intensities $I_{tr}/I_{b1,2}$ (I_{tr} and $I_{b1,2}$ are the intensities of the responses, excited by triangular and bell-shaped pulses with n = 1 and n = 2, respectively) $I_{tr}/I_{b1} = 0.87$, $I_{tr}/I_{b2} = 0.92$.

Thus the maximum amplitude and intensity of the echo signal are obtained with bell-shaped and triangular excitation pulses, while for square pulses they are minimum. To determine correctly the effect of the pulses shape, the width of the spectrum of a pulse of any shape must be less than the inhomogeneous width of the line. Otherwise the same number of spin packets, irrespective of the pulse shape, will be drawn into the excitation process. In [2], in a study of the spin echo on E_1' centers in quartz the experimental conditions corresponded to the approximation of a wide spectral line, which is what made it possible to follow the effect of the shape of the exciting pulses on the intensity of the echo signal.

We thank V. V. Samartsev for valuable remarks, which he made while reading the manuscript.

LITERATURE CITED

1. B. P. Smolyakov and E. P. Khaimovich, Zh. Éksp. Teor. Fiz., 76, No. 4, 1303-1308 (1979).
2. G. G. Fedoruk, Candidate's Dissertation in Physical-Mathematical Sciences, Minsk (1981).
3. A. A. Kharkevich, Spectra and Analysis [in Russian], Moscow (1962).
4. S. O. Elyutin, S. M. Zakharov, and É. A. Manykin, Zh. Éksp. Teor. Fiz., 76, No. 3, 835-845 (1979); S. O. Elyutin, S. M. Zakharov, and V. A. Zuikov, Zh. Éksp. Teor. Fiz., 88, No. 2, 401-416 (1985).
5. A. G. Shagidullin, Proceedings of the 1st All-Union Symposium on Light Echoes, Kazan' (1973), pp. 107-112.
6. É. A. Manykin and V. V. Samartsev, Optical Echo-Spectroscopy [in Russian], Moscow (1984).

BRIGHTENING IN THE UV REGION OF GSGG CRYSTALS AFTER γ-IRRADIATION

M. Kh. Ashurov, I. N. Nasyrov,
V. V. Osiko, and P. K. Khabibullaev

UDC 535.34:539.12.04

The use of a laser based on gadolinium–scandium–gallium garnet (GSGG) in various devices [1, 2] makes the detailed study of the properties of this active medium topical [3]. In this paper we report the results of studying the effect of thermal treatment and γ-irradiation on the optical absorption of GSGG crystals.

The crystals studied were grown by the Czochralski method. The absorption spectra were recorded at 300 K over the range 200-800 nm. Heat treatment was carried out in air and in vacuum for 1 h up to 1500 K. The specimens were irradiated by ^{60}Co γ-radiation with a power of 1400 R/sec to a dose of 10^6 R. The thermoluminescence curves of the irradiated specimens were recorded over the range 300-500 K using a rate of heating of 0.2 deg/sec.

Figure 1 shows the abosrption spectra of a GSGG crystal which had not undergone thermal treatment and had been annealed in air and in vacuum at 1300 K. Against a background of narrow absorption bands corresponding to the f–f transitions of the Gd^{3+} ions a structureless absorption band is observed in the UV region ($\lambda < 300$ nm), the intensity of which increases with a decrease in the wavelength. Compared with the initial specimen the concentration of the centers absorbing in the UV region after annealing in air is increased but after annealing in vacuum it decreases.

After γ-irradiation a charge transfer of the absorbing centers takes place. The resulting changes in the absorption spectra are reflected in Fig. 2. In the visible region a broad, structureless absorption band appears, while in the UV region at $\lambda < 300$ nm the absorption intensity is reduced substantially (the "brightening effect"). For the crystal annealed in air the brightening observed in the UV region is stronger and the absorption

Translated from Zhurnal Prikladnoi Spektroskopii, Vol. 48, No. 1, pp. 124-127, January, 1988. Original article submitted July 17, 1986; revision submitted July 14, 1987.

 © 1988 Plenum Publishing Corporation

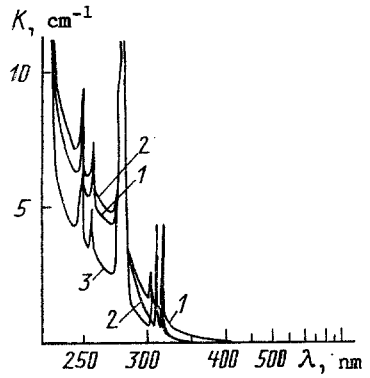

Fig. 1

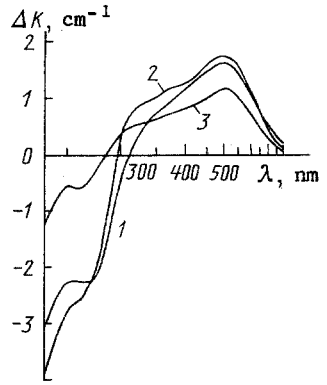

Fig. 2

Fig. 1. Absorption spectra of GSGG crystals: freshly grown (1), after annealing at 1300 K for 1 h in air (2) and in vacuum (3).

Fig. 2. Induced absorption spectra of GSGG crystals after γ-irradiation at 300 K with a dose of 10^6 R: initial (1), heat-treated in air (2), and in vacuum.

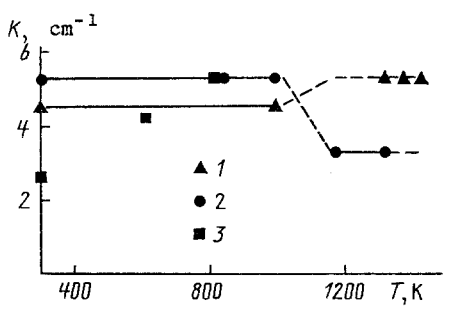

Fig. 3

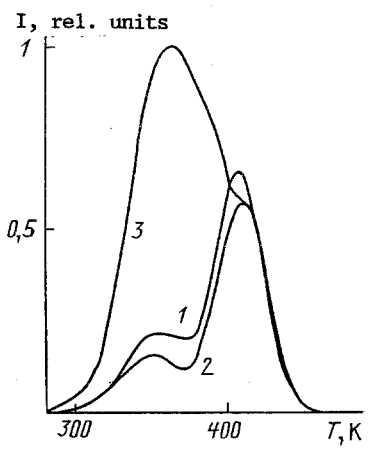

Fig. 4

Fig. 3. Variation with temperature in the UV absorption of GSGG crystals at a wavelength λ = 260 nm for a constant exposure time of 1 h after thermal treatment in air of the initial crystal (1) and in air of the crystal annealed in air (2), as well as after γ-irradiation with a dose of 10^6 R of a crystal annealed in air, exposure time 1 min (3).

Fig. 4. Thermoluminescence of GSGG crystals γ-irradiated with a dose of 10^6: initial (1), heat-treated in air (2), and in vacuum (3).

induced in the visible region is greater, while for the crystal annealed in vacuum the illumination is weaker and the induced absorption is lower than for the crystal not subjected to thermal treatment.

According to the relationship obtained between intensity of the induced absorption and the irradiation dose in the region of the absorption maximum (λ = 500 nm), the intensity of induced absorption for the specimen annealed in air reaches saturation at higher doses and at higher levels, while for the specimen annealed in vacuum saturation is reached at lower doses and at a lower level compared with the freshly grown specimen. For example, saturation up to 95% of the maximum intensity of the induced absorption for the specimen annealed in air occurs for a dose of $5 \cdot 10^4$ R, for the freshly grown specimen it occurs at $4 \cdot 10^4$ R, and for the specimen annealed in vacuum it occurs at $2 \cdot 10^4$ R.

A study of the variation in the absorption spectrum of a GSGG crystal as a function of the annealing temperature for a constant exposure time of 1 h showed that the concentration of centers absorbing in the UV region varies principally at a temperature above 1000 K. Figure 3 shows the variation in the absorption coefficient for a wavelength of λ = 260 nm. There is a saturation region at T > 1000 K, where the concentration of these centers is virtually unchanged. Annealing in vacuum at T = 1500 K leads to a darkening at the center of the crystal and the formation of an opaque whitish layer on the surface.

The changes caused by γ-irradiation in the absorption spectra disappear on heating at a temperature far below 1000 K. For example, at T = 800 K the absorption in the UV spectrum (λ = 260 nm) of the specimen annealed in air is restored completely to the initial absorption (Fig. 3).

A study of the thermoluminescence of γ-irradiated specimens shows that simultaneously with the decrease in the number of centers absorbing in the UV region after annealing in vacuum an increase occurs in the number of centers which release charges captured during the irradiation, which corresponds to the recombination luminescence maximum at 360 K (Fig. 4). However, the increase in the number of centers absorbing in the UV region after annealing in air is accompanied by a decrease in the intensity of the peak having a maximum at 360 K.

The results obtained are in good agreement with previously conducted studies of other crystals having a garnet structure. For example, for specimens of yttrium–aluminum garnet (YAG) grown in a nitrogen atmosphere, the absorption observed in the UV region is appreciably greater than for specimens grown in vacuum [4]. After shortwave irradiation brightening is observed in the UV region in YAG crystals grown in a nitrogen atmosphere, while in the visible region induced absorption is observed [5]. In [6] brightening in the UV region was also observed after γ-irradiation for gallium garnet crystals grown by the Czochralski method. The centers absorbing in the UV region are interpreted as structural defects of the oxygen sublattice which are formed during the growth of the crystals, the recharging of which after γ-irradiation leading to a decrease in the UV absorption.

Numerical modeling which we conducted of the kinetics of induced coloration buildup as a function of irradiation dose shows that the experimentally observed saturation, more rapid and at a lower level, of the induced absorption of the crystal annealed in vacuum may be obtained both as a result of a general decrease in the number of defects and as a result of the decrease in the number of defects of only one type; e.g., creating electron capture center, even with a simultaneous increase in the number of hole capture centers.

Thus, a combination of the results obtained enables a hypothesis to be put forward on the nature of the structural defects of the oxygen sublattice. A change in the concentration of these defects after heat treatment, and also the dependence of their recharging after γ-irradiation on the heat treatment conditions, the degree and state of saturation of the induced coloration indicate that the defects absorbing in the UV region are caused by the entry of oxygen into the matrix. The rather low temperature for the change in the concentration of this oxygen, the existence of a saturation region at T > 1000 K, as well as the simultaneous increase in the number of defects creating the thermoluminescence peak at 360 K with a decrease in the amount of this oxygen indicates that it is localized at defects already existing in the structure, for example, associated with the breakdown in the stoichiometry of the composition of gallium garnets from the melt [7].

LITERATURE CITED

1. E. V. Zharikov, A. N. Kolerov, V. V. Laptev, et al., Dokl. Akad. Nauk SSSR, 285, No. 1, 92-95 (1985).
2. E. V. Zharikov, V. V. Laptev, S. Yu. Natarov, et al., Kvantovaya Elektron, 12, No. 11, 2198-2199 (1985).
3. M. Kh. Ashurov, E. V. Zharikov, V. V. Laptev, et al., Izv. Akad. Nauk SSSR. Ser. Fiz., 48, No, 7, 1343-1345 (1984).
4. N. A. Kulagin, A. E. Ovechkin, and E. V. Antonov, Zh. Prikl. Spektrosk., 43, No. 3, 478-484 (1985).
5. K. Mori, Phys. Status Solidi (a), 42, No. 1, 375-384 (1977).
6. V. I. Litvinenko, K. Yu. Sugak, and A. O. Matkovskii, et al., Zh. Prikl. Spektrosk., 43, No. 6, 1014-1016 (1985).
7. M. Kh. Ashurov, Yu. K. Voron'ko, V. V. Osiko, and A. A. Sobol', The Spectroscopy of Crystals [in Russian], Leningrad (1978), pp. 71-83.