Spontaneous Symmetry Breaking by Meniscus Streaming

Connor W. Magoon†, Jian H. Guan*, Pedro J. Sáenz

Department of Mathematics, University of North Carolina at Chapel Hill

Experiments*

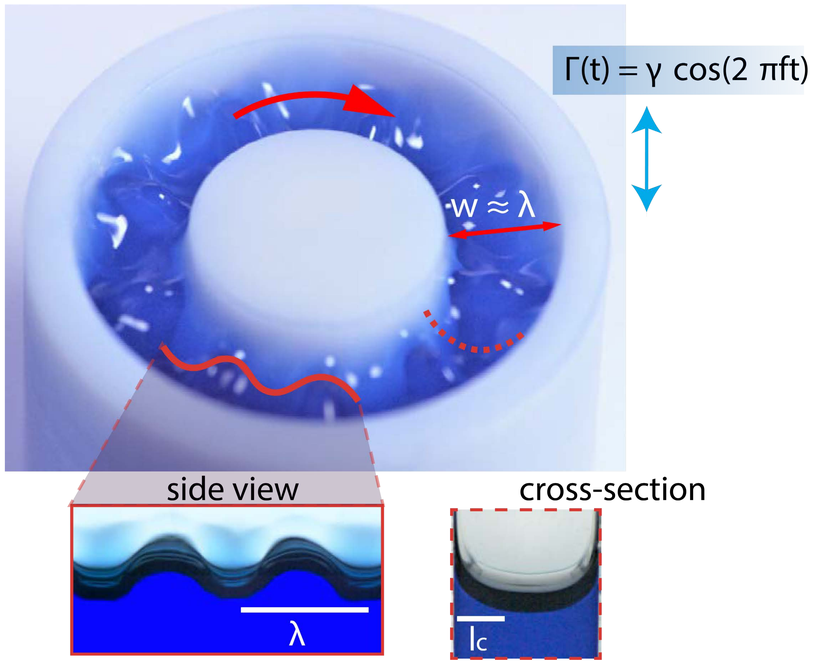

Figure 1

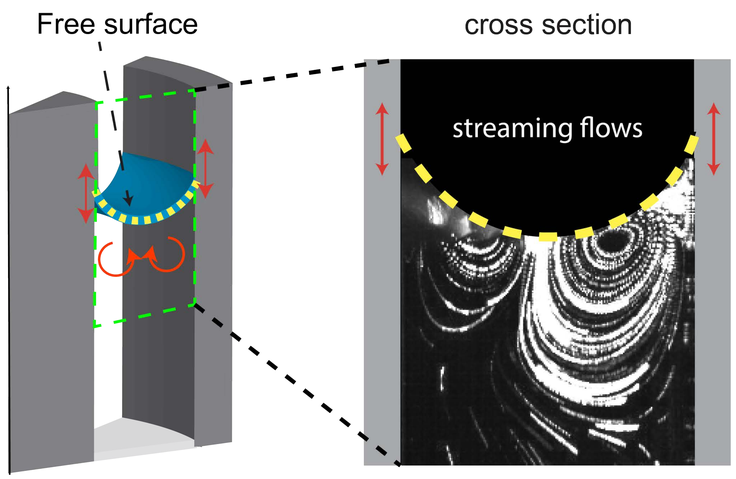

Figure 2

Faraday waves are a parametric fluid instability induced by vertically vibrating a fluid bath[1]. We confine Faraday waves to an annulus in Fig. 1, spontaneously exciting a horizontal drifting instability[2] that depends on the amplitude and frequency of the vibration. This symmetry breaking drifting is expected to be coupled to the underlying streaming (mean) flows that arrise from nonlinear behavior near the interface and boundaries. In Fig. 2 we show streaming flows by using particle image velocimetry and strobing at the wave frequency. We obtain fast drifting regimes and construct phase diagrams extending previous experimental work.

Simulations†

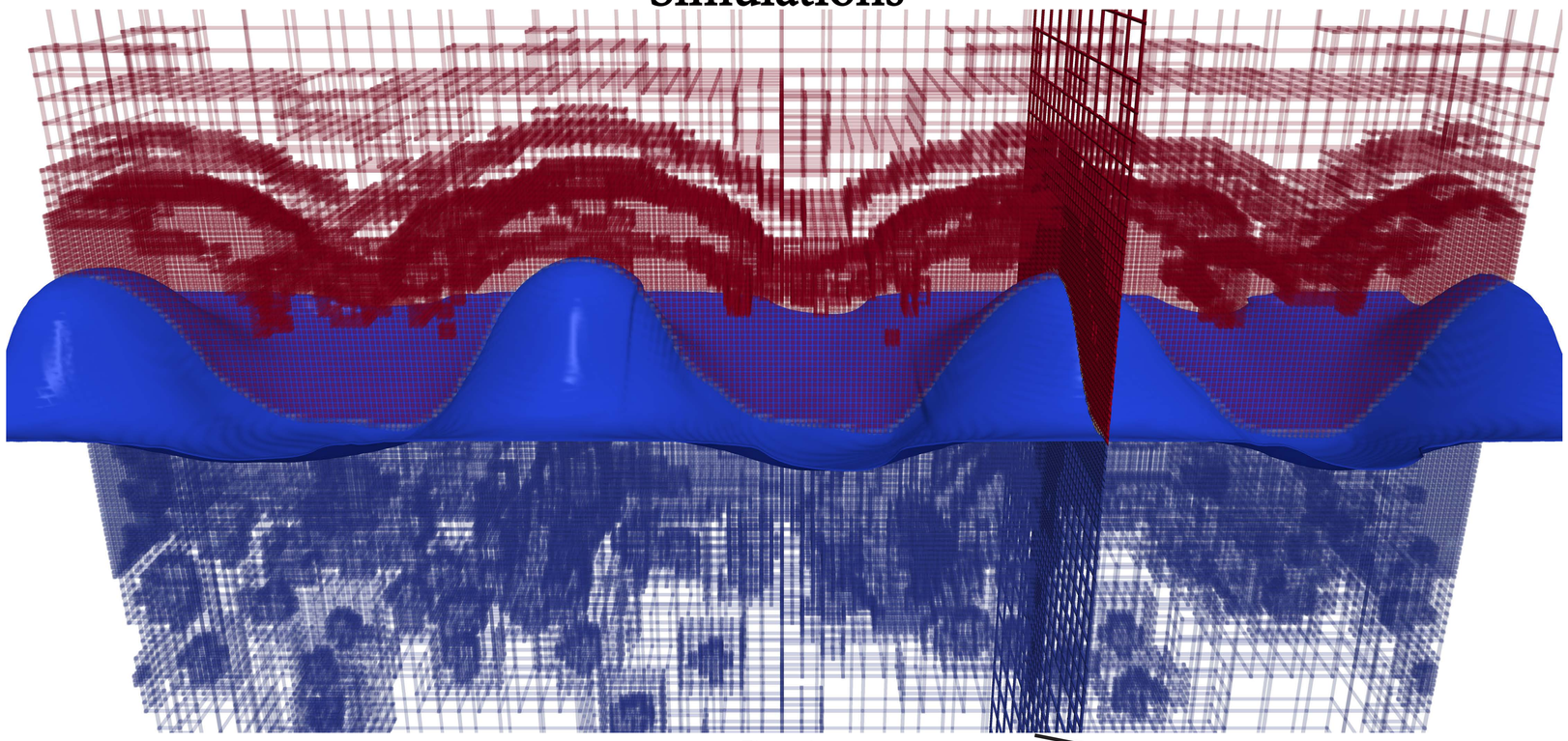

Figure 3

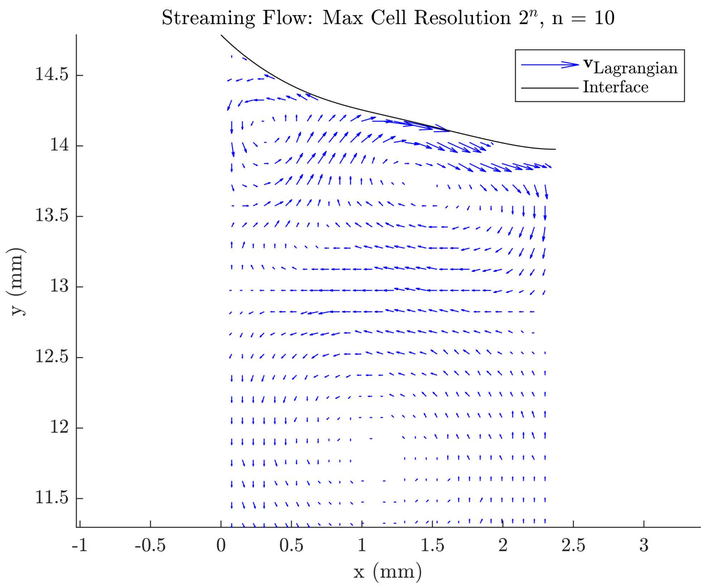

Figure 4

We use the interfacial two-phase volume-of-fluid solver Basilisk[3,4] and UNC's Longleaf computing cluster to simulate these instabilities. In Fig. 3 we show pinned Faraday waves in a periodic domain that supports 3 wavelengths. Simulations are performed using an adaptive octree (colored) and are symmetrized about a periodic cross-section. We advject tracer particles in 2D cross-sections to obtain Lagrangian streaming flows in Fig. 4. These flows are compared to instantaneous flows in Fig. 5.

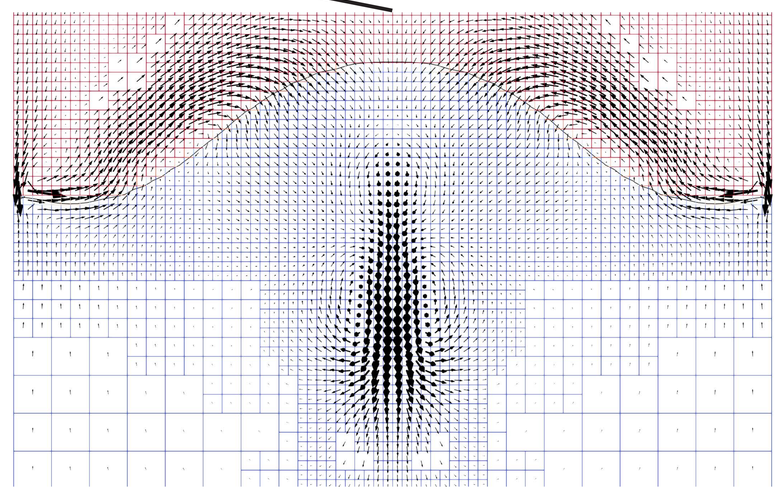

Figure 5

We seek to decouple meniscus (harmonic) and Faraday (sub-harmonic) wave contributions to the streaming flows. In particular, extending these numerical results will allow us to understand how the streaming structure couples to the drifting. We are working to use these computational and experimental results to inform extensions of existing mathematical descriptions of the drift instability[2].

[1]Douady, S, et al., vol. 10, no. 4, 1989, pp. 309–315.
[2]Marín, Elena, et al. Journal of Fluid Mechanics, vol. 467, 2002, pp. 57–79.
[3]http://basilisk.fr/
[4]Popinet, Stéphane. Journal of Computational Physics, vol. 228, no. 16, 2009, pp. 5838–5866.