Optical and laser properties of YAG:Nd crystals grown by the HDC method in carbon-containing atmosphere

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Yttrium aluminum garnet $Y_3Al_5O_{12}$ (YAG) doped by Nd^{3+} ions is the crystal most used as a lasing medium in various types of solid-state lasers for industrial, medical, military and scientific purposes. This is due to a good combination of advantages: high thermal conductivity, chemical inertness, mechanical strength and good generation properties (low generation threshold and losses, high efficiency). Currently YAG:Nd laser crystals are predominantly grown by the Czochralski method in an oxidizing atmosphere using expensive iridium crucibles.

In this work we report the production and investigation of spectroscopic and laser properties of YAG:Nd single crystals with a neodymium concentration of up to 1 at.% grown by the horizontal directional crystallization method (HDC) with using molybdenum crucibles and protective carbon-containing atmosphere (Ar+CO) [1]. To study the influence of the growth conditions on the optical properties, the crystals were annealed in vacuum and reducing atmosphere at 1700 ^oC and in air at 1100 ^oC.

It was established that, in addition to the lines due to the transitions of neodymium ions, the optical absorption spectra of the grown crystals contain absorption bands in the ultraviolet region of the spectrum. The maxima of these bands were recorded at $\lambda \approx 240$ nm, 290 nm and 370 nm. Its intensity is inhomogeneous along the length and thickness of the crystal and gives it a violet-blue coloration. Annealing in a reducing medium resulted in a significant increase in the absorption maxima. The annealing in vacuum or in air led to a decrease in the intensity of these peaks. The additional coloration of crystals completely disappears after oxidative annealing. This phenomenon is explained by that the corresponding bands are caused by F-centers appeared due to oxygen vacancies that were formed by the presence of carbon and/or carbon monoxides in growing atmosphere.

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Generation tests of annealed YAG:Nd elements (Ø4mmx50mm) in lamp-pumped laser systems demonstrated efficiency of ~1-1,2 % in free generation mode and obtaining pulse generation with pulse energy ~ 18-20 mJ and a duration of ~ 15 ns. These results correspond to the standard parameters of crystals obtained from iridium crucibles. Thus, we have shown for the first time the possibility of using the iridium-free technology of HDC in molybdenum crucible and reducing Ar+CO atmosphere to obtain laser grade YAG:Nd crystals.

References

[1] Nizhankovskyi S et al. Formation of longitudinal aggregation of inclusions in bulk sapphire and yttrium-aluminum garnet grown by horizontal directed crystallization method. Crystal res. and tech., 2015, 50: 223 - 229.