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Modelling the electro-optic behavior of liquid crystal lenses with multiple electrodes

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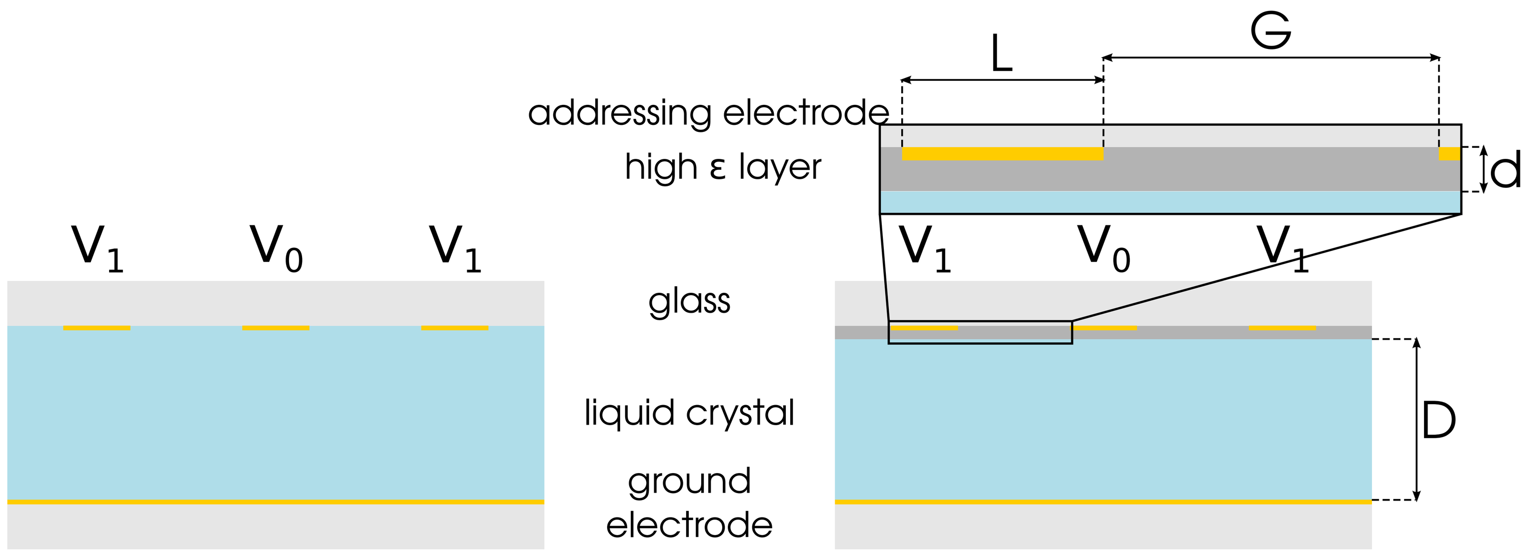
INTRODUCTION

Fully electro-optical beam steering of light offers several advantages over classical systems in which mechanical movements of components cause the actual redirection of light, such as reduced maintenance cost and speed.
Using the electro-optic effect of liquid crystals, we intend to fabricate a lens with an electrically tunable focal length that is both polarization independant as well as relatively cheap. The polarization independance will be investigated in a different communiqué, here we focus on a simplified addressing scheme to reduce the cost of such devices.

HYPOTHESIS

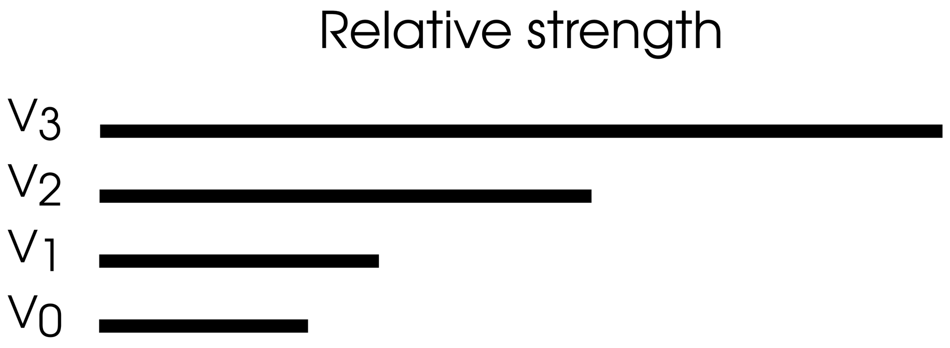


VFS without buffer layer   VFS with buffer layer

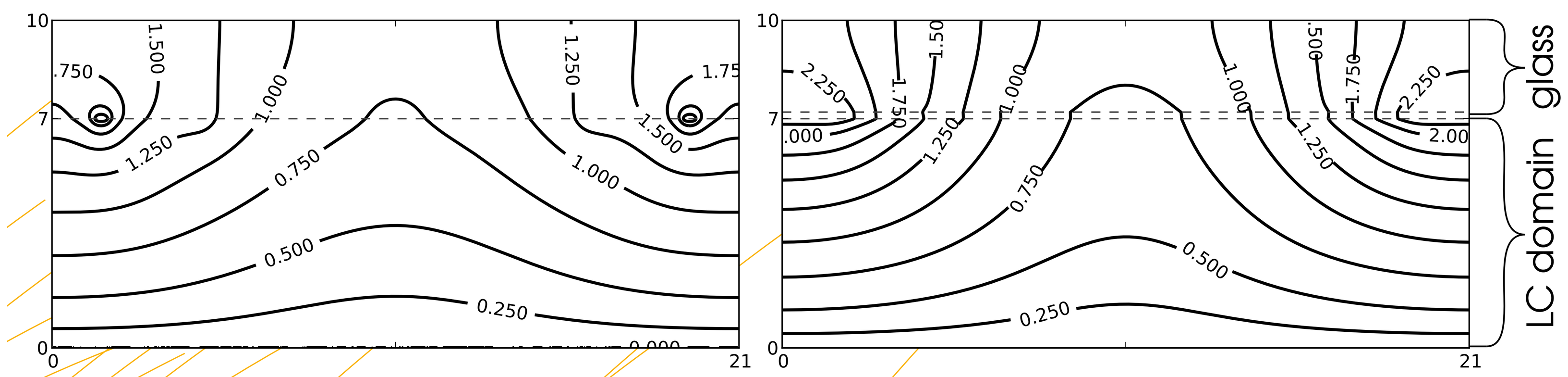
Addition of a layer with high dielectric constant should smoothen the fringe fields in the VFS cell.

We simulate the electro-optic behavior of a VFS nematic liquid crystal (LC) cell with 7 electrodes that are driven in such a way as to obtain a parabolic phaseprofile for light polarized along the y-axis and propagating along the z-axis. Two configurations are compared: one ordinary LC cell with addressing electrodes on the top and a ground electrode at the bottom and another where the electrodes are covered by a layer with high dielectric permittivity. The alignment layer causes a preferential orientation along the y-axis.

L=0.3μm
G=2.7μm
d=0.2μm
$\varepsilon_\perp$ = 600
$\Delta\varepsilon$=100



ELECTRICAL SIMULATION[1]

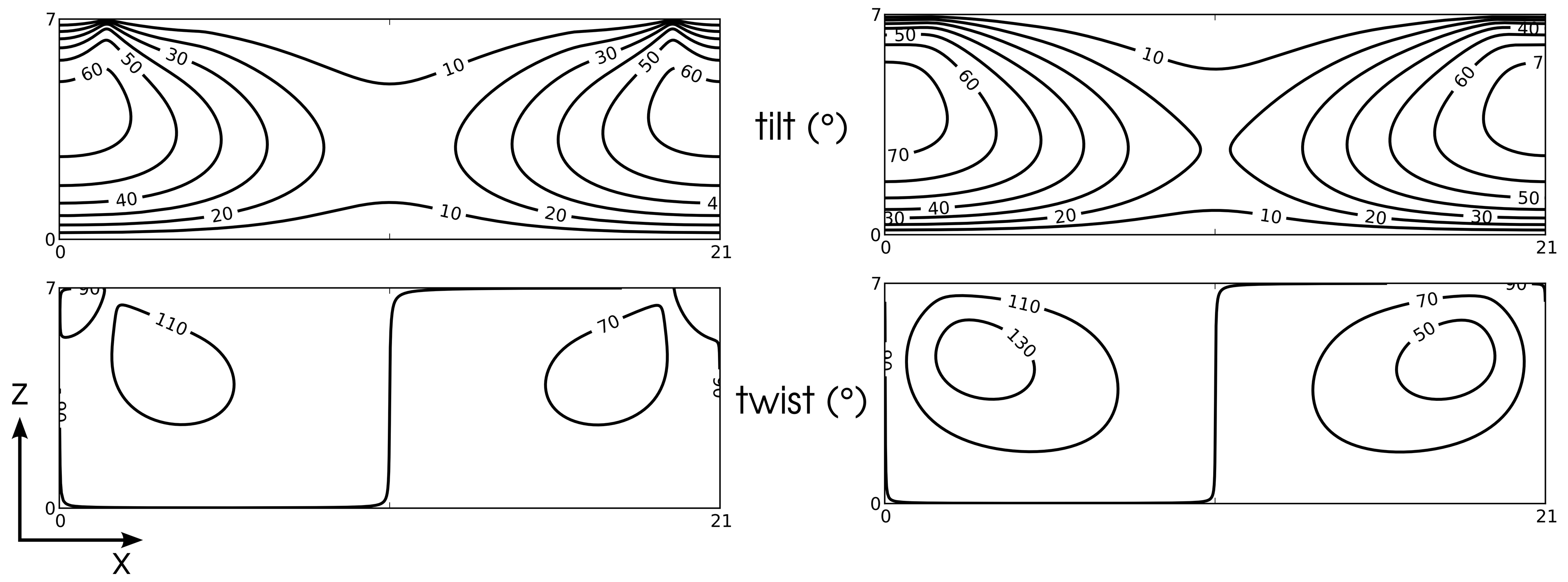


The isopotential lines within the LC vary less consistently when the liquid crystal is addressed directly. When a material with high dielectric constant is introduced, it acts as an interpolator between the electrodes, thereby reducing fringe field effects. The liquid crystal (E7 in the simulations) will reorient more gradually, which is desirable for a lens where the required phase profile is parabolic.

OPTICAL SIMULATION

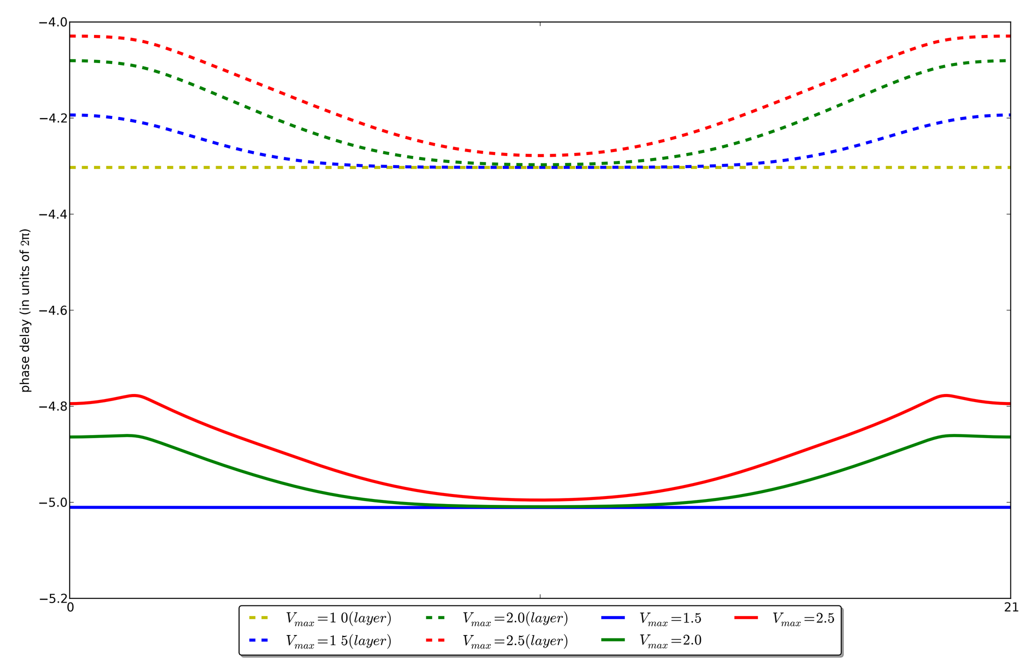
DIRECTOR ORIENTATION

Using **E**=-∇V, we obtain the electric field from the previous simulation. Now the orientation of the LC director can be calculated.



PHASE PROPAGATION

Using the simple **Jones-matrix formalism**, the overall phase delay is computed at different voltage strengths. All voltages are multiplied with the same scaling factor, thereby preserving their-ratio.



There is an overall phase delay of about .7 waves, which is attributed to the propagation through the layer with high dielectric constant.

Next, the voltage threshold for the device without the layer is higher. When $V_3 = V_{max}$ = 1.5V the device with the layer has already induced a much larger tilt on the molecules (>40° near V_3), whereas for the layerless device, the generated tilt is <2°.

For both configurations, the phase delay is nearly parabolic. However, near the edges of the cell, the phase changes abruptly for the layerless configuration. In such a case, we can expect more scattering. Further simulations have shown that in all tested configurations of (L,G,D,d) the phase profile is more parabolic when the layer of high dielectric constant is present.

CONCLUSIONS

We have simulated the electro-optic behavior of an electrically tunable lens. To reduce the cost & complexity, we are looking into an addressing scheme whereby the electrodes are spaced much further apart than in spatial light modulators. This would make it more difficult to control the orientation of the liquid crystal in such a way as to obtain a parabolic phase profile over the entire geometry.
We have found that the **addition of a layer of high dielectric constant** has a **beneficial effect on the phase delay**. Such layers are being made in our research group. Furthermore, addition of the layer has **lowered the threshold voltage**.

The simple Jones-matrix formalism does not take into account any reflections or scattering based on large variations of the indicatrix. We are therefor looking into optical simulations that take into account the scattering by using a beam propagation method[2].

REFERENCES

(1) R. James, *Modelling of High Resolution Liquid Crystal Devices.* (2006) doi: 10.1093/jmp/jhs077.
(2)P. J. M. Vanbrabant e.a. *A finite element beam propagation method for simulation of liquid crystal devices.* In: Optics express 17.13 (jun 2009), p.

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