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Optical gain of CdSSe-doped glass

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Abstract

The optical gain of the CdSSe-doped glass JB8 was measured by means of the ASE technique. At wavelength 625 nm, it is about 8 cm^{-1}. We attribute the optical gain to the population inversion between the top of the valence band and the middle trap levels.

1. Introduction

In recent years CdSSe-doped glasses have been extensively studied because of their interesting optical nonlinearities [1]. This kind of material is considered as a hopeful candidate in the fields of waveguide, optical bistability, and optical phase conjugation.

The aim of this paper is to investigate if CdSSe-doped glasses can be used as laser materials.

In order to match the laser we have, we chose the CdSSe-doped glass JB8 as the sample. JB8 is a kind of commercial sharp-cut color filter, made in China, and consists of silicate glass doped with CdSSe microcrystals, the size of which is about 10 nm. Its optical properties are similar to the OG515 cut-off filter made in Germany. Such a system is generally considered as a three-level one, including a conduction band, a valence band, and middle trap levels [2]. The transition from trap levels to the valence band results in a broad luminescence band. It is in this band, at wavelength 625 nm, that an optical gain $g \approx 8\ cm^{-1}$ was measured by means of the Amplified Spontaneous Emission technique [3]. This technique has the advantage that the sample does not need to be fabricated into an optical cavity in order to determine its laser potential [3].

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2. Experimental

The experimental set-up used to measure the optical gain is shown in Fig. 1. The pumping beam B (the second harmonic of a Quanta-Ray Q-switched Nd:YAG laser, $\lambda = 532$ nm) was focused onto a pencil-shaped region of the sample by a cylindrical lens. The pulse duration was 10 ns, the pulse repetition rate was 10 Hz, and the maximum peak pumping density on the sample surface was 20 MW/cm^2.

The length of the excited region of the sample l was determined by an adjustable slit AS. The error in measuring the excitation length is within ± 5 μm. To ensure the uniformity of the pump beam, the excitation length in the experiment was varied within only 1 mm, while the total length of the focused beam was larger than 1 cm. Spontaneous luminescence was amplified (stimulated luminescence) as it passed through the excited volume to the edge of the sample. The stimulated emission intensity $I(l)$ was detected as a function of the excited length l.

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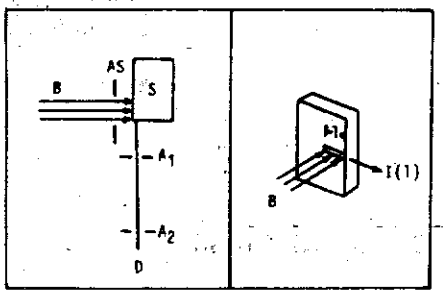

Fig. 1. Experiment set-up for measuring optical gain. AS: adjustable slit; A1, A2: apertures; D: detecting system; B: pumping beam; S: sample.

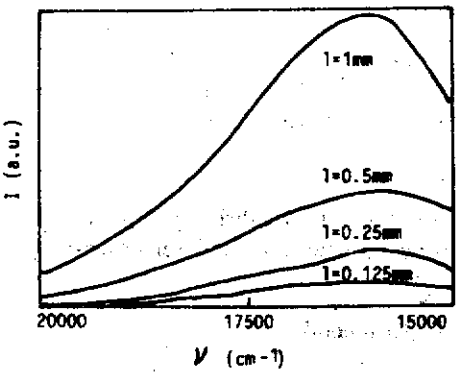

Fig. 2. Measured stimulated emission intensities of JB8 as the function of excited length l: (a) $l = 1$ mm; (b) $l = 0.5$ mm; (c) $l = 0.25$ mm; (d) $l = 0.125$ mm.

The detecting system consisted of a SPEX-1403 double grating monochromater, a photomultiplier, and a BOXCAR integrator. Apertures A1 and A2 were used to insure that none of the light passing out of the excited volume before reaching the edge of the sample was detected.

In order to make the sample have a right angle with very sharp edge, 'light-glue' technique was employed in polishing its surfaces.

3. Result and discussion

Fig. 2 shows the measured stimulated emission intensity $I(l)$. The superlinear increase of $I(l)$ indicates that there exists a net optical gain $I(l)$ is given by

$$I(l) = (I_s A/g)\,[\exp(gl) - 1], \qquad (1)$$

where I_s is the spontaneous emission rate per unit volume, A is the cross-sectional area of the excited volume, and g is the gain due to stimulated emission [3].

By using Eq. (1) and the measured $I(l)$, the net optical gain at wavelength $\lambda = 625$ nm was determined as $g \approx 8\,\mathrm{cm}^{-1}$.

We measured the photoluminescence spectrum of JB8 and found that there were two photoluminescence bands. One band looked narrower, peaking at 520 nm. The other was much broader, peaking at about 625 nm. The narrow one comes from band to band transition, and the broad one is due to recombination of the middle trap levels.

We attribute the optical gain to the population reversal between the top of the valence band and the middle trap levels. It is well known that the electron lifetime in the conduction band of CdSSe-doped glass is several tens of ps. We measured the luminescence decay time τ at $\lambda = 625$ nm and found τ was several hundreds of ns, much longer than the former. The electrons in the top of the valence band are pumped to the conduction band and then transit nonradiatively to the middle trap levels, which act as a metastable level. This results in optical gain.

The optical gain g is only $8\,\mathrm{cm}^{-1}$. It might result from photodarkening effects [4], for the sample is well darkened under the pumping power density used in our case, and there is no detectable absorption in this wavelength range.

Such an optical gain is not ideal for a laser material. However, if the photodarkening effects could be diminished or overcome, CdSSe-doped glasses are still hopeful candidates for laser materials. To our knowledge, this is the first report on their optical gain. To some extent, it might give a hint for exploring the possibility of using quantum dots as laser materials.

References

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