THE LANTHANUM OXY-SULFIDES, ACTIVATED BY NEODYMIUM IONS ARE PERSPECTIVE CRYSTALS FOR THE MINIATURE LASERS

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The decay kinetics of $^4F_{3/2}$ of level Nd^{3+} in the crystals La_2O_2S has been investigated. The dependence of threshold of generation on the nonresonance losses and the output power on the input one at the multimode regimes has been calculated.

In spite of the fact, that three-valence neodymium ions in the crystals La_2O_2S have intensive absorption bands and the big cross-section of the laser transition in the comparison with the corresponding parameters of three-valence neodymium ion in YAG, because of the bad optical quality, La_2O_2S-Nd^{3+} hasn't been widely applied in laser technique. In the work [1], it is informed, that in La_2O_2S-Nd^{3+} at the impulse pumping, the generation with the threshold lower, than YAG-Nd^{3+} has been obtained and is proposed, that the differential efficiency in 8-12 times bigger, than YAG-Nd^{3+} in the continuous mode can be achieved. In the difference from the lamp pumping, at the pumping by the semiconductor lasers or light emitting diode, the crystals with the bigger sizes don't need and that's why La_2O_2S-Nd^{3+} can become the perspective materials for miniature lasers. The aim of the present work is the comparison of the dependence of threshold generation on the nonresonance losses, and also the dependence of output on the pumping power for La_2O_2S-Nd^{3+} with the analogical dependence YAG-Nd^{3+} and the investigation of the concentration quenching of neodymium ions in La_2O_2S.

1. The concentration quenching of neodymium ions in La_2O_2S

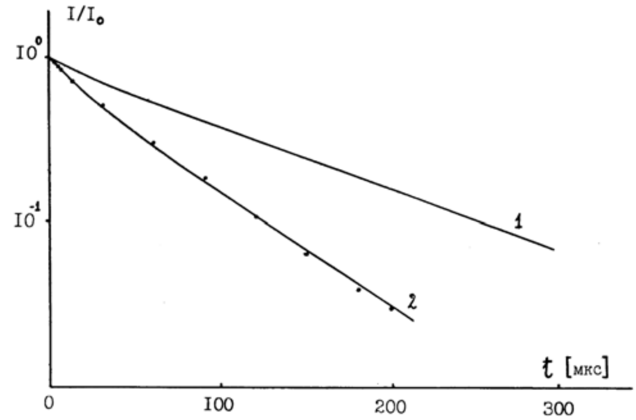

Fig. 1. The experimental (total lines) and calculated (dots) decay curves of the upper laser level of neodymium in the crystal La_2O_2S at the different neodymium concentrations and the excitation with λ=0,53mcm: 1-0,8%; 2-x=1,8%.
The curve 1 corresponds to the radiation decay.

The decay curves of $^4F_{3/2}$ of Nd^{3+} layer ions in La_2O_2S is presented on the fig.1. The decay curve is exponential with the constant time 100mcsec at the small ion concentration. This time is radiation time. At the big concentration the curve becomes the nonexponential, however on the far stage the output on the exponential part takes place.

As it is known, the concentration quenching of neodymium ions goes in three stages, which reveal on decay curves.

The first stage is the statically ordered, the second stage of the statistically disordered decay connects with acceptor relative intensity y ($y=\frac{n_A}{n_0}, n_0$ – is the total number of lattice points in the volume unit, which can be full of acceptors) by the ratio [2]

$$W_{CT} = yC_{DA}\sum_i R_i^{-6} \tag{1}$$

where sum is taken by all points of acceptor sublattice (center in donor), but C_{DA} is microparameter, which characterizes the donor-acceptor interaction. For the definition of C_{DA} microparameter it is need to know the lattice sum $\sum_i R_i^{-6}$.

At the definition of lattice sum the structural data, taken from the work [3], according to which La_2O_2S has space group $D_{3d}{}^3$ were used. The point symmetry, filled by lanthanum (neodymium) is $C_{3\upsilon}$. The elementary cell of La_2O_2S is ortorombical with parameters: a=4Å, c=6,82Å, c/a=1,7. The lattice sum, calculated by us, is equal to $3{,}4\cdot10^{45}$ cm^{-6}, and minimal distance between neodymium ions R_0=3,7Å. Knowing the lattice sum and velocity of the statical ordered decay, the microparameter of donor-acceptor interaction, which is equal to $C_{DA}=4{,}3\cdot10^{-40}$ cm^6sec^{-1}, was defined by us.

In the work [4], the theory of quenching of luminescence at the presence of excitation migration on donors is spread, kinetics of the luminescence decay in all time scale is found and the expression for the velocity of migrated quenching in the common form is obtained:

$$\Pi(t) = \int_0^t W(t')dt' \tag{2}$$

$$W(t) = 4\pi n_A \int_0^\infty W_{DA}(R)n(R.t)R^2 dR \tag{3}$$

$$n(R.t) = (1+W_{DA}\tau)^{-1}\{1+W_{DA}\tau \exp\left[-(\tau^{-1}+W_{DA})t\right]\}, \tag{4}$$

here $\Pi(t)$ -function of the nonradiation energy transfer, n_A is acceptor concentration, $W_{DA}=C_{DA}/R^S$ is probability of the couple donor-acceptor interaction, S is the multiplicity of donor-acceptor interaction, $n(R.t)$ is the instant excitation density on the donor, being on the distance R from acceptor (it is considered, that $n(R.0)=1$), τ - is the more probable time of the one excitation "jump", which is equal to the case of dipole-dipole donor-donor interaction:

$$\tau = \left(\frac{8}{27} \pi^3 C_{DD} n_D^2 \right)^{-1} \qquad (5)$$

The consideration the real crystalline structure of the sample leads to the expression, obtained in [5] in limits of approach [4]:

$$W(t) = \frac{n_A}{n_D} \sum_i W_{DA} n(R_i, t), \qquad (6)$$

summation on the points of donor lattice, n_D is the number of donor points in the volume unit. The calculation of total kinetics decay of the excited state on the expression [6] allows to define the microparameter of donor-donor transmission C_{DD} without use of the approximation treatment methods of experimental results, based on the asymptotic approximations, the evidence of which needs the special consideration. The definition circuit C_{DD}, offered in the work [6] is following. The decay curves in all time interval corresponding to the experimental plots at the above mentioned definite value C_{DD} are calculated. The design lattice of the curves puts on the experimental plot, which is obtained at the given concentration of donors and acceptors and from the condition of the best agreement of calculated and experimental kinetics, the microparameter C_{DD} value is defined. The best agreement of the calculated and experimental decay curves in the all time range at $C_{DD}=3\cdot10^{-38}cm^6sec^{-1}$. Thus, the microparameters, defined by us, allow to define such characteristics of the substance, as luminescence quantum output, optimal concentrations of the active impurities and e.t.c.

2. The comparison of the generation parameters $La_2O_2S\text{-}Nd^{3+}$ and $Y_{2,97}Nd_{0,3}Al_5O_{12}$

The wave lengths of λ_p pumping, corresponding to the transfer maximums ${}^4I_{9/2} \rightarrow {}^4F_{9/2}$ of Nd^{3+} ions, are equal to 820 nm and 808 nm for the crystals La_2O_2S-1%Nd^{3+} and $Y_{2,97}Nd_{0,3}Al_5O_{12}$, correspondingly. The crystal length ℓ was considered as optimated one $\ell \sim \frac{1}{\alpha_P}$, where α_P is absorption coefficient on the wave length of pumping. The life times τ of upper laser layer ${}^4F_{3/2}$ are equal to 100 mcsec ~~and 230 mcsec, the value of resonance loss Γ_R is equal to~~ 0,16% and 0,2%, the cross-section of the generation transfer (σ) is equal to $2{,}1\cdot10^{-18}cm^2$ and $46\cdot10^{-20}cm^2$, particle part (F) on the Stark sublevel of upper laser level is equal to 0,52 and 0,4 for the crystals La_2O_2S-1%Nd^{3+} and $Y_{2,97}Nd_{0,3}Al_5O_{12}$, correspondingly.

Applying the expression

$$P_{порог} = \frac{hc(\Gamma_0 + \Gamma_R)}{2\lambda_p \left[1 - \exp\left(-\alpha_p \ell\right)\right] \cdot F \cdot \tau \cdot \sigma} \qquad (7)$$

for the calculation of the generation threshold at the longitudinal excitation, the plots of dependencies P_{thres} on nonresonance loss Γ_0 for crystals La_2O_2S-1%Nd^{3+} and $Y_{2,97}Nd_{0,3}Al_5O_{12}$ have been constructed by us. From the fig.2 it is well seen, that power of generation threshold of $Y_{2,97}Nd_{0,3}Al_5O_{12}$ is higher, than La_2O_2S-1%Nd^{3+}.

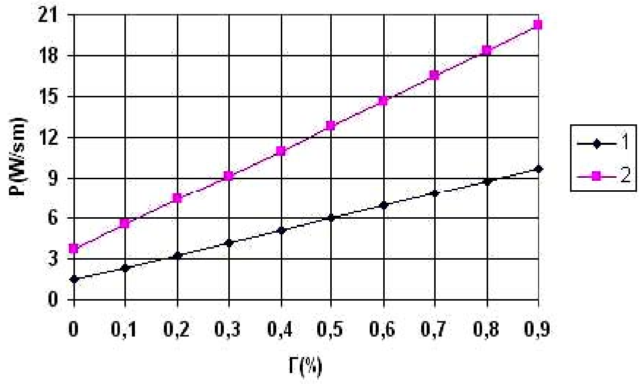

Fig.2. The dependence of the density of pumping threshold power on the nonresonance losses at the longitudinal pumping: 1- La_2O_2S-1%Nd^{3+}
2 - $Y_{2,97}Nd_{0,3}Al_5O_{12}$

Fig.3. The dependence of output power on the input one at the longitudinal pumping in the multimode regime: 1 - La_2O_2S-1%Nd^{3+}
2 - $Y_{2,97}Nd_{0,3}Al_5O_{12}$

The laser output power is defined by the following expression

$$P_{output} = f(\frac{\nu_L}{\nu_P})(P_{input} - \frac{\Gamma_R}{\Gamma}P_{thres})\left(1 - \frac{1}{\sqrt{\dfrac{P_{input} - \dfrac{P_R}{\Gamma}P_{thres}}{(1 - \dfrac{\Gamma_R}{\Gamma})P_{thres}}}}\right)^2 \quad (8)$$

The ratio $\left(\frac{\nu_L}{\nu_P}\right)$, (where ν_L, ν_P are frequencies of generation and pumping) is equal to 0,763 for the crystals La_2O_2S-1%Nd^{3+} and $Y_{2,97}Nd_{0,3}Al_5O_{12}$. The values of nonresonance losses were accepted as 0,15%.

The calculated values of P_{thres} were equal to 0,079 mW and 0,8 mW for the crystals La_2O_2S-1%Nd^{3+} and $Y_{2,97}Nd_{0,3}Al_5O_{12}$ at the beam diameter *D*=60mcm and Γ_0 =0,15%.The plots, describing the dependences of P_{output} on the P_{input} are given on the fig.3. It is seen, that both plots are almost coincide. This is connected with the fact, that at $P_{input} \rangle \frac{\Gamma_R}{\Gamma} P_{thres}$ in formula (8) the P_{input} gives the main deposit.

Thus, we conclude, that it is possible to create miniature lasers with the record characteristics on the crystal base La_2O_2S-1%Nd^{3+}.

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NEODİMLƏ AKTİVLƏŞDİRİLMİŞ LANTAN OKSİSULFİDİ - MİNİATYÜR LAZERLƏR ÜÇÜN PERSPEKTİVLİ KRİSTALLARDIR

La_2O_2S kristallarında Nd^{3+} ionlarının $^4F_{3/2}$ səviyyəsinin kinetikası tədqiq olunub. Generasiyanın baş vermə həddinin qeyri-rezonans itkilərdən və çox modalı rejimdə çıxış gücün giriş gücündən asılılığı hesablanıb.

Г.И. Абуталыбов, А.А. Мамедов

ОКСИСУЛЬФИДЫ ЛАНТАНА, АКТИВИРОВАННЫЕ ИОНАМИ НЕОДИМА - ПЕРСПЕКТИВНЫЕ КРИСТАЛЛЫ ДЛЯ МИНИАТЮРНЫХ ЛАЗЕРОВ

Исследована кинетика распада $^4F_{3/2}$ уровня Nd^{3+} в кристаллах La_2O_2S. Вычислена зависимость порога генерации от нерезонансных потерь, а также выходная мощность от входной при многомодовых режимах.

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