Methodological Note: Interactive Cymatics Visualization

Reduced-order standing-wave models for educational exploration, reproducibility, and responsible visual interpretation

Instrument	Cymatics Visualizer v1.0
Default apparatus	Circular water vessel, top-down view
Computational scope	Browser-based reduced modal and interference renderer
Classification	Educational visualization; not a calibrated predictive solver

Purpose. This note documents what the visualizer computes, what its outputs can and cannot support, and how users can preserve a reproducible parameter state.

1. Scope and interpretive position

Cymatics is commonly used as an umbrella term for visible pattern formation in driven vibrating systems. Historically important cases include particles collecting near nodal lines on elastic plates and surface-wave patterns in periodically forced fluids. The visualizer brings these related but mechanically distinct cases into one interface while preserving explicit labels for apparatus, medium, geometry, drive, and model status.

The application has two experience modes. Scientific mode uses a restrained reduced-order field and prioritizes parameter visibility. Cinematic mode applies enhanced color, glow, and optional transformations. Mercury-like and light/plasma media are explicitly speculative visual modes. Cultural or popular frequency demonstrations are separated from scientific presets and do not constitute validation of extraordinary claims.

Core principle

A rendered pattern is treated as the output of an identified parameter state, not as a universal signature of a frequency. Real patterns depend on apparatus dimensions, material properties, depth, temperature, boundary conditions, excitation geometry, coupling, drive amplitude, and measurement method.

2. Reduced mathematical model

For a circular domain, the display combines a Fourier-Bessel-like modal field with damped radial terms centered on user-defined excitation points. The implementation uses approximate radial eigenvalues to provide stable, interactive mode families rather than calibrated eigenfrequencies for a particular vessel.

```
u(r, theta, t) = sum_i A_i J_m(alpha_mn r) cos[m(theta - theta_i) + phi_i] sin(omega_i t + phi_i)
```

Square and rectangular stages use separable sine fields of the form:

```
u(x, y, t) = sum_i A_i sin(m pi x / Lx) sin(n pi y / Ly) sin(omega_i t + phi_i)
```

Local excitation points add damped radial oscillations. Optional harmonics introduce bounded nonlinear visual terms. The renderer does not solve the full plate biharmonic equation, Navier-Stokes equations, moving contact lines, free-surface breakup, magnetic constitutive behavior, or granular collision dynamics.

3. Media parameters and visual behavior

The medium selector modifies color, damping, particle behavior, and displayed reference properties. Reference values are representative interface defaults and are not substitutes for measured laboratory values.

Medium	Display treatment	Interpretive status
Water	Continuous luminous height-field proxy; density, viscosity, and surface tension shown	Grounded reduced-order
Fine sand	Particles drift toward low-amplitude regions	Interpretive granular proxy
Salt	Coarser particle accumulation near nodes	Interpretive granular proxy
Lycopodium	Light particle response with lower visual inertia	Interpretive granular proxy
Ferrofluid	Dark, high-contrast crest emphasis	Qualitative only; no magnetic-field solver
Mercury-like	Reflective metallic surface treatment	Speculative visual mode
Light / plasma	Luminous non-material field treatment	Speculative visual mode

4. Controls and outputs

Drive controls. The main frequency dial is logarithmic. Direct entry, musical-note selection, sweep range, sweep speed, and harmonic multiplier modify the displayed field. Laboratory mode expands the user range to 20 Hz-20 kHz but does not imply that every selected apparatus can physically respond across that range.

Oscillators. Up to four visual/audio oscillators can be combined with independent amplitude and phase. The first oscillator is primary. Additional oscillators produce superposition and interference.

Live HUD. Frequency and selected medium properties are direct state values. Wavelength, nodal count, mode numbers, phase, and energy are model-derived indicators and must not be treated as instrument measurements.

FFT and waveform. The signal plots visualize the synthesized drive state. They are not microphone, accelerometer, hydrophone, or laser-vibrometry measurements.

5. Reproducibility workflow

A responsible visual experiment should preserve both the pattern and the state that generated it. Use the following workflow:

1	Select and record the apparatus, geometry, medium, and mode.
2	Set frequency, harmonic multiplier, sweep behavior, and active oscillators.
3	Record amplitude, phase, waveform, excitation-point coordinates, and enabled effects.
4	Export the parameter JSON and a PNG snapshot.
5	Add observations in the local comments panel and export the comment JSON.
6	For physical comparison, document measured dimensions, medium depth, temperature, transducer location, coupling, and sensor calibration outside the visualizer.

Minimum JSON record

```
{ mode, apparatus, medium, geometry, frequency, harmonic, oscillators[], excitationPoints[],
effects{}, mediumProperties, classification }
```

The browser stores comments in localStorage only. Users must export JSON to preserve or transfer those notes. Clearing browser storage may remove locally saved comments.

6. Limitations and misuse safeguards

The visualizer should not be used to infer hidden material composition, biological effects, healing efficacy, archaeological intent, or universal symbolic meaning from a visual resemblance. Similar geometries can arise in different systems, and small changes in boundaries or excitation can produce large pattern changes.

Cultural/popular presets are intentionally separated and accompanied by a classification note. The 432 Hz and solfeggio demonstrations are interface examples only; the tool does not endorse claims of unique therapeutic, cosmological, or consciousness-altering effects.

Audio safety

Audio is muted on load and capped to a conservative interface range. Device output levels vary. Users should keep playback comfortable, avoid prolonged high-frequency exposure, and stop playback if discomfort occurs.

7. Selected references

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2. Perlin, M., & Schultz, W. W. (2000). Capillary effects on surface waves. Annual Review of Fluid Mechanics, 32, 241-274. https://doi.org/10.1146/annurev.fluid.32.1.241

3. Javidinejad, A. (2013). Vibration modal solutions developing of the elastic circular membrane in polar coordinates based on the Fourier-Bessel series. Journal of Theoretical and Applied Mechanics, 43(1), 19-26. https://doi.org/10.2478/jtam-2013-0002

4. Kovacic, I., & Kanovic, Z. (2023). Chladni plate in anechoic chamber: Symmetry in vibrational and acoustic response. Symmetry, 15(9), 1748. https://doi.org/10.3390/sym15091748

5. Perinet, N., Juric, D., & Tuckerman, L. S. (2009). Numerical simulation of Faraday waves. Journal of Fluid Mechanics, 635, 1-26. Preprint: arXiv:0901.0464.

6. Chasman, L. M. (2011). Vibrational modes of circular free plates under tension. Applied Analysis, 90(12), 1877-1895. Preprint: arXiv:1004.3316.

Implementation statement

The delivered web application is dependency-free and executes entirely in the browser. It uses HTML5 Canvas for the visual field, Web Audio for optional sound, browser MediaRecorder for short WebM capture, localStorage for local comments, and standard browser printing for PDF report generation.