Efficient non-volatile holographic recording in doubly-doped lithium niobate

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Photorefractive materials are of high interest for read-write holographic data storage. One of the main problems that makes the practical implementation of these memories difficult is the erasure of stored information during read-out. Several solutions like thermal fixing, electrical fixing, and two-step recording have been proposed for this problem[1–3], but they need some special requirements like heating the crystal, using high electric fields, or high light intensities.

We present here a simple and practical solution to the erasure problem. The idea is to use two different deep traps, for example iron and manganese in lithium niobate. The energy band diagram for such a system is depicted in Fig. 1. The electrons are initially in the deeper traps. Light of short wavelength (with high energy photons) can transfer some of these electrons to the shallower traps via the conduction band. This makes the recording of the holograms using longer wavelength light feasible. The final hologram is recorded in the deeper traps, and therefore is not erased during the read-out by the recording (long wavelength) light. For efficient holographic recording, the electron transfer should be considerable. Doubly-doped $LiNbO_3$ crystals are excellent candidates for this recording scheme since they show strong photochromic effects[4], i.e. absorption changes under illumination, which is attributed to the redistribution of a considerable amount of electronic charge between centers of different absorption.

We performed experiments with a 0.85 mm thick $LiNbO_3$ crystal doped with 0.075 wt.% Fe_2O_3 and 0.01 wt.% MnO. The crystal is sensitized for recording by homogeneous illumination with 365 nm light of a 100 W mercury lamp. The intensity of this illumination is

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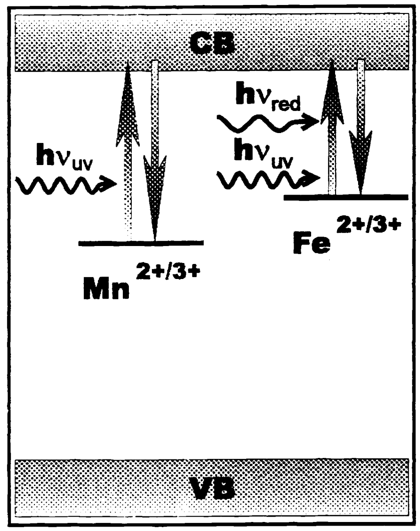

Figure 1: Energy band diagram for a doubly-doped lithium niobate crystal

20 mW/cm^2. The recording beams are two plane waves at 633 nm with equal intensities of 300 mW/cm^2. The read-out is performed by one of these beams while the other one is blocked. The recording and read-out beams are all ordinarily polarized.

Initial illumination with homogeneous ultraviolet light sensitizes the crystal by transferring some of the electrons from the manganese sites to the iron traps. If we then record the hologram by red beams without simultaneous ultraviolet illumination, the final diffraction efficiency is very small as shown in Fig. 2. This is due to the total bleaching of the crystal, i.e. at first the electrons in the iron traps are transferred to the manganese centers at the high intensity regions, and then the same thing occurs for the low intensity regions. Therefore, all electrons move by approximately the same distance and are re-trapped by manganese centers. This results in a very small space charge field and diffraction efficiency. However, if we keep the ultraviolet light on during recording, the re-excitation of the electrons trapped in the manganese centers would be possible. This results in higher diffraction efficiencies. Finally, we block the ultraviolet light and illuminate the crystal with a homogeneous red beam to transfer the electrons from iron traps to the manganese centers. This in fact reduces

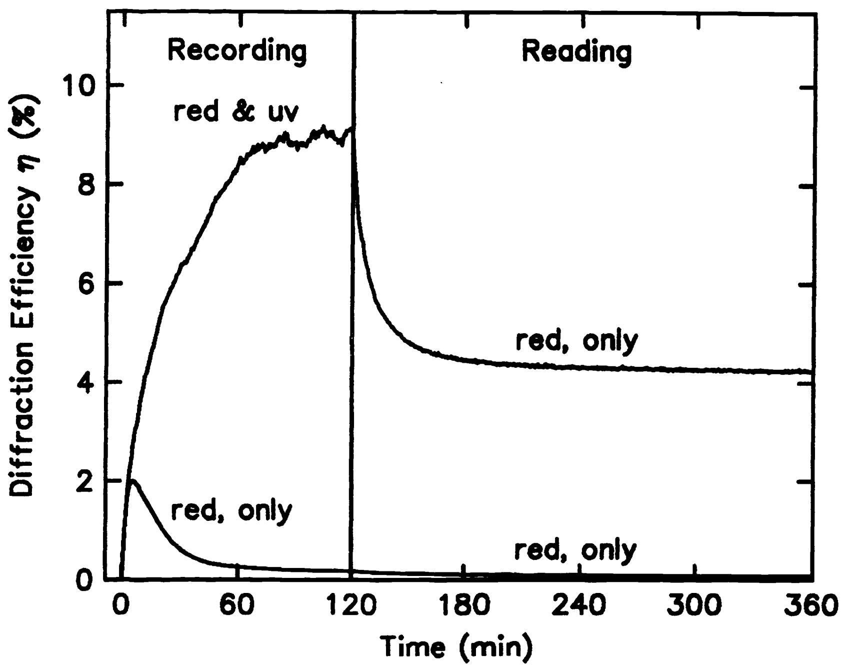

Figure 2: Holographic recording and read-out curves for doubly-doped lithium niobate

the diffraction efficiency of the hologram, but the final hologram can not be erased by the read-out at red, since it is stored in the manganese centers. This is shown in Fig. 2.

If we use extraordinary polarization for the read-out beam, we can achieve a final diffraction efficiency of 32 %. This is due to the larger corresponding electro-optic coefficient. Besides the good diffraction efficiency, this method does not suffer from holographic scattering and screening fields due to the presence of the ultraviolet light.

The theoretical analysis indicates that the final diffraction efficiency depends only on the ratio of the intensities of the sensitizing (ultraviolet) and recording (red) beams and not on the absolute intensities. Depending on the traps and their corresponding doping levels, there is an optimum value for this intensity ratio that results in the maximum achievable diffraction efficiency.

References:

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