INDUCED ABSORPTION CHARACTERISATION OF INFRARED SENSITIVE PHOTOREFRACTIVE $BaTiO_3$.

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INTRODUCTION

Photorefractive materials such as $BaTiO_3$, have been extensively researched over the last fifteen years, and have shown themselves to be very efficient for generation of novel self-pumped and mutually pumped phase conjugate geometries. So far, most attention has been focussed on the visible spectral region, where the efficiency has tended to be highest, and the speed of response fastest. More recently however, interest has turned towards the near-infrared spectral region, due to the increasing availability and technological importance of very efficient solid-state laser diode sources operating at the ~800nm region. Such infrared active $BaTiO_3$ crystals have been supplied for our use by Sandoz Huningue, and we have been investigating their unique properties for self-pumping, mutual pumping and two-beam coupling[1]. The question of why these crystals, which are deep blue in colour, behave so well at these longer wavelengths is still open for discussion, but it undoubtedly involves their multiple dopant, many level impurity states which in turn involve both deep and shallow traps[2].

We have characterised their behaviour therefore using simultaneous excitation from two different wavelength laser sources: a He-Ne, and a tunable Ti:sapphire, operating at ~800nm to simulate typical diode laser operation. This characterisation, together with a two-level model developed at Imperial College London, has allowed us to evaluate the relevant material parameters for these blue crystals, thus generating feedback for the crystal growers who seek to improve the material response out to beyond 1μm.

EXPERIMENTAL WORK

The first experiments to test photoinduced absorption involved measuring the transmission of o-polarised He-Ne light as a function of the laser intensity. Figure 1 shows a plot of the maximum change in the absorption coefficient as a function of the log. of the incident intensity. The upper intensity limit was restricted by the maximum He-Ne power available, and powers less than 10μW proved extremely hard to measure reliably. The form of the graph resembles a saturable absorption characteristic, implying two absorption levels with different cross-sections. The solid line is the best fit obtained using a numerical simulation of the shallow trap model. The parameters used for the fitting are listed in table 1.

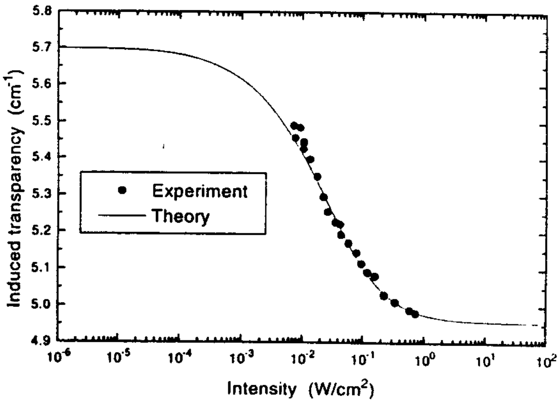

Figure 1. Induced transparency in blue $BaTiO_3$, as a function of incident He-Ne laser intensity.

	Deep traps	Shallow traps
Total density of species	$N_D=N+N^+=1\times10^{18}cm^{-3}$	$M_T=M+M^+=1.3\times10^{18}cm^{-3}$
Effective trap density	$N_{(dark)}=N_D-N_A$ $=N_D/50=2\times10^{16}cm^{-3}$	$M_{(dark)}=M_T$
Photoexcitation coefficient at λ_R = 633nm (red)	$s_R=17.8cm^2J^{-1}$	$s_{SR}=5.9cm^2J^{-1}$
Photoexcitation coefficient at λ_{IR} = 800nm (infrared)	$s_{IR}=5.2cm^2J^{-1}$	$s_{SIR}=7cm^2J^{-1}$
Recombination rate	$\gamma=5\times10^{-8}cm^3s^{-1}$	$\gamma_s=1.2\times10^{-8}cm^3s^{-1}$
Thermal excitation rate	$\beta=4\times10^{-3}s^{-1}$	$\beta_s=0.4s^{-1}$

Table 1. Materials parameters used in fit to experimental data.

Additionally, light induced absorption has also been observed as well as the light induced transparency of figure 1. The crystal was first exposed to a 1mm diameter, 6.7mW o-polarised He-Ne beam, whose intensity was held constant throughout the experiment, at a point near the saturation limit of figure 1. The He-Ne transmission was then monitored as a function of the intensity of a second, near infra-red beam from the Ti:sapphire laser, which was also o-polarised to minimise photorefractive grating effects. As seen in figure 2, an increase in the absorption experienced by the He-Ne beam of up to 0.2 cm^{-1} is observed when the crystal is simultaneously exposed to both laser wavelengths. Although the 800nm light appears to have a slightly more significant effect than the 750nm light, this may not be true when one considers that the bulk absorption coefficient at 750nm is greater than for 800nm, hence more light is absorbed at 750nm before it overlaps spatially with the He-Ne laser beam. The solid curve again shows a theoretical fit, using the same parameter set in table 1.

Both light induced absorption and transparency were observed in the last experiment, which again used dual wavelength excitation. As previously, o-polarised light from both lasers was arranged to overlap within the crystal. For this arrangement, the intensity of the infra-red laser was held constant at 1.3 Wcm^{-2}, and the transmission of the He-Ne probe laser was monitored as a function of intensity. These results indicate the role of the excitation wavelength in exciting and filling the deep and

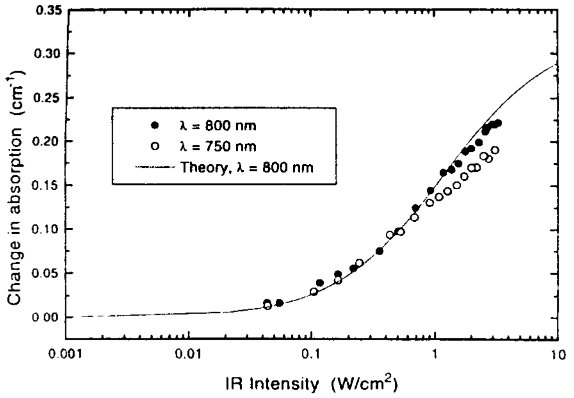

Figure 2. Light induced absorption at He-Ne wavelengths induced by simultaneous illumination with infra-red light at 750nm, and 800nm respectively.

shallow levels. Figure 3 shows that for intensities greater than $\sim 0.02 \mathrm{Wcm}^{-2}$, light induced absorption occurs, while for lower intensities, light induced transparency prevails. Once again the solid line is a theoretical fit based on the same common set of parameters listed in table 1.

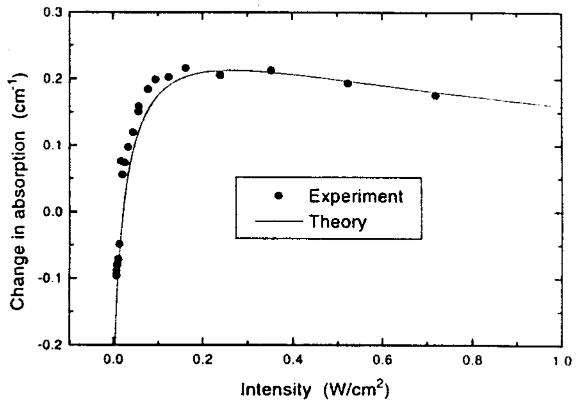

Figure 3. Light induced absorption and transparency at He-Ne wavelength, for a constant intensity incident infra-red intensity.

CONCLUSIONS

The simultaneous illumination technique used for this infra-red sensitive $BaTiO_3$ has allowed detailed modelling of the relevant materials parameters. It is clear that both deep and shallow traps are required to explain the absorption/transparency characteristics, and this in turn goes some way to explain the characteristic infra-red sensitivity of this crystal. No information can be extracted at this stage concerning the exact nature of the traps involved, and this would require a separate spectroscopic analysis. However, the important fact is that the dual wavelength technique allows parameters such as total trap density, and photoexcitation coefficient to be evaluated. Further work is in progress on evaluation of similar parameters in ion-beam implanted waveguides which have been grown in these crystals, where evidence shows a gain direction reversal has occurred.

ACKNOWLEDGEMENTS

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