-state light sources, so to speak “Chroma Chip Lasers,” will assist the research of molecular science.

In this projects we are developing Chroma Chip Lasers based on diode-pumped-microchip-solid-state lasers and advanced nonlinear frequency conversion technique.

IX-S-1 300W Continuous-Wave Operation of Diode Edge-Pumped, Hybrid Composite Yb:YAG Microchip Laser

TSUNEKANE, Masaki; TAIKA, Takunori


300 W continuous-wave operation of a diode edge-pumped, hybrid (single-crystal/ceramic) composite, Yb3+:YAG microchip laser with a 5-mm-diameter and 300-μm-thickness, single-crystal core uniformly bonded to a water-cooled heat-sink by the new Au–Sn soldering system has been demonstrated. The beam quality factor, M2 follows the mode-mismatch between the core and the fundamental mode, and was improved to 17 with the maximum output power of 230 W. The thermally induced convex mirror with a spherical radius of curvature ranging from –2.5 to –1.5 m, which decreases as the pump power increases by thermal deformation of a microchip, was observed.

Figure 1. CW output power and the beam quality characteristics (M2 factor) with four different cavity configurations as a function of input pump power.


SATO, Yoichi; TAIKA, Takunori; IKESUE, Akio

[OSA Topical Meeting of Advanced Solid State Photonics TuB3 (2006)]

We have fabricated the all-ceramic layered composite device with Nd:YAG and Nd:YSAG, which can perform efficient laser oscillation. From its spectroscopic properties, this layer-by-layer composite device will offer new function of laser oscillation by pump wavelength tuning. For example when pumped from YSAG side at 810.5 nm, it can oscillate at 1064 nm. On the other hand,! it will oscillate at 1061 nm when pumped at 808.5 nm.

Due to the difference in the dependence on the wavelength of the portion of the pumped power absorbed in Nd:YAG-layer and in Nd:YSAG-layer depends on the pumping wavelength. This resulted in the tuning of the component ratio of the Nd:YAG and Nd:YSAG in the fluorescence. The dependence of fluorescence profiles in this composite on the pump wavelength is shown in Figure 1.

Figure 1. Measured fluorescent spectral profiles by changing pumping wavelength.

IX-S-3 Thermal Properties of Y3Al5O12, GdVO4, and YVO4

SATO, Yoichi; TAIKA, Takunori
We have measured thermal conductivity of Y₃Al₅O₁₂, GdVO₄, and YVO₄. In order to avoid the misleading from three-dimensional (3D) thermal diffusion, we developed the quasi-one-dimensional (q1D) flash method. By taking into account the heat radiation effect in transparent materials for this measurement, YVO₄ was found to have larger thermal conductivity than GdVO₄. The measured thermal conductivities were 12.1, 10.5, 10.1, 8.9, and 8.5 W/mK for c-cut YVO₄, c-cut GdVO₄, YAG, a-cut YVO₄, and a-cut GdVO₄, respectively. The measured value in the range from room temperature to 200 °C is shown in Figure 1. The dependence of Nd-conductivity coefficient (dκ/dC Nd) for convenient evaluation of the doping effect in thermal conductivity is also discussed.

IX-S-4 Spectroscopic Properties and Laser Operation of RE³⁺-Ion Doped Garnet Materials

TAIRA, Takunori; SATO, Yoichi; SAIKAWA, Jiro; IKESUE, Akio¹
(¹JFCC)

Lately developed RE³⁺-ion-doped disordered laser ceramic materials, Y₃ScₓAl₅₋ₓO₁₂ (YAG), have been interested in because of its compositional tuning of parameter x. The disordered Y₃ScAl₄O₁₂ (YAG/YSAG) ceramics exhibit relatively low minimum pump intensity (Iₘₐₓ) and broad emission bandwidth. The value of Iₘₐₓ in the Yb:Y₃ScAl₄O₁₂ ceramics was found to be 2/3 compared with the Yb:YAG single crystal under 970nm zero-line pumping. Efficient laser oscillation of 72% slope efficiency was obtained for input power. Next, we have demonstrated passively mode-locked Yb:Y₃ScAl₄O₁₂ disordered ceramic laser by using a semiconductor saturable-absorber mirror. Pulses as short as 280 fs having an average power of 62 mW at 1035.8 nm was obtained as shown in Figure 1. As a conclusion, the possibility of tailored fluorescence spectral profile in layer-by-layer type ceramic composite is also discussed.

IX-S-5 Comparative Study on the Spectroscopic Properties of Nd:GdVO₄ and Nd:YVO₄ with Hybrid Process

SATO, Yoichi; TAIRA, Takunori

We have proposed the hybrid procedure of determining spectroscopic parameters for uniaxial solid-state laser crystals. Figure 1 shows the procedure of this process. By using our procedure the spectroscopic properties of Nd:GdVO₄ were evaluated and compared to those of Nd:YVO₄. The product of stimulated emission cross section and fluorescence lifetime (στ product) of Nd:GdVO₄ was smaller than that of Nd:YVO₄ under 1.0-at.% of Nd³⁺-doping concentration. Because of the low value of radiative quantum efficiency of Nd:GdVO₄ (50%), careful cavity design is required for creating a well performing solid-state laser with Nd: GdVO₄, based on the larger σₑσₜ product than σₑσₜ product of Nd:YAG.

IX-S-6 High-Energy, Narrow-Bandwidth 2-µm Optical Parametric Oscillator/Power Amplifier Based on Periodically Poled MgO:LiNbO₃

SAIKAWA, Jiro; FUJII, Masaaki¹; ISHIZUKI, Hideki; TAIRA, Takunori

We have proposed the hybrid procedure of determining spectroscopic parameters for uniaxial solid-state laser crystals. Figure 1 shows the procedure of this process. By using our procedure the spectroscopic properties of Nd:GdVO₄ were evaluated and compared to those of Nd:YVO₄. The product of stimulated emission cross section and fluorescence lifetime (στ product) of Nd:GdVO₄ was smaller than that of Nd:YVO₄ under 1.0-at.% of Nd³⁺-doping concentration. Because of the low value of radiative quantum efficiency of Nd:GdVO₄ (50%), careful cavity design is required for creating a well performing solid-state laser with Nd: GdVO₄, based on the larger σₑσₜ product than σₑσₜ product of Nd:YAG.
We demonstrated a high-energy, high-efficiency quasi-phase-matched optical parametric oscillator/power amplifier system based on $5 \times 5$ mm$^2$ large aperture periodically poled MgO:LiNbO$_3$. Maximum pulse energy of 52 mJ (optical conversion efficiency of 60%) with resolution limit spectral bandwidth of < 2 nm at 2.128 $\mu$m degeneracy point was obtained. These experimental results show that large aperture PPMgLN device is useful for the development of the high-energy, efficient, narrowband 2$\mu$m light source.

**IX-S-7 High-Energy Quasi-Phase Matched Optical-Parametric Oscillation in Periodically Poled MgO:LiNbO$_3$ Device with 5 mm x 5 mm Aperture**

ISHIZUKI, Hideki; TAIRA, Takunori

Fabrication of 5mm-thick periodically poled MgO-doped LiNbO$_3$ device with 32.1$\mu$m period for mid-infrared generation was demonstrated. The periodic structure was evaluated by measurement of second-harmonic generation with $d_{31}$-coefficient. Optical-parametric oscillation using the device with uncoated 5 mm x 5 mm aperture and 36mm effective length realized a high-energy output of 77 mJ for both signal (wavelength: 1.83 $\mu$m) and idler (2.54 $\mu$m) waves with 72% slope efficiency at 110mJ pumping of Q-switched Nd:YAG laser with 12ns pulse duration.