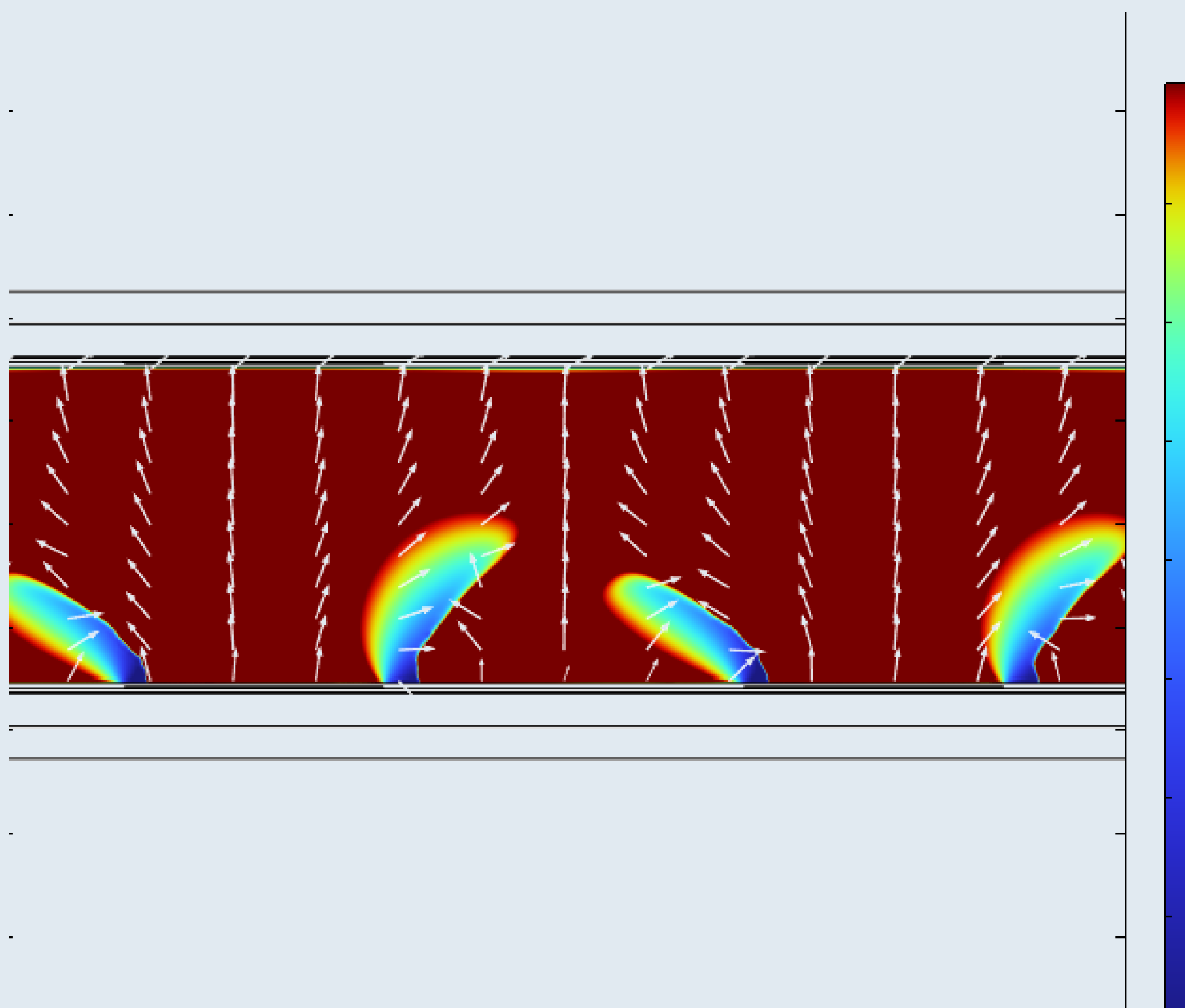


Theoretical modelling of fast-switching fountain-fringe field LC cells for AR-HMD device applications

This work presents an investigation into the configuration and geometry of an FFF-LC cell's electrodes, dielectric layers and spacers by employing finite-element method modelling. An optimal configuration of these has been found. Switching dynamics have also been successfully modeled.

Ciro F. Tipaldi, Aianrs Ozols | e-mail: tipaldi@cfi.lu.lv

Institute of Solid-State Physics, University of Latvia, LV-1063 Riga, Latvia



Goals

Liquid crystal (LC) displays are well-established in the modern world; however, they still have a whole host of characteristics and applications which require optimization. One such direction is their application in augmented reality head-mounted display devices (AR-HMD), especially in professional applications such as healthcare. Currently, the vergence-accommodation effect is the main cause for virtual reality sickness, limiting sustained use of such devices [1]. The remedy is to use multiple focal planes in the so-called volumetric projection screen [2].

However, because of the multiple screens needed, we run into the problem where the switching speed heavily impacts the maximum obtainable framerate. While the switch-on is easily made quicker with more voltage, the opposite is more difficult, since it depends on the LC relaxation. The idea of this work is to use fountain-fringe fields (FFF) to increase the switching speed of a twisted nematic LC cell between the transparent and diffuse state (Figure 1). For this, finite element modelling with COMSOL Multiphysics® has been used.

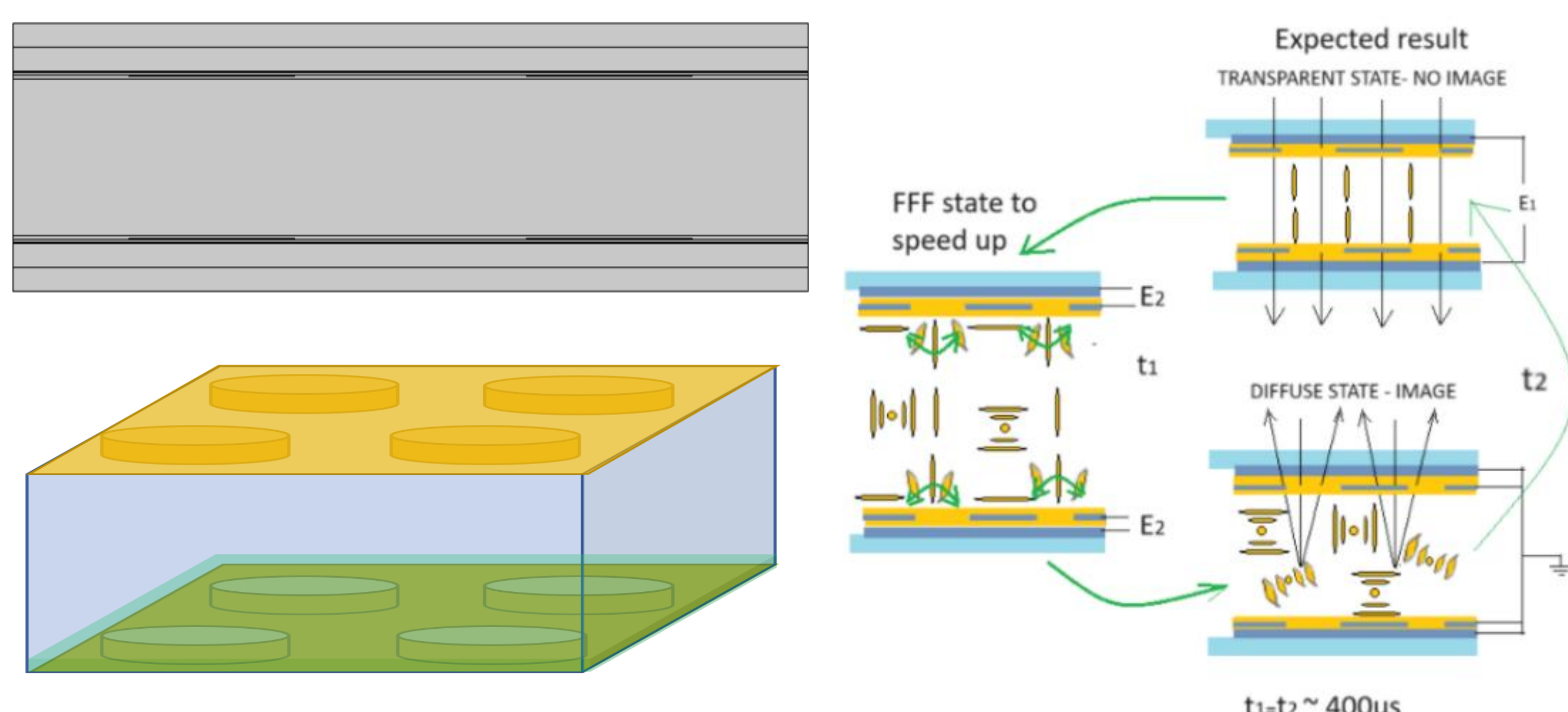


FIGURE 1. Left: Schematic and FEM model of the FFF cell. Right: Principle of operation.

Methodology

The LC cell is modelled in 2D, though the directors are defined 3-dimensionally. Oseen-Frank differential equations are variationally solved for the stationary case, where electrodes are optimized for transmittance:

$$\delta F = \delta \left[\frac{1}{2} K_{11} (\nabla \cdot \mathbf{n})^2 + \frac{1}{2} K_{22} (\mathbf{n} \cdot \nabla \times \mathbf{n})^2 + \frac{1}{2} K_{33} (\mathbf{n} \times \nabla \times \mathbf{n})^2 - \epsilon_0 \Delta \epsilon \mathbf{n} \cdot \mathbf{E} \right]$$

A Weak Form PDE interface is used, in conjunction with the Electrostatics and an Electromagnetic Waves physics interfaces. For the dynamical case, Ericksen-Leslie theory is employed which adds time derivatives and viscosity:

$$\delta F_\theta = \delta \left[\gamma \frac{d\theta}{dt} + K \left[\cos^2 \varphi \left(\frac{\partial \theta}{\partial x} + \frac{\partial \theta}{\partial y} \right) \right] - \epsilon_0 \Delta \epsilon \mathbf{n} \cdot \mathbf{E} \right] = 0$$

For photospacers, their density was minimized by performing calculations with the Solid Mechanics interface and checking the gap variance.

Results

FEM modelling has yielded an optimal secondary electrode configuration for maximal transmittance in the FFF state, as seen in Figure 2 left. The ratio of electrode size to distance is ideally around 0.84. Additionally, the density of photospacers has also been optimized by balancing optical transmittance and mechanical stability.

Switching dynamics have also been successfully modelled, with the molecules (directors) subject to the secondary FFF fields clearly showing a hastened change in the tilt angle theta (Figure 2 right). The switch-off time can thus be reduced down to 500 μs, in contrast to the circa 50 ms required when the LC molecules relax naturally. However, the FFF fields are too localized, which leaves part of the molecules unaffected by them. This requires further study, as well as experimental verification.

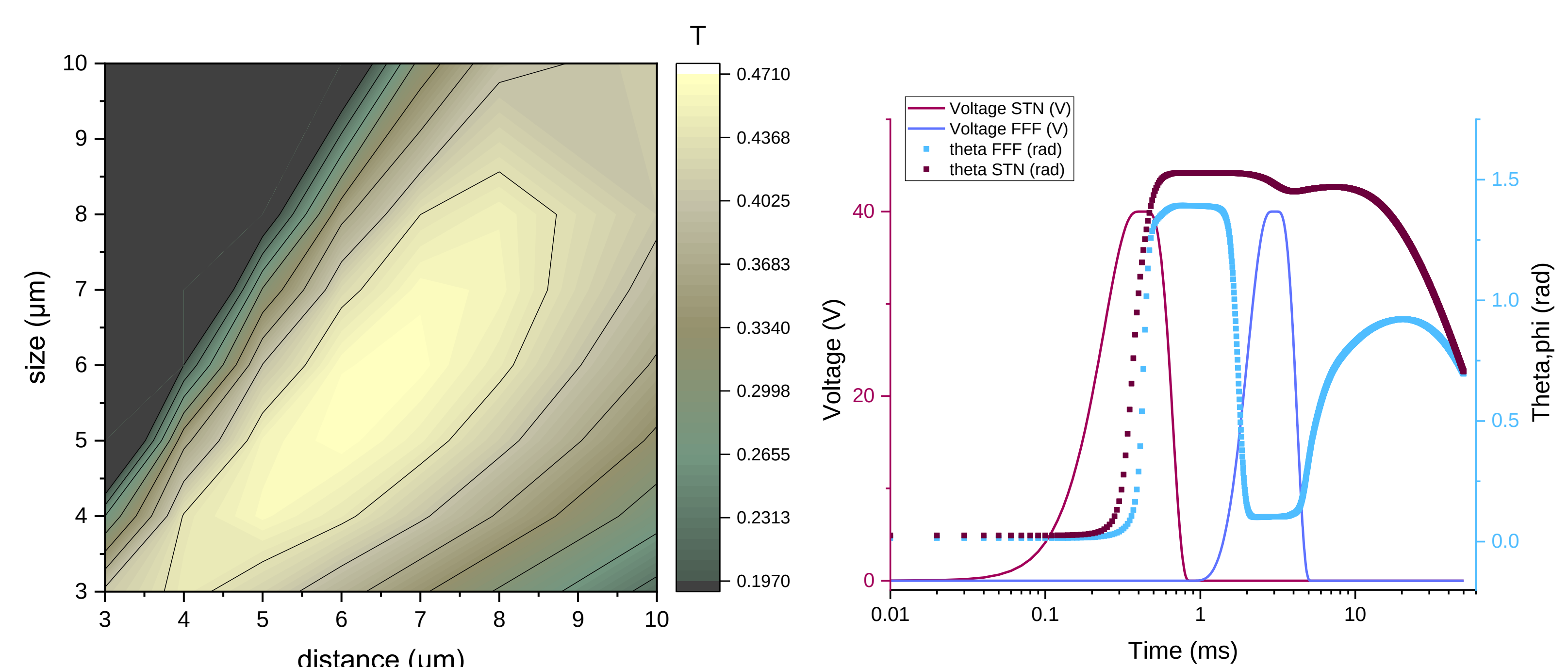


FIGURE 2. Left: Transmittance map for varying electrode configurations. Right: Dynamics of tilt angle depending on voltage.

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