THE "BLEACHING" EFFECT IN ZnS(Co) CRYSTALS UNDER THE ACTION OF GIANT PULSES OF A RUBY OPTICAL QUANTUM GENERATOR

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THE "BLEACHING" EFFECT IN ZnS(Co) CRYSTALS UNDER THE ACTION OF GIANT PULSES OF A RUBY OPTICAL QUANTUM GENERATOR

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Recently, the ability of a number of substances to change their transmission under the action of powerful light fluxes has been discovered ([1]). The present work describes the "bleaching"effect in a zinc sulfide crystal activated with cobalt, when it is irradiated by radiation from a high-power ruby optical quantum generator (OQG).

At present it is possible to formulate certain principles that make it possible to predict whether bleaching will be observed in a given substance at realistically attainable light-flux powers or not.* First, the color center may be a substance that is in the ground state and has absorption in the required region of the spectrum.** Second, there must be no absorption of light by a center in the excited state.*** Third, the matrix itself must also be transparent for the given spectral region and, finally, fourth, it is desirable that the given center possess photoluminescence. The last condition determines a certain "inhibition" of transitions between the terms of the center, owing to which, in particular, observation of radiative transitions becomes possible; the probability of these transitions is, as a rule, considerably smaller than that of nonradiative ones.

Zinc sulfide activated with cobalt satisfies all these conditions. In ([2]) it was shown that the cobalt ion Co^{2+} has several absorption bands in the visible and infrared regions of the spectrum. It is essential for us that one of them falls in the emission region of the ruby OQG. Figure 1 gives the transmission spectrum, recorded on an SF-4 spectrometer, of a zinc sulfide crystal activated with cobalt. At a cobalt concentration $N_{Co} = 2 \cdot 10^{18}$ cm^{-3} and a sample thickness of 1 mm, its transmission at the wavelength 694 mμ was 4%.

The transmission at high light fluxes was measured on an apparatus (see Fig. 2) consisting of a single-pulse ruby quantum generator **1**, a system of neutral light filters **2** with total density $D_{10} = 2.5$, the investigated sample **3**, and a radiation receiver **4**. The flux incident on the sample was varied by mutually rearranging it and the neutral light filters. In the path of the OQG radiation a

Fig. 1

Figure 1: Fig. 1

diaphragm **5** was installed, selecting the part of the flux most uniform over its cross section. The radiation was recorded by means of a sensitive calorimeter **4**. The energy incident on it was evaluated from the magnitude of the thermo-e.m.f. from built-in thermocouples. An FEU-15 amplifier **6** was connected between the latter and the output instrument **7**. The stability of the generator operation was monitored by the energy incident on the auxiliary calorimeter **8**. The radiation was directed to the latter by means of a beam-splitting plate **9**.

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* Here we consider substances to which center models of coloration are applicable (elements and ions with unfilled d- or f-shells, organic dyes, etc.).

** By selecting the matrix, it is sometimes possible to shift the absorption band of the center in the required direction, since the distance between the energy terms of the center is to a considerable degree determined by the internal force interaction between the center and the matrix.

*** This statement is not applicable to systems that have absorption at the working wavelength from a metastable state (see, for example, ([3])).

Figure 3 shows the results of measuring the bleaching of a ZnS(Co) filter as a function of the power of the incident radiation I_0.

Fig. 1. Transmission spectrum of a ZnS crystal activated with cobalt, $N_{\text{Co}} = 2 \cdot 10^{18}$ cm^{-3}, thickness 1 mm. The arrow marks the wavelength of the ruby optical quantum generator.

Bleaching of 50% is reached at an incident flux power $I_0 \simeq 50$ MW/cm^2.

In the bleaching process a considerable fraction of the cobalt ions Co^{2+} passes from the lower state $^4A_2(F)$ to the state $^4T_1(P)$. Let us estimate the relaxation time of the reverse transition. For this we shall have to assume that the shape of the optical-quantum-generator pulse is rectangular and that its duration is such that a stationary equilibrium is established in the system. For this case (bleaching equal to 50%) the relaxation time constant τ, according to (3), is

$$\tau = \frac{1}{\sigma I_0}(D_e - \ln 2);$$

assuming $\sigma = 1.6 \cdot 10^{-17}$ cm^{-2}, for our sample we obtain $\tau \simeq 1 \cdot 10^{-9}$ sec. For ions in the excited state (n/N_{Co}), this amounts to

$$n/N_{\text{Co}} = (D_e - \ln 2)/[(D_e - \ln 2) + 1],$$

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

or, in our case, $n/N_{\mathrm{Co}} \simeq 0.42$.

Fig. 2

Fig. 3

Fig. 2. Diagram of the setup for measuring the nonlinearity of transmission of saturable filters.

Fig. 3. Change in the transmission $I/(1-R)I_0$ (R is the reflection coefficient) of a ZnS crystal activated with cobalt, as a function of the incident intensity I_0 of the ruby optical quantum generator.

Such rapid relaxation between the states ${}^4T_1(P)$ and ${}^4A_2(F)$ indicates that only an insignificant fraction of the ions will be in the metastable state ${}^4T_2(F)$, the transition from which to the lower state ${}^4A_2(F)$ has a relaxation time of tens of microseconds ([4]) and is accompanied by radiation. Consequently, the transitions ${}^4T_1(P) \to {}^4A_2(F)$ and ${}^4T_2(F) \to {}^4A_2(F)$ turn out to be quasi-independent when the ions are irradiated by short light pulses.

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CITED LITERATURE

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