ıcrease of Curie temperature of magnetic ıemiconductors by illumination

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Results are presented of an investigation of the influence of illumination on the magnetization of the domains in ferromagnetic europium sulfide ($T_c = 16$°K). It follows from the experimental results that illumination leads to an increase of the magnetization, a fact interpreted as an increase of the Curie temperature of EuS by an amount on the order of 10^{-1}°K under the influence of the light.

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We report here the results of an investigation of the influence of illumination n the domain magnetization in ferromagnetic europium sulfide ($T_c = 16$ °K). he use of high-frequency modulation of the light intensity made it possible to eparate the nonthermal action of the illumination on the magnetization. The btained experimental data lead to the conclusion that illumination increases ıe magnetization, a fact interpreted as an increase of the Curie temperature f EuS under the influence of the light.

An increase of the Curie temperature by absorption of light was predicted by onsovskiĭ *et al.*[1] This effect is connected with the fact that the electrons exited by the light into the conduction band take part in the indirect exchange.

It appears, so far,[2] that no increase of the Curie temperature induced by ght has been observed in experiment. It is suggested in[2] that this is caused y the need for producing a high concentration of photo-excited electrons. hus, according to the estimates given in[3], to increase T_c of EuS by 100 °K it s necessary to produce a nonequilibrium carrier density on the order of 10^{21} m^{-3}. The production of high densities calls for the use of powerful light ources. It must be taken into account here that simple heating by laser radiaon can mask the increase of T_c to a considerable degree. Consequently, exeriments aimed at observing the optically-induced temperature rise should e so performed as to reduce to a minimum the thermal action of the light.

To decrease the thermal action of the light, we used high-frequency modulaon of the intensity of the acting beam. The inertia of the thermal process auses the temperature modulation to decrease with increasing illumination ıodulation frequency. At the same time, the alternating component of the urie temperature, which is due to the modulation of the illumination, is not ensitive to an increase of the modulation frequency (ω) if $\omega\tau < 1$. Here τ is the ngest of the times characterizing the processes of establishment of stationary istribution of the electrons in the conduction band. These processes include ıergy and momentum relaxation of the photoexcited electrons as well as the ecombination of the electrons with the holes. Rough estimates made for EuS eld $\tau \lesssim 10^{-6}$ sec. Consequently, by increasing the light-intensity modulation equency to a value $\omega \sim 10^6$ sec^{-1} we can significantly weaken the thermal action the light, and change in practice the influence of the illumination on T_c.

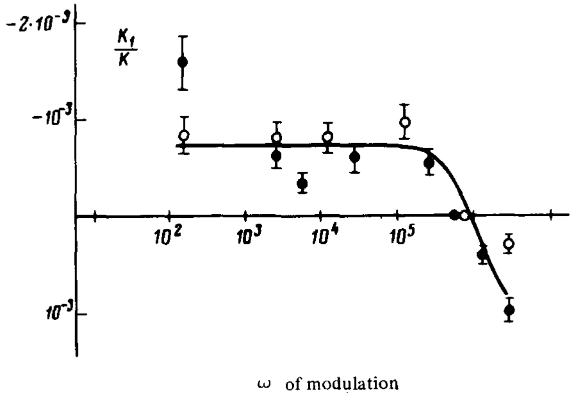

FIG. Dependence of the absorption-coefficient modulation on the illumination-intensity modulation frequency. The laser pump powers in different measurement runs can differ somewhat.

To detect the change of T_c we used the dependence of the absorption coefficient of light of wavelength $\lambda = 0.63\ \mu$ on the microscopic magnetization (in the domains). It is well known that with increasing ordering of a spin system (with increasing magnetization) the optical-absorption edge in EuS experiences an appreciable "red shift."[3] Thus, the increase of T_c under the influence of illumination should lead to an increase of the magnetization, and consequently to an increase of the absorption coefficient. Heating of the sample by light should, owing to the decrease of the magnetization, lead to a decrease of the absorption.

In the vicinity of T_c the magnetization depends essentially on the difference $T - T_c$. Therefore, the thermal and nonthermal action of the light combine additively.

The experiment was performed with the installation described in[4]. The density of the excitation by the pump light was of the order of 10^{24} cm^{-3} sec^{-1}, and the temperature of the sample at the illuminated point was estimated at 10—12 °K.

The sign of the absorption coefficient modulation was determined in the following manner: The synchronous-detection channel was tuned to the frequency and phase of the pump-beam intensity modulation, after which the photoreceive was transferred from the pump beam to the probing beam. The intensity modulation produced in the probing beam by the modulated pump was registere without changing the setting of the measuring circuit, and the signs could be compared directly.

The figure shows a plot of K_1/K against the illumination intensity modulation frequency. Here K_1 is the amplitude of the alternating component of the absorption coefficient, which is in phase with the pump modulation, and K is the dc component of the absorption coefficient. We see that in the region 10^2 sec^{-1} $< \omega < 10^5$ sec^{-1} the ratio K_1/K is negative and is practically independent of the modulation frequency.

In this range of ω, the characteristic depth of penetration of the changes of the temperature in the interior of the substrate is $r = \sqrt{2\lambda/c\omega}$ (λ and c are the thermal conductivity and the specific heat of the substrate) and is much smallr than the dimensions of the sample, but much larger than the dimension r_0 $\approx 10^{-2}$ cm of the light spot. It is easy to show that the alternating component of he temperature is in this case practically constant, $T \approx N/2\pi r_0 \lambda$, where N is he alternating component of the pump power. With further increase of the fre- uency, r becomes smaller than the dimension of the focused light spot, and he modulation of the sample temperature begins to decrease rapidly with in- reasing ω. The positive values of K_1/K which were obtained in the experiment or frequencies $\omega > 10^6$ sec^{-1} show that the illumination leads in this case to an ncrease of the magnetization, i.e., to an increase of the Curie temperature nder the influence of the illumination.

The experimentally obtained values make some estimates possible. The tem- erature modulation in the region 10^2 sec$^{-1} < \omega < 10^5$ sec^{-1} is of the same order s the change in the Curie temperature and amounts to $T \sim 0.1$°K. The density f the photoexcited conduction electrons determined from this is $n \sim 10^{18}$ cm^{-3}, orresponding to an electron lifetime $\tau \sim 10^{-6}$ sec prior to recombination.

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