Addressable and erasable photonic neurons using solitonic X-junctions in lithium niobate thin films

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Introduction

This paper reports the first implementation of an X-Junction structure made of lithium niobate thin films through the intersection of photorefractive soliton guides, which can act as photonic neurons by changing the signal addressing output according to an external control [1,2]. Moreover, we report the innovative discovery of the possibility of partially or totally erasing soliton structures in a targeted and selective way. The thin film acts as a planar waveguide for the input beams. The photorefractivity was controlled by the application of an external bias voltage generated through the pyroelectric effect [3,4] Therefore, the sample was placed on a feedbacked Peltier heater. The applied thermal gradient was of DT = 15 °C. During the heating procedure, the two beams were kept obscured to avoid any uncontrolled photorefractive effect in the crystal. In figure 1 (a) the light distribution at the output face is reported: in particular, figure 1 (a_1) shows the free-diffracting behaviors of the beams. However, when the propagation occurs at the same time as the excitation of the nonlinearity, the beams begin the self-focusing process. The X-junction can change the distribution of an injected signal (characterized by powers of the order of nW) towards the two output channels as a function of the writing power. If the input powers are equal, $W_1 = W_2$, the written structure results balanced. In this case, the signal inserted by one of the input channels will split equally to 50% in the two output channels, as represented by figure 1 (a_2). Instead, if the writing power of one channel is higher than the other, the resulting X-junction is unbalanced towards one specific output. By setting the highest power two times the other, the signal switches asymmetrically 70-30 towards the strongest channel, shown in figure 1(a_3); by setting the highest power triple than the other, the signal switches again towards the strongest channel, but asymmetrically 80-20 (figure 1(a_4)). We have observed that whatever structure is written, it is possible to carry out an erasing procedure to bring the crystal back to initial conditions and thus perform new experiments. To erase the written solitonic waveguides, the lasers are obscured and the Peltier is turned off so that the crystal temperature returns to the ambient one (DT = 0). This operation allows to annul the thermal gradient At this point an input laser is activated, in the same position it had at the time of writing, with an input power about 80 times higher. Typical writing powers that have been used are of the order of 10 mW which allow the formation of soliton waveguides in a time of the order of 5 min. This produces a fast movement of charge which is homogeneously redistributed throughout the crystal, canceling the local refractive index contrast at the base of the solitonic structures. Figure 1 (b) shows 4 frames relating to the erasing process of an unbalanced X junction with left channel characterized by a higher index contrast. Frames were chosen to well show the induced variation both in the short-term time range (within 1 min after having started the process and in the long term, (beyond 1 min). Observing the evolution of the structure, the channel characterized by a stronger refracrtive index modification requires a longer erasing time.

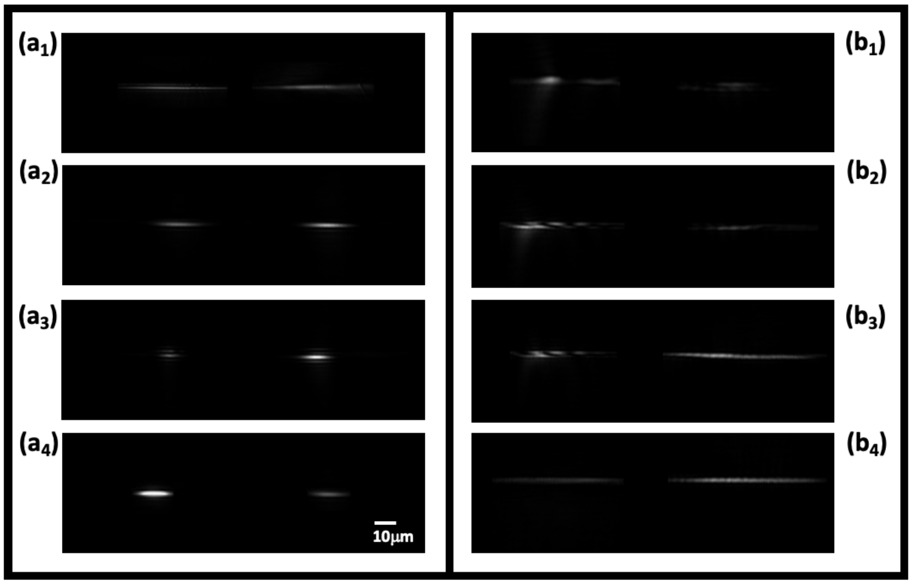

Figure 1: Light distribution at the output face is reported. (a) the signal-switching behaviors after writing phase is shown: (a_1) initial diffracting beams in linear regime; (a_2) writing with same intensities beams produces a balanced X-Junction which split signal 50-50 towards the outputs; (a_3) if the right channel is written with double intensity with respect to the other, the signal split is 70% in his favour; (a_4) if the left channel is written with tirple intensity with respect to the other, the signal split is 70% in his favour. (b) the erasing process of an unbalanced X-Junction on the left is shown with subsequent frames (b_1-b_4).

Conclusions

We have experimentally shown the formation all-optical addressable X-junctions in slab waveguides of LiNbO3 by using pyroelectric effect for self-focusing mechanism, which are able to switch the energy addressing towards outputs and to be partially or totally erased. The behavior illustrated is typical of biological neurons. Thus, X-Junctions in lithium niobate thin film can act as photonic neurons.

References

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