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SELF-FOCUSING AND OPTICAL BISTABILITY IN $Cd_{1-x}Mn_xTe$*

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Thermally induced self-focusing of laser beam and optical bistability in CdMnTe at room temperature has been investigated. Photothermal focal length as a function of intensity of laser radiation has been measured in $Cd_{1-x}Mn_xTe$ for $0.3 \leq x \leq 0.6$. The time-dependence of the transmitted power for various laser intensities has been investigated and the switching from the transparent to dark state has been observed. For the first time the optical bistable characteristic has been measured in CdMnTe. The results indicate that CdMnTe is a suitable material for cavityless, large contrast, thermally induced absorptive bistable operation in visible region.

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In recent years there has been great interest in thermally induced optical bistability. The positive feedback necessary for such bistability is provided by the local temperature rise in the illuminated spot and the temperature dependent absorption coefficient of the material, therefore no Fabry–Perot cavity is needed for these systems. Such bistable elements may have some interesting device application, due to the ease of their fabrication. A practical system, however, should work at room temperature, visible wavelength and low critical power. Thermally induced optical bistability has been achieved under band gap resonant conditions in several semiconductors: Si [1], GaAs [2], ZnSe [3, 4] and ZnS [4], however it has been demonstrated [3] that only ZnSe satisfies the above requirements and it opens the posibilities for device applications. Recently, thermally induced self-focusing was investigated in $Cd_{0.4}Mn_{0.6}Te$ [5] and $Cd_{0.5}Mn_{0.5}Te$ [6] crystals at room temperature.

In this paper the self-focusing in $Cd_{1-x}Mn_xTe$ for wide range of content of Mn ($0.3 \leq x \leq 0.6$) as well as in ZnSe is investigated and the reasons are discused for observed much stronger thermally-induced self-focusing for CdMnTe in comparison with ZnSe. The first observation of optical bistability in CdMnTe is reported.

The experiment was performed on uncovered samples at room temperature. The self-focused cw dye laser beam with photon energies just below the absorption

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edge was observed on a screen. As the incident power is increased, the transmitted beam profile breaks up into a set of rings of ever increasing radius and number. The focal length of thermally induced lens was found by measuring the image size. The reprocical of the measured focal length as a function of the laser power density for $Cd_{1-x}Mn_xTe$ with $0.3 \leq x \leq 0.6$ and for ZnSe is shown in Fig. 1. The results provide evidence that thermal lens power for CdMnTe is much higher than for ZnSe. Futhermore, the lens power for CdMnTe increases with content of Mn.

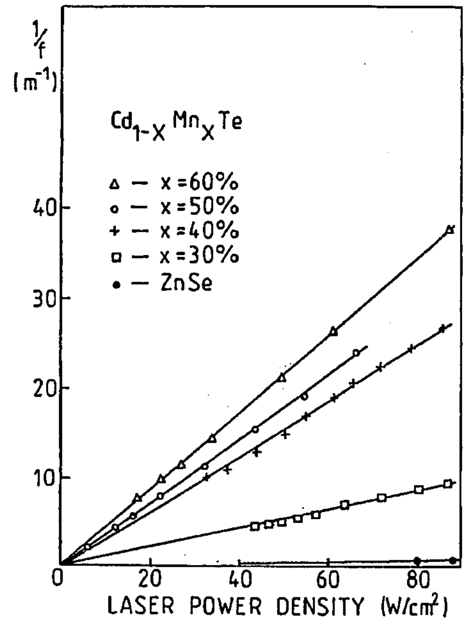

Fig. 1. The reciprocal of the measured focal length as a function of laser intensity for CdMnTe and ZnSe. The results are normalized to the same values of absorption coefficient and thickness of samples.

The focal length of thermal lenses can be given [7]

$$f = \frac{r\sqrt{2\pi K}}{\sqrt{(\frac{1}{n})(\frac{\partial n}{\partial T})\alpha P}}, \tag{1}$$

where r is the beam radius, n is the refractive index, K is the thermal conductivity, α is the absorption coefficient, P is the input power. The results presented in Fig. 1 can be explained using (1). The thermal conductivity is much smaller for Mn-doped CdTe (K = 0.075 W/cm deg) than for ZnSe (K = 0.19 W/cm deg) [8] and it may decrease with Mn content due to additional point impurity scattering. Due to smaller value of thermal conductivity, the focal temperature rise in the illuminated spot for CdMnTe is higher than for ZnSe at the same value of absorption coefficient and input power. The thermo-optic coefficient $(1/n)(\partial n/\partial T)$ is associated with the temperature dependence of the absorption edge.

It was presented in Ref. [9] that the temperature dependence of the absorption edge in $Cd_{1-x}Mn_xTe$ increases with content of Mn for $x < 0.5$ and has a constant value for $x \geq 0.5$. However, it should be noted that in $Cd_{1-x}Mn_xTe$ crystals with $x \geq 0.5$ the fundamental absorption is obscured by transitions within Mn ions and the self-focusing effect in these crystals is mainly due to the thermally induced shift of the transitions within localized states of manganese.

Initial experiments were performed to investigate the magnitude and speed of the thermally induced tuning of the transmission of CdMnTe. A shutter was used to pulse the laser beam "on" for 6 s. Figure 2 shows the resulting time depen-

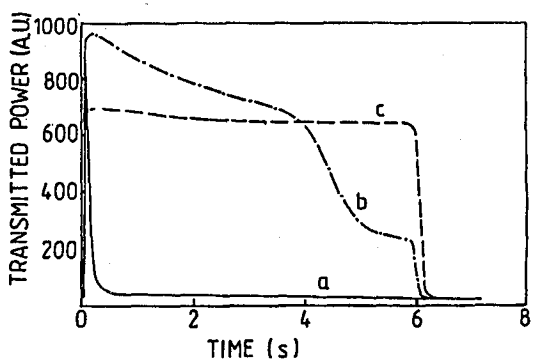

Fig. 2. Time dependence of 641 nm transmission through $Cd_{0.6}Mn_{0.4}Te$ at different laser power a) 840 mW, b) 420 mW, c) 280 mW.

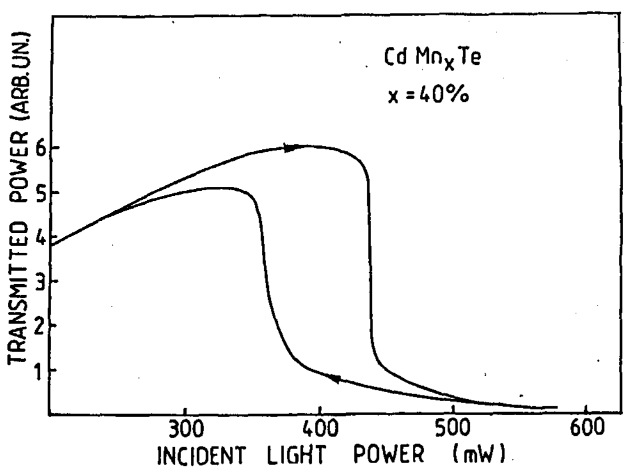

Fig. 3. Experimental input–output characteristic for $Cd_{0.6}Mn_{0.4}Te$ at 641 nm.

dence of the transmitted power for various powers of incident light. It can be seen that for the small value of laser power the transmission is constant during the laser pulse.The switching from the transparent to dark state appeares when the laser intensity is increased. The switching is caused by positive feedback between the temperature rise in the illuminated spot and the temperature dependence of the absorption coefficient. From the results presented in Fig. 2 one can estimate the value of change of the absorption coefficient $\Delta\alpha = 1.2$ cm^{-1} needed for switching. Then from the temperature dependence of the absorption coefficient, which was independently measured, the temperature rise in illuminated spot can be determined as 20 deg. From the relationship given in [10] the thermal conductivity for $Cd_{0.6}Mn_{0.4}Te$ was estimated as $K = 0.025$ W/cm deg.

The large contrast optical bistability was observed for the first time in CdMnTe (Fig. 3). The histeresis loop indicates that the observed optical bistability is thermally induced. The switch-down critical power is 430 mW (it coresponds to the power density about 100 W/cm^2). This value is about 30 times smaller than the power needed for switching-down in ZnSe.

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