Direct observation of photomagnetization of the ferromagnet $CdCr_2Se_4$ by circularly polarized light

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A photomagnetization ΔM has been observed in a polydomain $Cd_{1-x}Ag_xCr_2Se_4$ crystal ($x = 0.02\%$) at $T = 77$ K as the crystal is bombarded with a circularly polarized laser beam ($\lambda = 1.06\ \mu$m, power density $P \leq 10$ W/cm^2). The value of ΔM was measured as a function for various polarizations and power densities of the laser beam and for various strengths of magnetic field H_0. The results show that ΔM is maximized by circularly polarized light; when the polarization rotation direction is reversed, ΔM changes sign. For linear polarization, the results yield $\Delta M = 0$. For external magnetic fields near the saturation level, the results reveal $\Delta M = 0$. The results are explained in terms of a mechanism involving a change in the domain structure.

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It has been established elsewhere that light can cause changes in the magnetic properties of magnetic materials. Polarized light changes the dynamic permeability and the shape of the hysteresis loop (a photoferromagnetic effect) in the ferromagnetic semiconductor[1-3] $CdCr_2Se_4$. Circularly polarized light, on the other hand, can cause a magnetization of a ferromagnet.[4-6] We should emphasize that photomagnetization occurs when the ferromagnet is in a demagnetized (polydomain) state. Photomagnetization of EuS by circularly polarized light was observed experimentally in Refs. 4 and 5 by an indirect method: from the change in the circular dichroism caused by the light.

In this letter we are reporting direct observation of photomagnetization of a

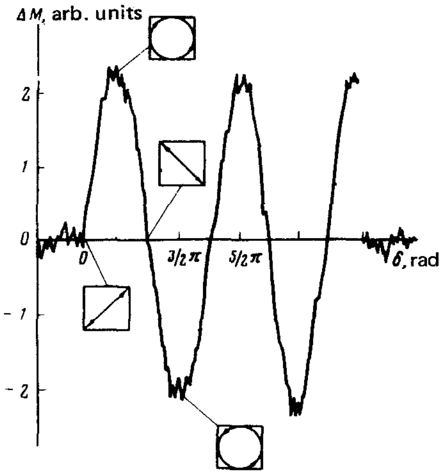

FIG. 1. Dependence of the photomagnetization ΔM on the polarization of the laser beam, with a wavelength $\lambda = 1.06$ μm, for an external magnetic field $H_0 = 0$. δ–Phase difference between the ordinary and extraordinary rays of the Babinet compensator. The polarizations of the light are indicated in the boxes.

$Cd_{1-x}Ag_xCr_2Se_4$ crystal ($x = 0.02\%$) by circularly polarized light. A linearly polarized, amplitude-modulated laser beam ($\lambda = 1.06$ μm, power density $P \leqslant 10$ W/cm^2) passed through a quartz Babinet compensator, which could change the polarization of the light, and was incident on the sample along the normal to the (101) plane. A coil was wound around the sample (with dimensions of 0.35 × 1.5 × 1.5 mm) in the plane of the maximum cross section. This coil measured the emf induced by the magnetic flux which was varying because of the modulation of the light intensity. The frequency of this modulation was varied over the range 0.8-2.5 kHz. Synchronous detection was used to detect the signal.

Figure 1 shows the dependence of the photomagnetization on the polarization of the light in a zero external magnetic field. The magnitude of the photomagnetization and its sign both depend on the polarization. For circular polarization, the magnetization is at a maximum (the emf is 10^{-8} V/turn at $P \simeq 10$ W/cm^2 and cor-

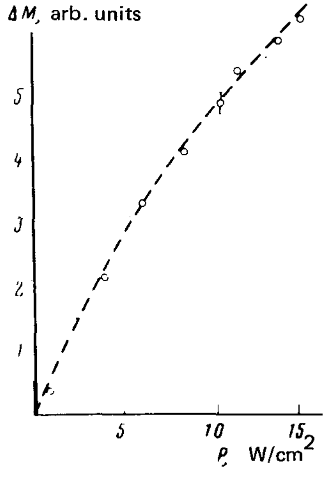

FIG. 2. Dependence of ΔM on the power density P of circularly polarized light with $H_0 = 0$.

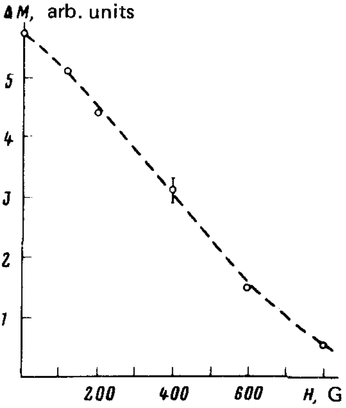

FIG. 3. Dependence of ΔM on the external magnetic field H_0, which is transverse with respect to the laser beam.

responds to a photomagnetization on the order of 10^{-1}-10^{-2} G). The photomagnitization changes sign when the polarization rotation direction is reversed. No photomagnetization occurs if the light is linearly polarized. Figure 2 shows the dependence of the photomagnetization on the power density of circularly polarized light. The behavior is nearly linear. We studied the effect of an external magnetic field on the photomagnetization. Figure 3 shows the dependence of the photomagnetization on a transverse (with respect to the laser beam) external magnetic field H_0 for circularly polarized light. We see that the photomagnetization decreases with increasing H_0, approaching zero in fields near the saturation level.1) As the modulation frequency is raised from 0.8 to 2.5 kHz, the emf increases linearly with the frequency.

Let us discuss these results. In the absence of an external magnetic field, the ferromagnet has a domain structure with a zero total magnetization. Since the $CdCr_2Se_4$ crystal exhibits a circular dichroism in its fundamental absorption region at the wavelength $\lambda = 1.06$ μm (Ref. 7), the illumination of this crystal with circularly polarized light at this wavelength creates different photoelectron concentrations and thus different effective exchange-interaction constants in domains with oppositely directed magnetizations. These effects should give rise to a photomagnetization[6] of the crystal, because of the increase in the volume of certain domains and the decrease in the volume of others. If the polarization rotation direction of the light is reversed, the change in the domain structure occurs in the opposite sense (the domains which previously became larger now become smaller, and vice versa). The photomagnetization thus changes in direction. For linearly polarized light, the absorption coefficients are the same in domains with oppositely directed magnetization vectors, so that no photomagnetization occurs. We thus have an explanation for the dependence of the photomagnetization effect on the polarization of the light. This model also explains the dependence of the effect on the external magnetic field: In saturation fields there is no domain structure, so that there is no photomagnetization. The dependence of the effect on the light power density P also corresponds to this interpretation: The photomagnetization ΔM is proportional to P according to Ref. 6. The linearity of the dependence of the emf on the light modulation frequency implies that the photomagnetization times are short

($\tau_{\text{phm}} < 10^{-5}$ s).

We might note that the observed effect could be used to study laser beams (polarizations and intensities) as well as to study the mechanism for photomagnetization itself.

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1)We determined the saturation field H_0^{sat} experimentally for the given sample.

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