MEASUREMENT OF THE QUANTUM YIELD OF LUMINESCENCE IN NEODYMIUM GLASS

PHYSICS

1969

SovietRxiv

Fig. 1. Schematic of the setup for measuring the quantum yield of luminescence in neodymium glass. —high-pressure mercury lamp SI-8 with an effective radiance temperature of ~3000° K; K —condenser; MDR-2 —grating monochromator with a dispersion of 40 Å/mm; M —mechanical light modulator; L —lens; O —sample under investigation; Φ —filters at the input of the FEU-28 photomultiplier; U —narrow-band amplifier U2-6; A —indicator

Figure 1: Fig. 1. Schematic of the setup for measuring the quantum yield of luminescence in neodymium glass. —high-pressure mercury lamp SI-8 with an effective radiance temperature of ~3000° K; K —condenser; MDR-2 —grating monochromator with a dispersion of 40 Å/mm; M —mechanical light modulator; L —lens; O —sample under investigation; Φ —filters at the input of the FEU-28 photomultiplier; U —narrow-band amplifier U2-6; A —indicator

Abstract

Full Text

UDC 535.2

PHYSICS

E. M. DIANOV, B. V. ERSHOV, Yu. P. PIMENOV, V. B. FEDOROV

MEASUREMENT OF THE QUANTUM YIELD OF LUMINESCENCE IN NEODYMIUM GLASS

(Presented by Academician A. M. Prokhorov, 17 V 1968)

The measurement of the quantum yield of luminescence in neodymium glass has been carried out by a number of authors ($^{1-3}$). In papers (^{1,3}) it was shown that the quantum yield does not depend on the frequency of the exciting radiation, whereas in paper (^{2}) a strong dependence of the quantum yield of luminescence on the wavelength of the exciting light was found. Clarification of this contradiction is essential for evaluating the effectiveness of glasses as laser material. In addition, a comparison of the absolute values of the quantum yield for glasses of different compositions is of interest. These two questions are considered in the present work.

Fig. 1. Schematic of the setup for measuring the quantum yield of luminescence in neodymium glass. —high-pressure mercury lamp SI-8 with an effective radiance temperature of $\sim 3000^{\circ}$ K; **K** —condenser; **MDR-2** —grating monochromator with a dispersion of 40 Å/mm; **M** —mechanical light modulator; **L** —lens; **O** —sample under investigation; —filters at the input of the FEU-28 photomultiplier; **U** —narrow-band amplifier U2-6; **A** —indicator.

Measurements in our experiments were carried out as follows. From the ratio of the number of absorbed and emitted photons, the quantum yield of luminescence in the region of 0.88μ was determined upon excitation in the absorption bands 0.53; 0.58; 0.74; 0.81 and 0.88μ. The width of the exciting-light spectrum was $\sim$ 100 Å. Measurements were made for several points within each absorption band. The total quantum yield was determined by recalculating the obtained data from the measured relative intensities of the luminescence bands 0.88; 1.06 and 1.35μ.

The experimental setup is shown in Fig. 1. The exciting light was focused onto the surface of the sample into a spot 3–5 mm in size. The investigated samples of KGSS-3 and KGSS-7 glasses had the form of plane-parallel plates—

plates with transverse dimension $\sim$ 15 mm. The optical thickness of the samples studied in the region $0.88\,\mu$ did not exceed 0.15. It was chosen to be small in order to eliminate error in measuring the luminescence at the wavelength $\lambda = 0.88\,\mu$ due to reabsorption inside the sample. The entrance aperture of the FEU-28 receiver was 2.5 cm, the acceptance angle $\varphi = 30^\circ$, and the distance from the sample to the photocathode was 16 cm. When measuring the absorption of the exciting light in the glass, the same receiver was used. In this case, in place of the sample, a diffusely reflecting mirror made of Al_2O_3 ceramic was placed; its reflection coefficient $R(\lambda)$ was measured separately in the working spectral region. The absorption was determined by measuring the light incident on and transmitted through the sample. In this case the sample was placed in front of the diffuse reflector.

A simple calculation shows that, for the experimental scheme described, the quantum yield of luminescence η at the wavelength $\lambda = 0.88\,\mu$ is determined by the relation

$$\eta_{0.88} = 4\cos\varphi \, \frac{\lambda_{\text{lum}}}{\lambda_{\text{abs}}} \, R(\lambda_{\text{abs}}) \, \frac{I_{\text{lum}}}{I_{\text{abs}}},$$

where I_{lum} and I_{abs} are the luminescence power and absorbed power measured directly by the receiver. The ratio $I_{\text{lum}}/I_{\text{abs}}$ is expressed through the readings of the indicating instrument at the output of the receiving device, A_{lum} and A_{abs}, through the reflection coefficients of the diffuse mirror $R(\lambda_{\text{lum}})$ and $R(\lambda_{\text{abs}})$, and through the spectral sensitivity of the entire receiving device (including the diffusely reflecting mirror), $f(\lambda)$. The final expression for the quantum yield $\eta_{0.88}$ contains only $R(\lambda_{\text{lum}})$:

$$\eta_{0.88} = 4\cos\varphi \, \frac{\lambda_{\text{lum}}}{\lambda_{\text{abs}}} \, R(\lambda_{\text{lum}}) \, \frac{A_{\text{lum}}}{A_{\text{abs}}} \, \frac{f(\lambda_{\text{abs}})}{f(\lambda_{\text{lum}})}.$$

When determining A_{abs} from the magnitudes of the signals at the receiver output, A_1 and A_2, corresponding to the incident exciting light and the exciting light transmitted through the sample, allowance was made, in addition to the absorption of the light entering the sample on the first pass, also for the absorption of light on the second pass after reflection from the rear end surface of the plate. For a reflection at the end face of 0.04, calculation gives

$$A_{\text{abs}} = 0.96A_1 - A_2(1 + 0.045A_2/A_1).$$

The spectral-sensitivity curve of the receiver was recorded using an SI-8 lamp, the spectrum of which, in turn, was calibrated against a VTG3/A cesium vacuum thermoelement with a flat frequency characteristic.

To determine the total quantum yield η, the relative intensities of the luminescence lines at the wavelengths $\lambda = 1.06$, 0.88, and $1.35\,\mu$ were measured in the glass using a germanium photodiode calibrated with an SI-8 lamp. The values obtained were, respectively, 1, 0.69, and 0.11. The final results of the experiments are given in Table 1. The relative accuracy of the data obtained is not worse than 0.1. The possible systematic error does not exceed 0.20.

Table 1 also gives the lifetimes τ of the metastable level ${}^4F_{3/2}$. These values of τ differ from the times indicated in Ref. (^{2}). The times τ were measured from the decay of luminescence excited by a short light pulse. As the pulsed source, the glow of plasma produced by an air breakdown at the focus of a neodymium laser was used. The duration of the exciting light pulse did not exceed $\sim 0.5\,\mu$sec. For glass with 2% Nd_2O_3, as in Ref. (^{4}), a substantial deviation from a simple exponential dependence of the luminescence decay on time was observed. The cited values of τ were found by processing points of the curve in the interval ~ 1 msec after the excitation pulse at full

of the luminescence observation duration, ~ 1.6 msec for KGSS-3 glass and ~ 1.2 msec for KGSS-7 glass. The random error in measuring the time τ does not exceed 5%.

When luminescence was excited by the light of a laser spark, in our experiments no process of population of the metastable level was observed for any absorption band. This means that the characteristic time of this process does not exceed the duration of the excitation pulse, which is 0.5 μsec.

Comparison of the quantum-yield values η and lifetimes τ obtained by us for KGSS-3 and KGSS-7 glasses shows that their ratio is the same for both glasses. It follows from these data that the radiative lifetime of the ${}^4F_{3/2}$ level is equal to $\tau_0 \simeq 2$ msec.

Table 1

Absorption bands λ, μ	KGSS-3 (2% Nd_2O_3; $\tau =$ 550 μsec.) $\eta_{0.88}$	KGSS-3 (2% Nd_2O_3; $\tau =$ 550 μsec.) η	KGSS-7 (6% Nd_2O_3; $\tau =$ 360 μsec.) $\eta_{0.88}$	KGSS-7 (6% Nd_2O_3; $\tau =$ 360 μsec.) η
0.53	0.09	0.30	0.05	0.17
0.58	0.10	0.30	0.06	0.17
0.74	0.10	0.30	0.06	0.17
0.81	0.10	0.30	0.06	0.17
0.88	0.10	0.30	0.06	0.17

The measurement data contained in Table 1 confirm the conclusion, obtained in works (^{1,3}), that the luminescence quantum yield is independent of the excitation frequency. From a comparison of the absolute values of η for KGSS-3 and KGSS-7 glasses and AOLux glass (^{1}), it follows that the effect of concentration quenching of luminescence in AOLux glass is less pronounced. This circumstance, as well as the ratio of luminescence intensities in the bands λ 1.06; 0.88 and 1.35μ that is different from that in KGSS-type glass (1 : 0.4 : 0.27), gives grounds for attributing the difference in the results of quantum-yield measurements to the different compositions of the glasses (^{4}).

Lebedev Physical Institute
Academy of Sciences of the USSR

Received
28 III 1968

REFERENCES

[1] L. G. Deshezer, L. G. Komai, J. Opt. Soc. Am., **55**, No. 8, 940 (1965).
[2] N. M. Galaktionova, V. F. Egorova et al., DAN, **133**, No. 6, 1284 (1967).
[3] R. A. Brandewie, C. L. Telk, J. Opt. Soc. Am., **57**, No. 10, 1221 (1967).
[4] E. Snitzer, Proc. IEEE, **54**, No. 10, 1249 (1966).

Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.