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Neodymium doped SrLaAlO₄. A new promising crystal for laser application

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ABSTRACT

Single crystals of neodymium doped SrLaAlO₄ have been grown by the Czochralski method and investigated using the methods of optical spectroscopy. Absorption band centered at 806nm is particularly intense in this crystal and this feature seems to be advantageous for side pumping with GaAlAs laser diode bars. Available spectroscopic data indicate that excited states absorption might be of low importance in SrLaAlO₄:Nd.

SrLaAlO₄ belongs to a wide family of compounds of general formula ABCO₄, where A = Sr,Ca; B = Y, La-Gd; C = Al or Ga. Single crystals samples of undoped and Nd doped SrLaAlO₄ have been grown by the Czochralski method. The growing procedure is extremely difficult since the material tends to form nonstoichiometric compositions displaying various colours associated with absorption of light by structural defects.

At the present stage of development of our growing technique, the crystals produced contain an appreciable amount of colour centres which absorb in the blue region of spectrum.

X - ray investigation showed that the crystals are tetragonal in space group I4/mmm with lattice constants $a = 3.85$ pm and $c = 12.95$ pm. The crystal structure is built up from translationally equivalent AlO₆ layers formed in the ab plane. The aluminum atoms occupy mmm (D_{4h}) sites and are surrounded by six oxygen atoms. Among them two terminal oxygens are situated in the C_{4v} sites and the remaining four in the D_{2h} sites. Between the layers the Sr and La atoms are randomly distributed in nine-coordinated sites of C_{4v} symmetry. Resulting structural disorder broadens strongly the spectral lines associated with electronic transitions of neodymium in the doped compound.

Degree of inhomogeneous broadening of Nd luminescence is high in this matrix. In Fig. 1

Figure 1. Room temperature luminescence band associated with the ${}^4F_{3/2} - {}^4I_{11/2}$ transition

Figure 2. Effect of temperature on luminescence lifetimes for two Nd concentrations.

we present a room temperature luminescence band associated with the ${}^4F_{3/2} - {}^4I_{11/2}$ transition. Effective bandwidth of this transition is about 22 nm and may be even higher in nonstoichiometric compositions [1]. Broad luminescence band offers some output wavelength tunability, but reduces the value of stimulated emission cross section. Two samples with different Nd concentration have been investigated. One of them contained 1 at% and the other contained 5 at% of Nd. Influence of temperature on the ${}^4F_{3/2}$ luminescence lifetime is shown in Fig.2. At room temperature the selfquenching of luminescence is important and it will be a limiting factor which should be considered in evaluation of optimal doping level for laser application. At liquid helium temperature the measured lifetimes are essentially the same for both the samples. In Fig. 3 we plotted the rate of selfquenching of Nd luminescence versus temperature for the heavily doped sample. The points in this figure indicate the values obtained by subtracting the inverse values of measured lifetimes for 5 at% sample from those recorded for 1 at% sample. Strong increase of luminescence quenching with increasing temperature indicate that the process is phonon assisted or condition of resonance for cross relaxation is fulfilled for higher energy components of the ${}^4I_{9/2}$ ground state. In Fig.4 the absorption band corresponding to the ${}^4I_{9/2} - {}^4F_{5/2}, {}^2H_{9/2}$ transition of Nd in SrLaAlO_4 is presented. It should be noted that almost all band intensity is comprised in unusually narrow spectral region from about 800 nm to 813 nm. As the oscillator strength for this transition in $\text{SrLaAlO}_4\text{:Nd}$ is higher than in YAG:Nd , the absorption coefficient in the band maximum is particularly high. The pumping light from GaAlAs laser diode tuned to 806 nm will be attenuated by two orders of magnitude over only 0.5 mm of crystal containing 5 at% of Nd.

Figure 3. Rate of concentration quenching of Nd luminescence versus temperature

Figure 4. Absorption band corresponding to the $^4I_{9/2} - ^4F_{5/2}, ^2H_{9/2}$ transition.

This feature seems to be particularly advantageous for side pumping with laser diode bars. Like other disordered crystals, $\text{SrLaAlO}_4\text{:Nd}$ is expected to be an intermediate gain laser material suited for repetitively pulsed high energy lasers. However, overall efficiency of a diode laser pumped $\text{SrLaAlO}_4\text{:Nd}$ laser can not be predicted basing on spectroscopic data obtained thus far. Slope efficiencies recorded for lasers employing disordered crystals are lower than that of YAG:Nd . Unsatisfactory performance is attributed to low extraction efficiency [2] or to excited state absorption (ESA) from the metastable $^4F_{3/2}$ level [3].

Figure 5. Polarized absorption band recorded at 5K and corresponding to the $^4I_{9/2}(1) - ^2G_{19/2}$ transition.

We made an attempt to estimate the importance of the latter process using the results of spectroscopic investigation. In Fig. 5 we present a polarized absorption band recorded at 5K and corresponding to the $^4I_{9/2}(1) - ^2G_{19/2}$ transition of neodymium. Energies of the crystal field components of the $^2G_{19/2}$ state may be easily identified. Two arrows in the figure indicate the wavelengths corresponding to sums of expected laser photon energy (determined from the maximum

of luminescence band shown in Fig.1) and the energies of lower and higher crystal field components of the $^4F_{3/2}$ state. It can be seen that at low temperature the condition of resonance for ESA is not fulfilled. The mismatch is not high however. With increasing

temperature the energy levels may shift making the energy mismatch higher or lower. The experimental verification of these predictions is now being prepared.

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References

- [1] W.Ryba-Romanowski, Acta Phys. Polon. in press.
- [2] N.Mermilliod, R.Romero, I.Charlier, C.Garapon, R.Moncorgé, IEEE J.Quantum Electron 28, 1179 (1992)
- [3] T.Y.Fan and M.Kokta, IEEE J.Quantum Electron. 25, 1845, (1989)