BRIEF COMMUNICATIONS

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Continuous lasing in $La_{1-x}Nd_xMgAl_{11}O_{19}$ crystals

Kh. S. Bagdasarov, L. M. Dorozhkin, A. M. Kevorkov, Yu. I. Krasilov, A. V. Potemkin, A. V. Shestakov, and I. I. Kuratev

N. S. Kurnakov Institute of General and Inorganic Chemistry, Academy of Sciences of the USSR, Moscow
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Investigations were made of the spectroscopic and lasing properties of lanthanum neodymium magnesium hexa-aluminate crystals. Continuous lasing was obtained for the first time in these crystals in the 1.06 μ range at room temperature.

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Investigations designed to search for neodymium laser materials having a high activator concentration are of considerable interest in quantum electronics since the problem of miniaturizing solid-state lasers can be solved to some extent by using these materials. Recent investigations in this field have resulted in the development of various stoichiometric neodymium crystals such as neodymium pentaphosphate NdP_5O_{14} and lithium neodymium tetraphosphate $LiNdP_4O_{12}$, which have unique spectral, luminescence, and lasing characteristics.

A major disadvantage of these active media is the lack of acceptable technology for growing large single crystals at present. We shall report the results of experiments on the synthesis and growth of single crystals and investigations of the lasing properties of lanthanum neodymium magnesium hexa-aluminate, $La_{1-x}Nd_xMgAl_{11}O_{19}$—a new laser material having an enhanced neodymium concentration. Unlike stoichiometric materials, this material can be obtained from the melt using well-developed and controlled methods.

The compound $LaMgAl_{11}O_{19}$ is formed in an $La_2O_3-MgO-Al_2O_3$ ternary system and melts congruently at 1970 °C (Ref. 1). Crystals of lanthanum magnesium hexa-aluminate doped with various rare-earth elements were obtained using the Verneuil method[2] and by spontaneous crystallization in lining slag.[3]

We synthesized hexa-aluminates having the compositions $La_{1-x}Nd_xMgAl_{11}O_{19}$ $(0 \leq x \leq 1)$. Single crystals were grown using the directional crystallization method and a technique described in Ref. 4. Large single crystals up to 14 mm in diameter and up to 50 mm long of satisfactory optical quality were obtained. A quantitative analysis showed that the crystal composition agreed with the composition of the initial charge and that neodymium replaced lanthanum isomorphically.

Even in the first experiments lanthanum neodymium magnesium hexa-aluminate crystals showed unique

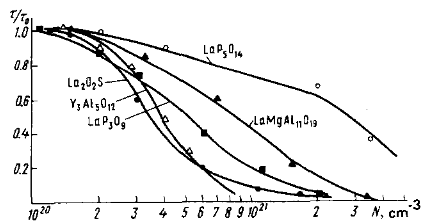

FIG. 1. Concentration dependence of the reduced lifetime of the $^4F_{3/2}$ Nd^{3+} metastable level in various laser crystals.

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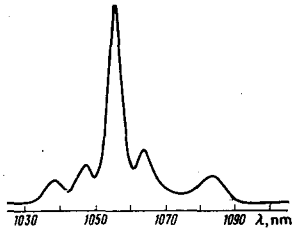

FIG. 2. Luminescence spectrum of neodymium in lanthanum neodymium magnesium hexa-aluminate corresponding to the $^4F_{3/2}$-$^4I_{11/2}$ transition at 300 K.

spectral and lasing characteristics. Figure 1 shows dependences of the reduced lifetime of the $^4F_{3/2}$ metastable state of hexa-aluminate and various known laser crystals on the neodymium concentration. It can be seen that the value of τ/τ_0 for $LaMgAl_{11}O_{19}$ varies negligibly in the range of neodymium concentrations of practical interest, 10^{20}–10^{21} cm^{-3}. In this sense, hexa-aluminate is inferior only to stoichiometric neodymium crystals. These results show good agreement with the data on the structure of hexa-aluminate. According to Refs. 2 and 3, these crystals have a magnetoplumbite $PbFe_{12}O_{19}$ structure a feature of which is the appreciable Ln–Ln distance compared with other refractory oxides. This is evidently responsible for the weaker interionic interaction and helps to suppress concentration quenching of neodymium luminescence when this is introduced into the matrix of lanthanum magnesium hexa-aluminate.

Figure 2 shows the luminescence spectrum of $La_{0,8}Nd_{0,2}MgAl_{11}O_{19}$ crystals corresponding to the $^4F_{3/2} \to I_{11/2}$ transition at room temperature. The effective cross section of the highest-intensity transition ($\lambda = 1.0547$ μ) determined from the results of spectral and lasing measurements is, according to our measurements, $\sigma = (3.5 \pm 0.3) \cdot 10^{-19}$ cm^2, which is slightly lower than the similar value for yttrium aluminum garnet and slightly higher than that for stoichiometric neodymium crystals (see Table I). The high value of σ is due to the fairly high branching coefficient of the $R_1 \to Y_1$ lasing transition ($\beta_{ij} = 0.28$) and to the relatively narrow width of the spectral line ($\Delta\nu = 26$ cm^{-1}). These properties of lanthanum neodymium magnesium hexa-aluminate mean that it can be used as an active medium for solid-state lasers in the concentration range (1–2) $\times 10^{21}$ cm^{-3}. Disadvantages of these crystals include the perfect cleavage which has meant that so far we have been unable to obtain bulk active elements.

TABLE I. Spectral and lasing parameters of lanthanum neodymium magnesium hexa-aluminate ($T = 300$ K).

Parameter	$La_{0,8}Nd_{0,2}MgAl_{11}O_{19}$	$LiNdP_4O_{12}$	Parameter	$La_{0,8}Nd_{0,2}MgAl_{11}O_{19}$	$LiNdP_4O_{12}$
$N \cdot 10^{-21}$, cm^{-3}	0.7	4.37	$\lambda = 0.580$ μ	34	—
τ, μsec	180	120	$\lambda = 0.82$ μ	26	100
λ_l, μ	1.0547	1.047	Thickness, mm	0.5	0.5
$\sigma \cdot 10^{19}$, cm^2	3,5	3.2	Passive loss factor, cm^{-1}	0.005	0.003
$\Delta\nu$, cm^{-1}	26	39			
$\varkappa$, cm^{-1}: for $\lambda = 0.5145$ μ	6	12	P_{th}, mW	0.26	0.35
			η, %	18	16

Note. The values of $\varkappa$ correspond to the maximum absorption coefficients in these spectral ranges.

Lasing experiments were carried out using active elements in the form of plates 0.5 mm thick. The pump source was a cw argon laser ($\lambda = 0.5150$ μ). The pump radiation was focused onto the active element in a hemispherical resonator. The radius of curvature of the spherical exit mirror was 10 mm and the transmission at the lasing wavelength was 0.5%. The transmission of the plane mirror did not exceed 0.1% at the lasing wavelength and was 90% at the pump wavelength.

Continuous lasing was obtained at $\lambda = 1.0547$ μ (the lasing parameters are shown in Table I). A comparison between the lasing parameters of $La_{0,8}Nd_{0,2}MgAl_{11}O_{19}$ and $LiNdP_4O_{12}$ crystals made under equivalent experimental conditions shows that in this case, hexa-aluminate has a certain advantage. In particular, the threshold pump energies are 0.28 and 0.35 mW, respectively. The efficiency of conversion of the pump energy to laser radiation is also slightly higher for hexa-aluminate ($\eta = 18$ and 16%, respectively). These results indicate that $La_{1-x}Nd_xMgAl_{11}O_{19}$ crystals are potentially useful for optically pumped solid-state lasers.

[1]C. Brisi, F. Abbattista, and M. Vallino, Rev. Intern. Haut. Temp. Refract. 17, 331 (1980).

[2]F. Haberey, R. Leckebusch, M. Rosenberg, and K. Sahl, Naturwissenshaften 68, 376 (1981).

[3]A. G. Avanesov, K. B. Achmiz, P. I. Bykovskiĭ, Yu. A. Kuznetsov, V. F. Pisarenko, and N. G. Chernaya, Izv. Akad. Nauk SSSR Ser. Neorg. Mater. 17, 833 (1981).

[4]P. A. Arsenev, C. M. S. Bagdasarov, K. E. Bienert, E. F. Kusto, and A. V. Potemkin, Kristalle in der modernen Lasertechnik [Technisch-Physikalische Mongraphien, Vol. 39], Akademie Verlagsgesellschaft; Geest und Portig K.-G., Leipzig (1980).

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