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Laser diode end-pumped cw BaLaGa₃O₇:Nd laser

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ABSTRACT

Laser diode end pumped CW laser action in disordered crystal BaLaGa₃O₇:Nd (BLGO:Nd) has been investigated. Optical slope efficiency exceeding 50% has been recorded. The process of excited state absorption in this material has been discussed.

Recently, some interest has been directed towards disordered laser crystals activated with rare earth ions and suitable for laser diode pumping [1-3]. It has been expected that strong inhomogeneous broadening of pump band will result in higher absorption efficiency and relative insensitivity of output laser power on pump wavelength variations. Several different disordered Nd doped laser crystals have been produced in the past few years and investigated. Structural disorder in some of these crystals has been induced by substituting partially selected cations of compound by cations with different size and charges, like in the case of so called substituted garnets. Alternatively, crystals with inherently disordered structure have been doped with Nd. Reported efficiencies of lasers based on disordered crystals are lower than expected. Unsatisfactory performance has been explained by additional losses due to excited state absorption (ESA) [1] or by reduced extraction efficiency associated with inhomogeneous broadening [2]. BLGO forms tetragonal crystals with inherently disordered structure resulting from statistical distribution of La³⁺ and Ba²⁺ ions [4]. Flashlamp pumped laser action in this material has been obtained earlier [5] but the laser performance was marginal owing to high losses in long laser rods. End pumping with powerful laser diode generates an appreciable amount of heat in very restricted volume of laser active material. The attainable power levels of all-solid-state laser will depend largely on laser material's ability to withstand the thermally induced stresses and to remove the heat from pumped region. Thermal

Table 1. Thermal properties of BaLaGa₃O₇ (BLGO)

Melting point [$^{\circ}\text{C}$]	1560
Specific heat at 300K [J/gK]	0.31
Thermal expansion at 300K [K^{-1}]	$12,9 \times 10^{-6}$
dn/dT [K^{-1}]	2.0×10^{-5}
Thermal conductivity at 300K [W/cmK]	0.11

properties of BLGO have been thus determined and they are presented in Table 1. It should be noted that thermal conductivity is comparable to that of YAG, but a value dn/dT for BLGO is roughly three times

higher than for YAG. Nd doping level in commonly used laser crystals is limited to several at% since the optical quality of crystal decreases with increasing activator content. Our crystal growth experiments indicate that a Nd doping up to about 10 at% should be feasible in BLGO without serious sacrifice of optical quality, but the neodymium content has to be lower because of selfquenching of luminescence. In Fig. 1 we compare the the influence of Nd

Figure 1. Luminescence lifetimes versus Nd content for YAG:Nd and BLGO:Nd. Straight line indicates dependence of selfquenching rate on Nd content for BLGO:Nd

Table 2. Spectral characteristics of BLGO:Nd

Luminescence lifetime [μs]	280
Quantum efficiency of $^4\text{F}_{3/2}$ state	0.94
Effective bandwidth of luminescence [cm^{-1}]	175
Stimulated emission cross section [cm^2]	5.0×10^{-20}
Losses	0.02

Figure 2. Output power of BLGO:Nd laser versus absorbed pumping power for different output mirror transmissions.

concentration on luminescence lifetimes for BLGO:Nd and for YAG:Nd. Basing upon these data we chose a doping level

of 5 at%, corresponding to 2.8×10^{20} ions/ cm^3 of Nd. Spectral characteristics of BLGO :Nd sample used for laser experiment are given in Table 2. Stimulated emission cross section

reported in the table has been evaluated using spectroscopic data. Roughly 50% higher value is obtained basing on laser threshold measurements, thus verification of these results is needed. In Fig. 2 the input-output characteristics of BLGO:Nd laser pumped by a 3W SDL 2482 diode laser are shown for different output mirror transmissions.

In this experiment a planoconcave

resonator with an output mirror radius of 5 cm was used. Laser crystal was only 2.8 mm thick so as to keep the optical losses at low level, and it absorbed about 50% of impinging power. At high absorbed power levels the optical slope efficiency is 51%, a value comparable to those reported for ordered crystals. A faint yellow luminescence emerged from pumped region of crystal indicating the presence of up conversion or excited state absorption (ESA). Since the visible luminescence is observed also when laser action takes place, we suppose that it is due to ESA. In Fig. 3 the spectrum of visible luminescence in BLGO:Nd excited at 808 nm is shown. All the band may be assigned to transitions from the excited levels indicated

Figure 4. Absorption spectrum recorded at 5K and corresponding to the $^4I_{9/2}(1) - ^2G_{19/2}$ transition of Nd in BLGO. See text for the explanation of arrows position.

investigation which is prepared.

Figure 3. Spectrum of BLGO:Nd luminescence excited at 808 nm

to the ground $^4I_{9/2}$ level. In Fig. 4 we present an absorption spectrum recorded at 5K and corresponding to the $^4I_{9/2} - ^2G_{19/2}$ transition. Two arrows indicate a laser photon energy plus energies of every of two components of the $^4F_{3/2}$ level. Condition of resonance for ESA from higher component is fulfilled at low temperature. Process of ESA and its effect on the performance of lasers based on disordered crystals will be examined more closely during

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