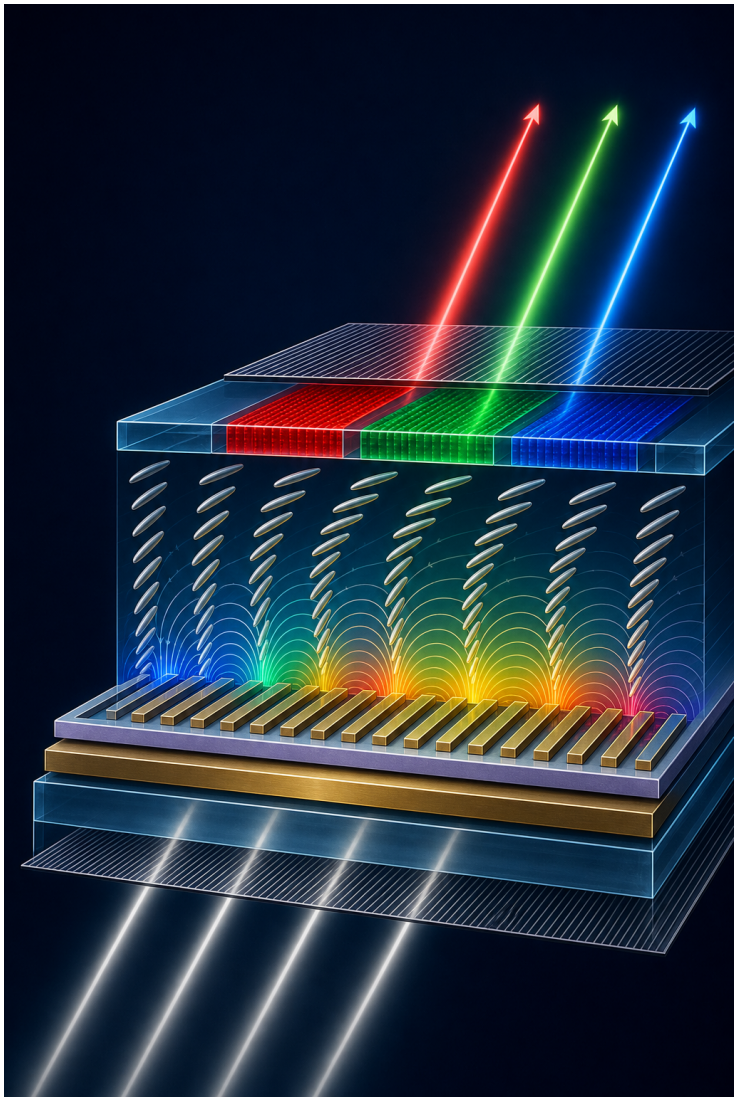
2D FFS LCD Simulator

User Manual



2D FFS LCD Simulator

July 2026

About this manual

This manual explains how to use the 2D FFS LCD Simulator: how to enter cell, material, optical, waveform, and solver parameters; how to run a simulation; and how to read and export the results. For equations and numerical details, see `doc/technical_note_en.pdf`.

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1 What This Simulator Does

The simulator calculates the electro-optical response of a two-dimensional cross section of an FFS (Fringe-Field Switching) LCD pixel. It can show:

- how the liquid-crystal director changes under an applied voltage,
- the optical transmittance and its time response,
- the pixel capacitance,
- the lateral transmittance profile, potential distribution, and director field,

- viewing-angle and contrast maps.

The calculation is controlled from the application window. Enter the parameters on the left side, press **[Run]**, and inspect the plots on the right side.

2 Starting the Application

2.1 Launch

Double-click the application icon. The application is ready when the main window appears.

The numerical engine is built into the application. There is no separate runtime compilation step. Runtime is mainly determined by the mesh size, number of time steps, convergence settings, and the number of viewing-angle points.

3 Window Layout

The window is divided into two main areas.

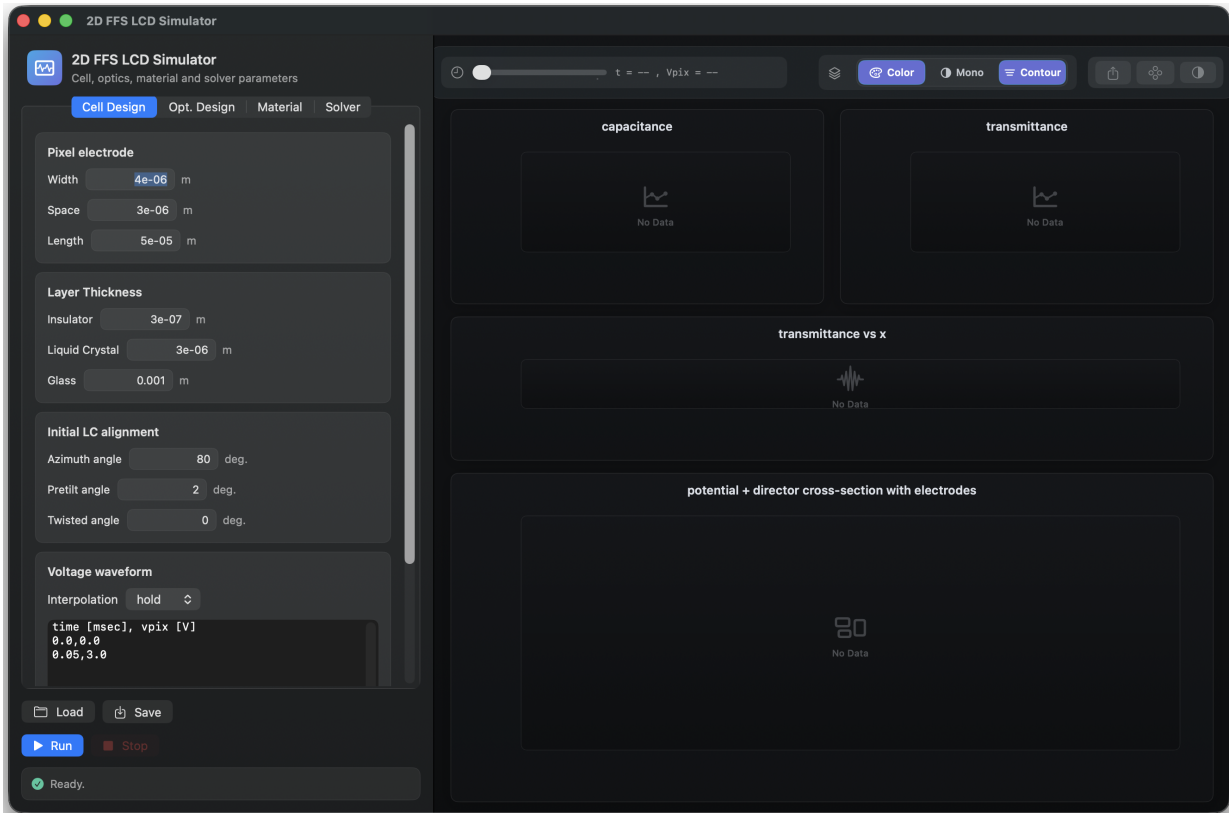


Figure 1: Main window at startup. The left panel contains input tabs and run buttons. The right panel contains the result controls and plots.

Left panel: inputs	Right panel: results
• Input tabs: **Cell Design**, **Opt. Design**, **Material**, **Solver** • **[Load]** and **[Save]** • **[Run]** and **[STOP]** • Status line such as Ready. or Running...	• Time slider, potential-display control, and analysis tools • Four result plots with tick labels, axis labels, and a time cursor • Axis-range dialogs opened by clicking plot axes

4 Quick Start

Run the first simulation

1. Launch the application.
2. Keep the default parameters.
3. Press **[Run]**.
4. Wait until the status line changes from Running... to Done: N snapshots.
5. Use the Time slider to inspect the stored snapshots.

While a simulation is running, **[Run]** is disabled and **[STOP]** is enabled. Use **[STOP]** to stop a long calculation.

5 Input Tabs

Numeric rows are organized as a label on the left, an editable value in the middle, and the unit on the right. For example, Width shows the unit m to the right of the input field. Dimensionless parameters leave the unit column blank.

5.1 **Cell Design:** Cell Geometry and Waveform

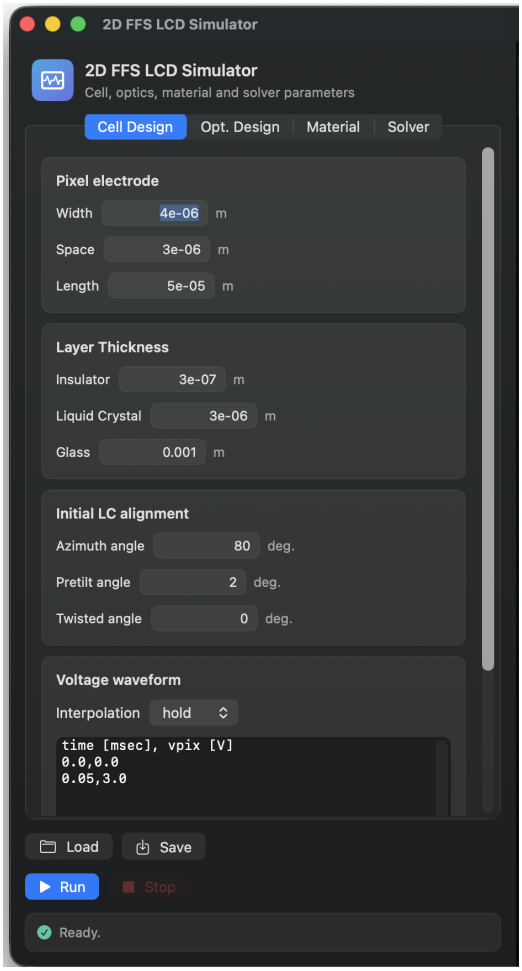


Figure 2: Cell Design tab.

Pixel electrode. Set the pixel-electrode width, gap width, and pixel length.

Layer thickness. Set the insulator thickness, liquid-crystal layer thickness, and glass thickness.

Initial LC alignment. Set the rubbing azimuth angle, pretilt angle, and twist angle.

Voltage waveform. The waveform editor accepts a two-column table: `time [msec], vpix [V]`. With hold interpolation, each voltage is held until the next time point. With linear interpolation, voltage is linearly interpolated between points. vcom is the common-electrode voltage in V, and End Time is the final simulation time in msec.

5.2 **Opt. Design:** Optical Stack

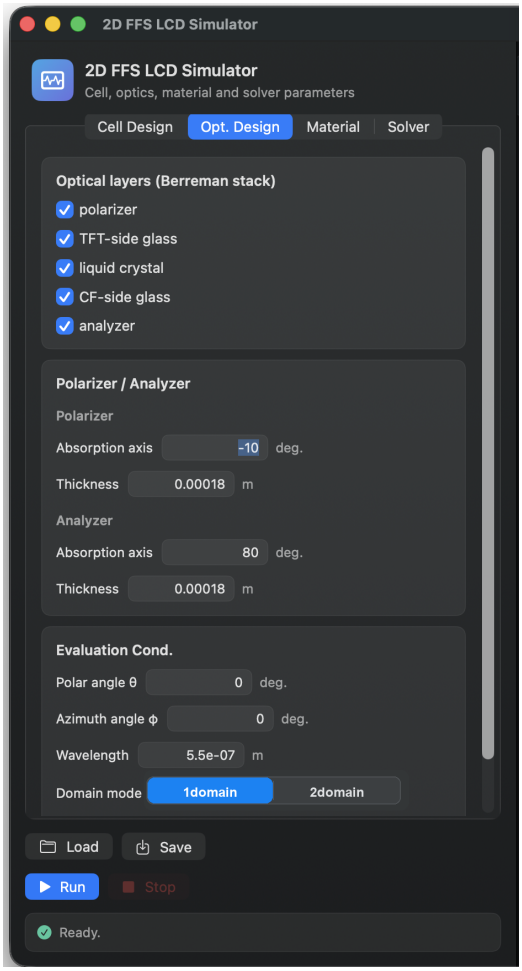


Figure 3: Opt. Design tab.

Optical layers. The checkboxes select which layers are included in the Berreman optical calculation: polarizer, TFT-side glass, liquid crystal, CF-side glass, and analyzer. A disabled layer is treated as optically absent.

Polarizer and analyzer. Set the absorption-axis azimuth and layer thickness. The absorption axis is perpendicular to the transmission axis. Nearly crossed absorption axes give a crossed-Nicol reference state.

Evaluation conditions. Set the incident polar angle, azimuth angle, wavelength, domain mode, and snapshot interval. Domain mode is selected with the 1domain/2domain segmented control. 1domain evaluates a single optical domain. 2domain averages two mirror-related azimuthal domains so that the FFS viewing-angle response becomes left-right symmetric when the geometry and material conditions are symmetric.

5.3 **Material:** Material Parameters

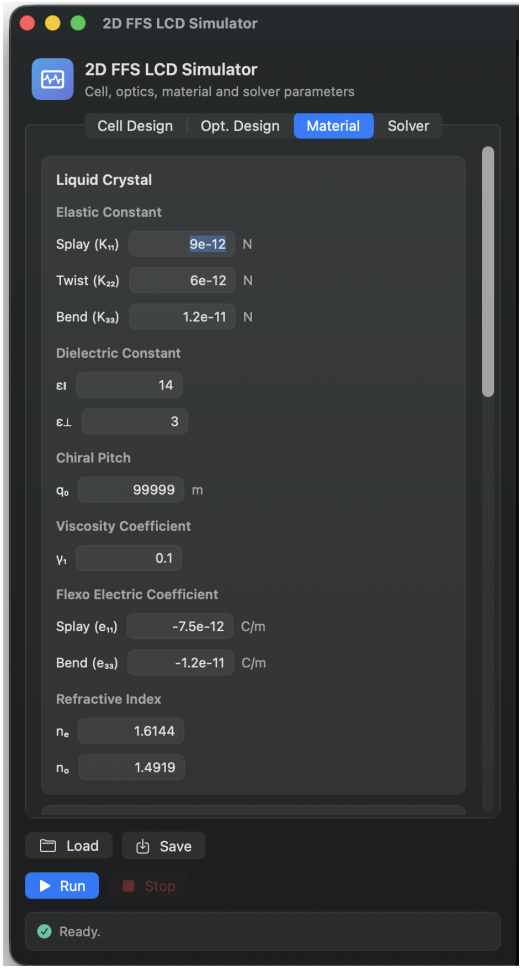


Figure 4: Material tab.

This tab sets liquid-crystal elastic constants, dielectric constants, rotational viscosity, chirality pitch, flexoelectric coefficients, optical indices, and the dielectric/optical constants of the surrounding layers.

The sign convention for the bend flexoelectric coefficient differs in the literature. This simulator uses the $(\nabla \times \mathbf{n}) \times \mathbf{n}$ convention. If a source uses $\mathbf{n} \times (\nabla \times \mathbf{n})$, reverse the sign of the bend coefficient before entering it.

The displayed capacitance is the small-signal capacitance at the current fixed director state. It is evaluated from the curvature of dielectric energy by a three-point method. Flexoelectricity affects capacitance indirectly through the evolved director and potential distributions.

5.4 **Solver**: Mesh and Convergence

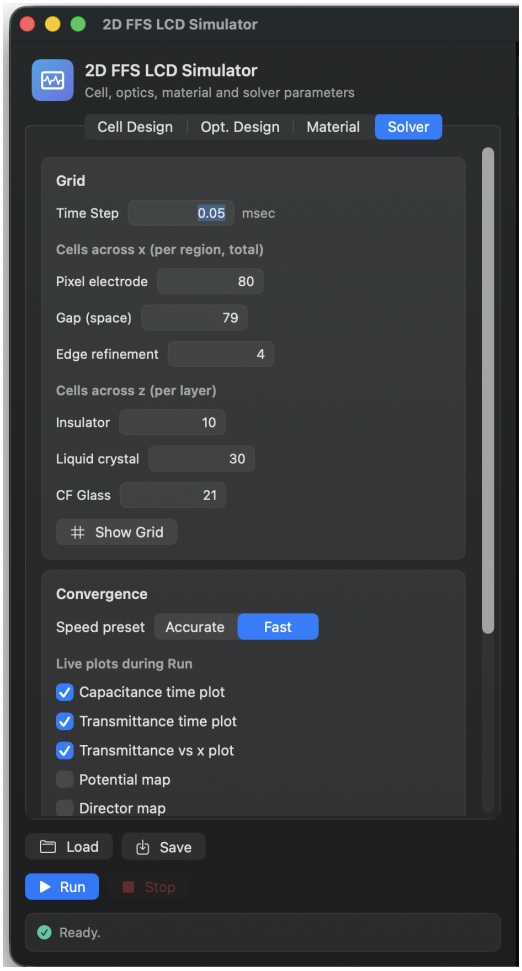


Figure 5: Solver tab. Mesh, speed preset, live-plot controls, and convergence settings.

Grid. Set the time step and the number of mesh cells in the pixel, gap, insulator, LC, and CF-glass regions. **[Show Grid]** displays the current mesh and electrode positions. Edge refinement controls the lateral geometric mesh grading. Larger values make the mesh finer near pixel-electrode and gap edges, and coarser near the electrode center and gap center.

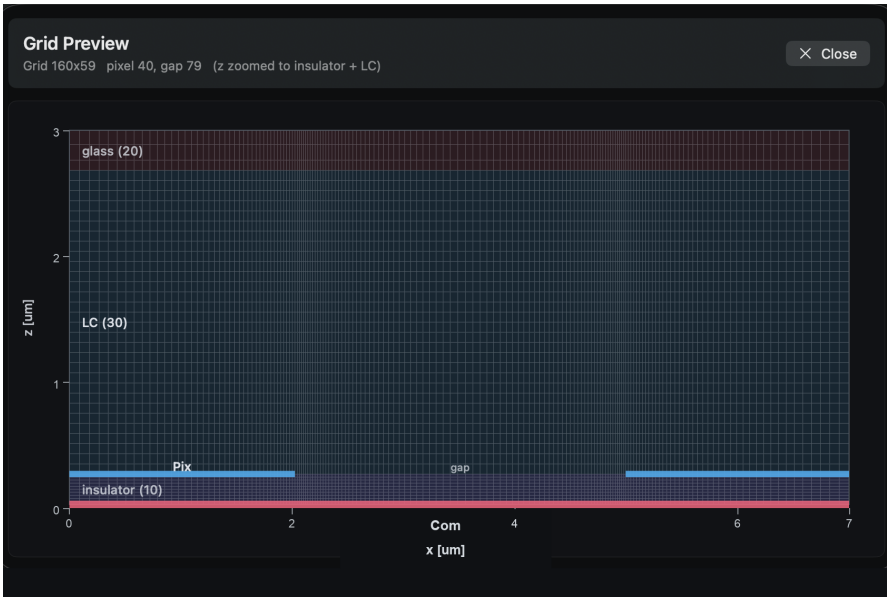


Figure 6: [Show Grid] preview. The grid, insulator, LC, glass, Com/Pix electrodes, gap, and x/z axis ticks can be checked before running the simulation. The vertical coordinate is compressed around the insulator and LC so that the thin layers remain visible.

Finer meshes improve spatial resolution but increase runtime and memory use. Start from the default settings and refine only after checking convergence.

Convergence. The Speed preset selects the balance between accuracy and runtime. Accurate is intended for verification, Fast is the default for normal use. Use Fast for routine exploration and Accurate for final checks or reference calculations.

Live plots during Run controls which plots are updated while a simulation is running: capacitance time plot, transmittance time plot, transmittance profile, potential map, and director map can be enabled or disabled independently. By default, the time plots and lateral transmittance profile are updated during the run, while the heavier potential and director map previews are off. Turning all live plots off minimizes drawing overhead and shows the full result after the run finishes.

The main controls are the potential relaxation factor, director relaxation factor, potential tolerance, director tolerance, maximum coupled iterations, and Coupled Poisson sweeps. Increasing Coupled Poisson sweeps can improve potential convergence inside each coupled iteration, but it also increases the cost per time step.

6 Running and Stopping

Run a calculation

1. Enter or load the parameter set.
2. If needed, choose which plots should update during the run in **Solver** Live plots during Run.
3. Press **[Run]**.
4. Watch the status line. Enabled live plots update during the calculation.
5. When the run completes, inspect the plots and export data if needed.

[STOP] requests cancellation. The application keeps any snapshots already computed before the cancellation is processed. A short delay can occur before the calculation reaches a cancellation point.

6.1 Quitting the Application

On macOS, the red button at the upper-left of a window primarily closes the window. To quit the application, choose 2D FFS LCD Simulator > Quit 2D FFS LCD Simulator from the menu bar or press Command-Q.

7 Reading the Results

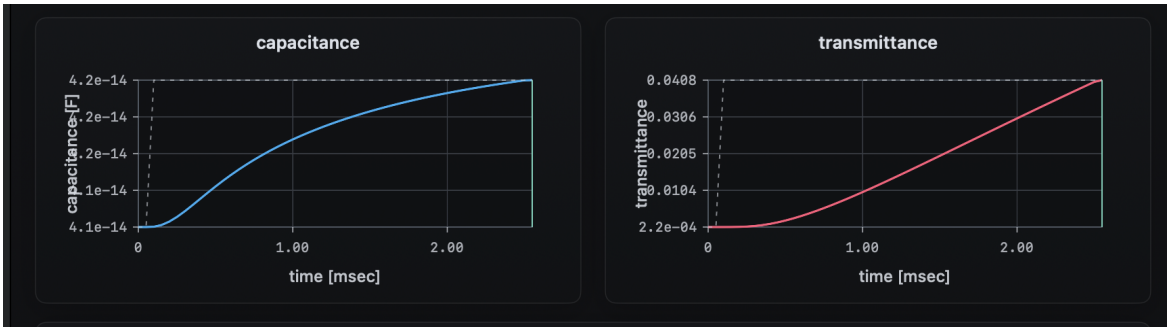


Figure 7: Example result plots. Capacitance and transmittance are shown side by side as time responses, with the applied voltage and current-time cursor overlaid on each plot.

Plot	Meaning
capacitance	Pixel capacitance in farads versus time.
transmittance	Time response of optical transmittance.
transmittance vs x	Lateral transmittance profile at the selected snapshot.
potential + director cross-section	Potential map with Color/Mono fill, optional contour overlay, three-dimensional-looking director rods, and electrode locations.

The top toolbar contains the Time slider, the Potential display selector, and three icon buttons. The share icon exports CSV files, the grid icon opens the viewing-angle calculation, and the half-filled-circle icon opens the contrast calculation. Hover over an icon to see its function name.

In the Potential control, Color and Mono select the fill style, while Contour independently toggles contour-line overlay. This allows Color+Contour and Mono+Contour displays. Contour labels use rounded voltage values, and the contour lines are drawn with a subtle outline so that they remain visible on both color and monochrome fills.

7.1 Axis Range Settings

For the capacitance and transmittance time plots, click near the vertical axis label to open the Y-axis range dialog. Click near the horizontal axis label to open the common time-axis range dialog.

- With Auto range enabled, the displayed data determine the range.
- Disable Auto range to enter Minimum and Maximum values manually.

8 Exporting Data

Use **[Export CSV]** from the share icon in the upper-right toolbar. The save dialog asks for a base file name. The application then writes several CSV files by adding suffixes to that base name.

Output file	Contents
`_series.csv`	Time series of all stored snapshots: time, pixel voltage, capacitance, and transmittance.
`_transprofile.csv`	Lateral transmittance profile at the currently selected snapshot.
`_director.csv`	Director field at the currently selected snapshot.
`_potential.csv`	Potential field at the currently selected snapshot.

Profile and field exports use the snapshot selected by the Time slider. Move the slider first, then export. The time-series file always covers all stored snapshots.

9 Viewing-Angle and Contrast Maps

After a time simulation, press **[View angle]** to calculate a polar viewing-angle map for the selected snapshot. Press **[Contrast]** to compare two snapshots and display their transmittance ratio.

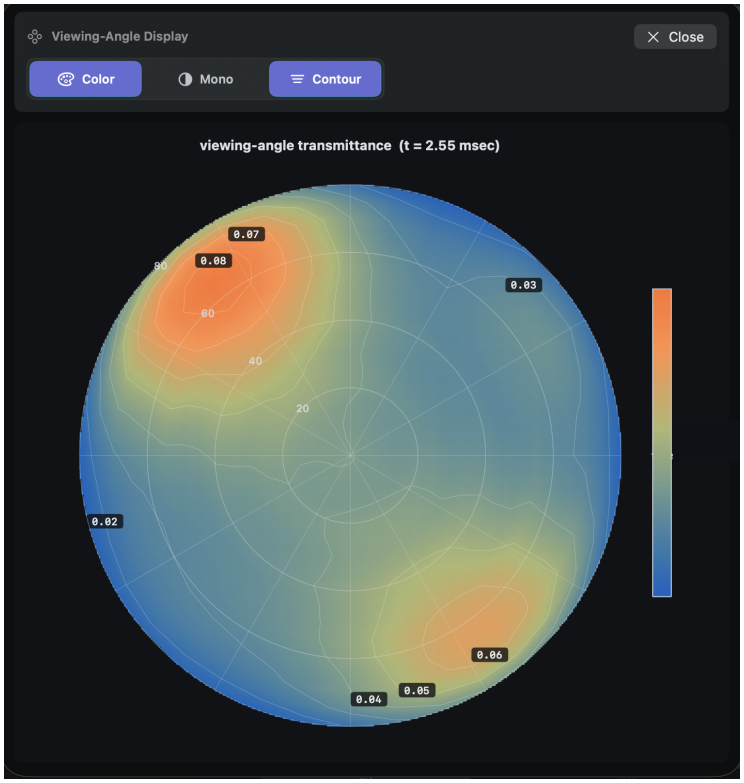


Figure 8: Example viewing-angle map. Radius is polar angle and angle around the circle is viewing azimuth. The right-side bar has tick labels so the color or gray level can be read quantitatively.

Calculate a viewing-angle map

1. Run a time simulation.
2. Move the Time slider to the snapshot you want to inspect.

3. Press **[View angle]**.
4. Set max polar angle theta, theta samples, and azimuth samples.
5. Press **[OK]**. A viewing-angle window opens when the calculation finishes. Use Color or Mono for the fill style, and turn Contour on or off independently. Contour labels and colorbar tick labels use rounded values.

Calculate a contrast viewing-angle map

1. Run a waveform that contains the two states you want to compare.
2. Identify the dark-state and bright-state snapshot numbers.
3. Press **[Contrast]**.
4. Enter the two snapshot numbers and the angular resolution.
5. Press **[OK]**.

10 Save, Load, and Export

- **[Save]**: writes the current parameter set to a text file.
- **[Load]**: loads a saved parameter file.
- **[Load CSV]**: imports a voltage waveform.
- **[Save CSV]**: exports the waveform table.
- **[Export CSV]**: writes result CSV files using the selected base name.

The application is compatible with the macOS sandbox. Save, load, and CSV export operations read and write only locations selected by the user. This does not change normal operation, but it is important for App Store distribution.

[Export CSV] writes several files by appending suffixes to the chosen base name:

Output file	Contents
`_series.csv`	Time series of time, voltage, capacitance, and transmittance.
`_transprofile.csv`	Lateral transmittance profile at the selected snapshot.
`_director.csv`	Director field (n_x, n_y, n_z) at the selected snapshot.
`_potential.csv`	Potential field in volts at the selected snapshot.

Saved parameter files use stable key-value names so that calculation conditions can be reused across versions.

11 Troubleshooting

Symptom	Suggested action
The window does not open	Check that the application is installed correctly.
[Run] or **[View angle]** is slow	Use Fast, disable unnecessary Live plots during Run, reduce mesh size, number of time steps, viewing-angle points, or restore Coupled Poisson sweeps near the default value.
[Export], **[View angle]**, or **[Contrast]** is disabled	Run a simulation first.
The run stops or fails	Check mesh divisions and convergence settings. If you pressed **[STOP]**, this is normal.
The result changes after changing mesh size	This is expected until mesh convergence is reached. Refine the grid and compare capacitance, transmittance, and director profiles.
Export CSV creates large files	Increase Snapshot interval or shorten End Time. Field exports grow with mesh size and stored snapshot count.
The viewing-angle map looks coarse	Increase theta samples and azimuth samples. This improves smoothness but increases calculation time.

12 Common Workflows

Change drive voltage and inspect brightness response

1. Open **Cell Design**.
2. Edit the voltage values in the waveform table.
3. Press **[Run]**.
4. Inspect the transmittance time plot.

Reduce exported data size

1. Open **Opt. Design**.
2. Increase Snapshot interval, for example from 1 to 10.
3. Run the calculation again.
4. Exported field/profile data now contain fewer stored snapshots.

Compare two geometries

1. Save the current parameter file with **[Save]**.
2. Change one geometry parameter, such as electrode width or gap.
3. Keep solver settings fixed.
4. Run both cases and compare capacitance, transmittance, and profiles.

13 Recommended Workflow

1. Start with default parameters.
2. Change one physical parameter at a time.

3. Keep solver settings fixed while comparing materials or geometries.
4. Confirm mesh convergence before drawing quantitative conclusions.
5. Save parameter files for every important result.

14 Control Reference

Location	Control	Function
Left panel	**Cell Design**	Cell geometry, initial alignment, waveform
	Opt. Design	Optical stack and evaluation conditions
	Material	LC and layer material constants
	Solver	Mesh, speed preset, live plots, convergence
	[Load]	Load a saved parameter file
	[Save]	Save current parameters
	[Run]	Start the calculation
	[STOP]	Request cancellation
Right panel	Time slider	Select stored snapshot
	Potential selector	Choose Color/Mono fill and optional Contour overlay
	Share icon	Export CSV files
	Grid icon	Calculate viewing-angle map
	Half-circle icon	Calculate contrast map
	Axis click	Open X/Y axis range dialog
Menu bar	Quit 2D FFS LCD Simulator / Command-Q	Quit the application