Fast Electro-Optical Switching in KLTN Crystal at the Paraelectric Phase Near T_C

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Potassium lithium tantalate niobate (KLTN) [1] at the paraelectric (PE) phase close to the phase transition temperature (T_C) exhibits a strong electro-optic (EO) effect in the VIS-MWIR range [0.4µm, 5.5µm]. However, It was shown that close to T_C the EO behavior is affected by the formation of dipolar clusters that cause it to slow down [2]. We present herein an in-depth study of the temporal EO response in the vicinity of T_C, attempting to quantify the relation between the temporal response and working temperature. **It will be shown that there is a trade-off**: it is possible to achieve fast rise-time (t_r)(~$20ns$) at high voltages (~10^3V) or slower t_r (~$400ns$) at low voltages (~10^2V) by choosing the right working temperature.

1. METHODS

The electrically induced changes in the birefringence (IBR) were measured in a **"crossed polarizers" EO modulator** [3] illustrated schematically in Figure 1.

The intensity at the output:

$$(1)\quad I_{out} = I_{in}\sin^2(\phi/2)\,;\ \phi = 2\pi\Delta n(E)L/\lambda + \phi_0 + \phi_{\lambda/4}$$

Fast EO switching was obtained by employing a special electronic circuit that produces a narrow square pulse at a high voltage while avoiding the "ringing" due to phase mismatch between the crystal and the pulse generator.

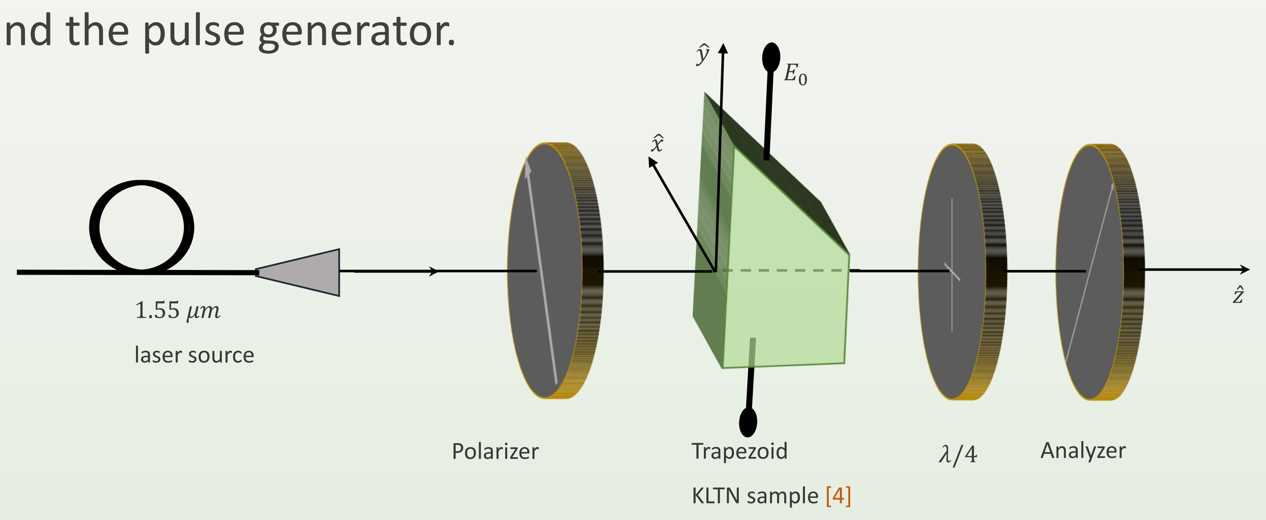

Figure 1: "Crossed polarizers" Electro-optics amplitude modulator

2. RESULTS

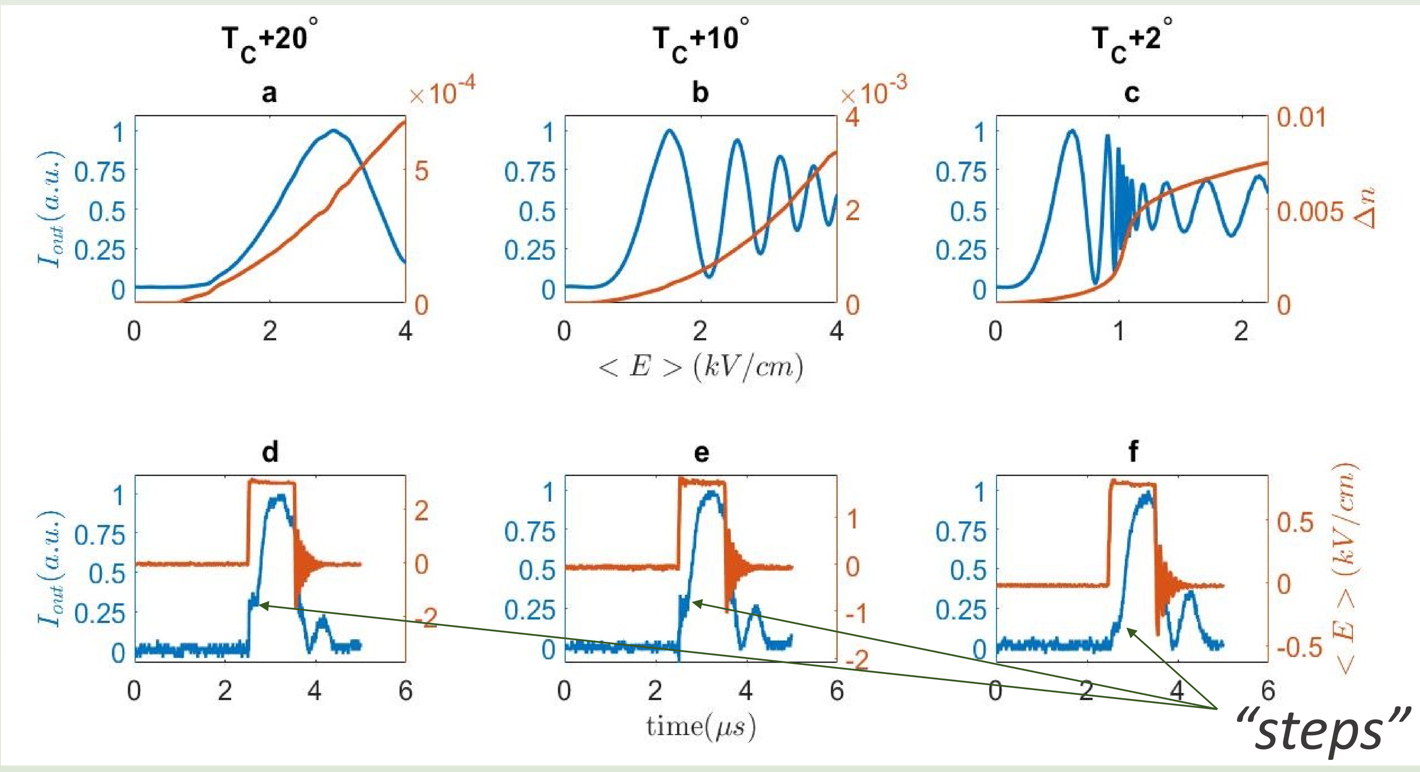

Figure 2: EO modulation (a-c) & EO switching (d-f)

In contrast to the uniform rise of the electrical pulse (d-f, orange), the optical (blue) exhibits a "step", in which height is temperature dependent. At the lower section, the optical output follows the electrical rise (t_r≈20ns), whereas a significant slowing down is exhibited in the upper (t_r≈400ns).

For fast switching, at T=T_C+25°, we can determine a threshold of 40%, and get a rise time of t_r≈20ns with an activating pulse amplitude of V_0≈1.6kV.

3. DISCUSSION

Previous DC studies indicate that close to TC the final IBR (Δn_0) can be written as a sum of two components, describing the IBR experienced by the part of the optical beam that propagated through the PE zone (Δn_{PE}), and through the dipolar clusters (Δn_{dip}):

$$(2)\quad \Delta n_{PE_{1-\chi}}(E,T) + \Delta n_{dip_{\chi}}(E,T) = \Delta n_0(E,T,\boldsymbol{r})$$

Where χ is the relative part of the beam trajectory that crosses the dipolar clusters [5]. Accordingly, we modeled the IBR under fast switching to consist of two components:

$$(3)\quad \frac{\Delta n_{PE}+\Delta n_{dip}}{\Delta n_0} = \frac{1}{2}\left((1-\chi)\cdot\tanh\left(\tau_{PE}\left(t-t_{0_{PE}}\right)\right)+\chi\cdot\tanh\left(\tau_{dip}\left(t-t_{0_{dip}}\right)\right)+1\right)$$

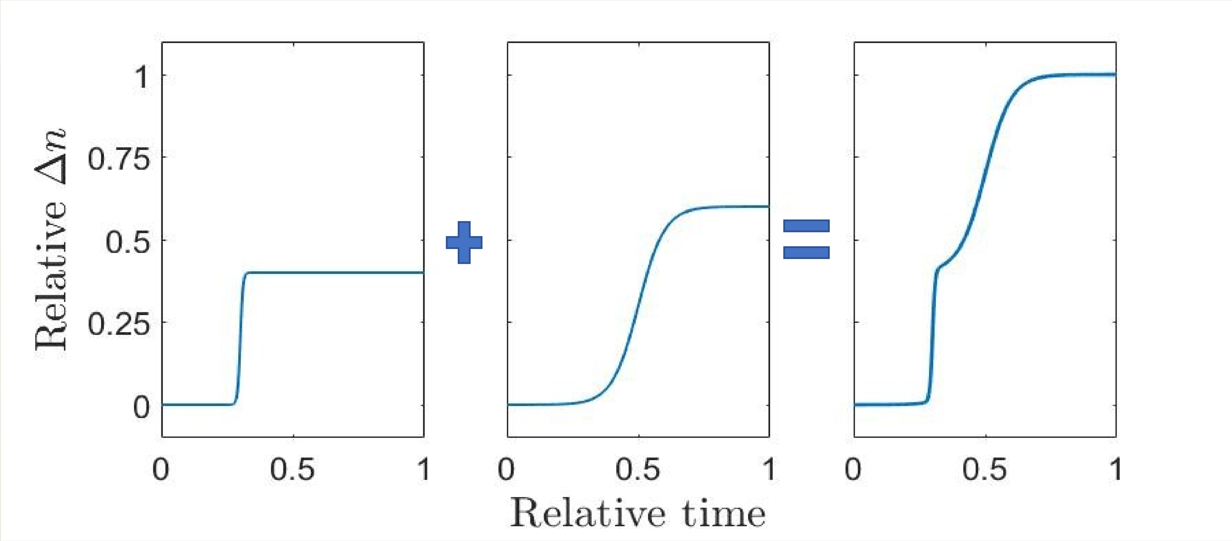

Figure 3: Step response of the IBR close to T_C - model

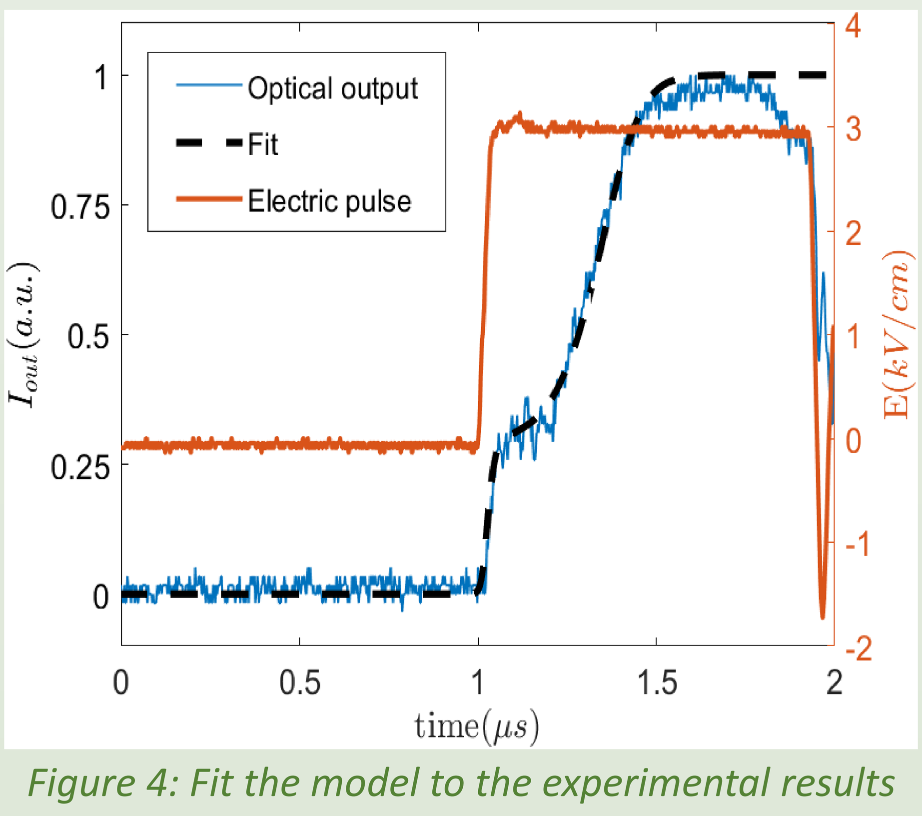

Figure 4: Fit the model to the experimental results

Figure 4 shows that expression (3) indeed provides an accurate approximation of the experimental results.

In conclusion, operating the crystal close to T_C, leads to elongation in the rise time due to the slow rearrangement of the dipolar clusters. An optimal choice of the working point as well as of the switching threshold will allow optimization of the results in different applications.

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