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Instability of Two Species Interfaces Via Vibration

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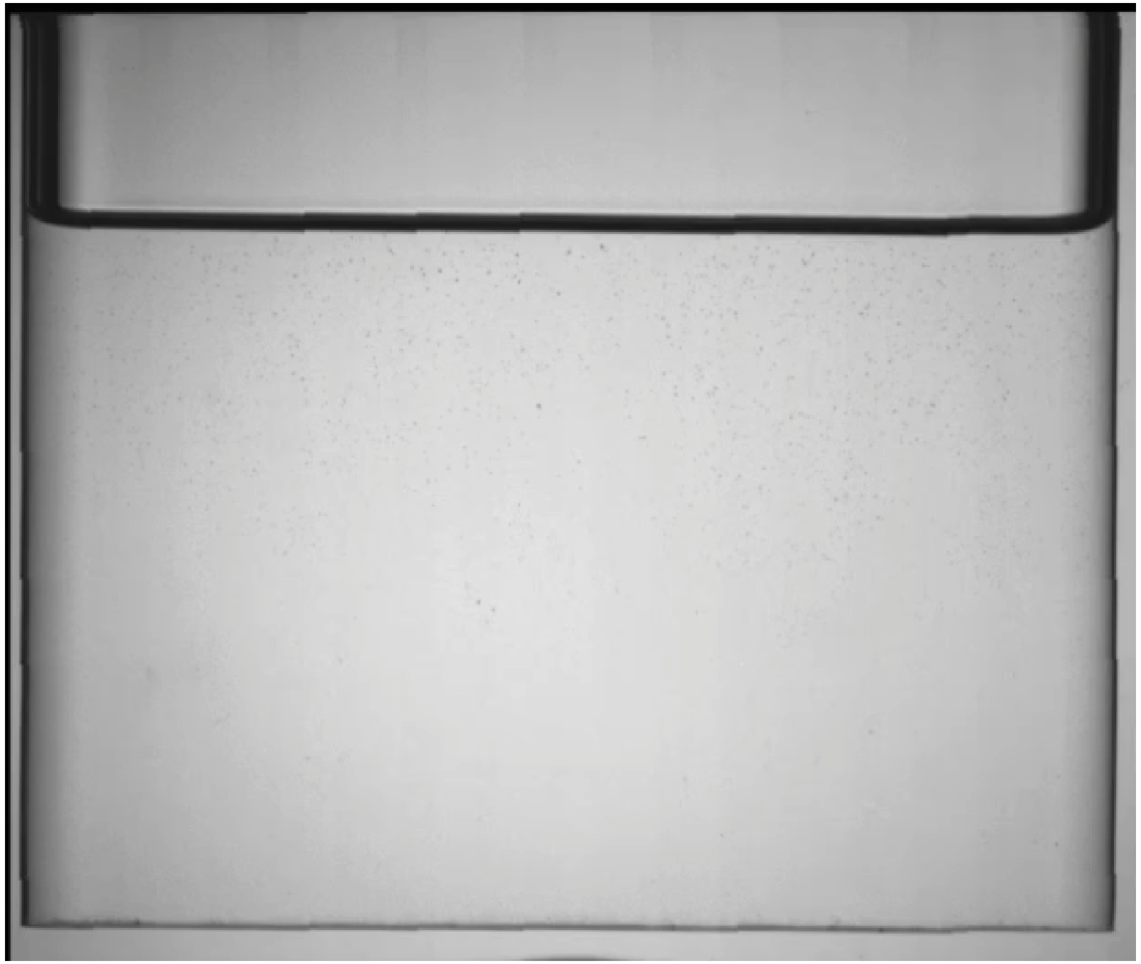
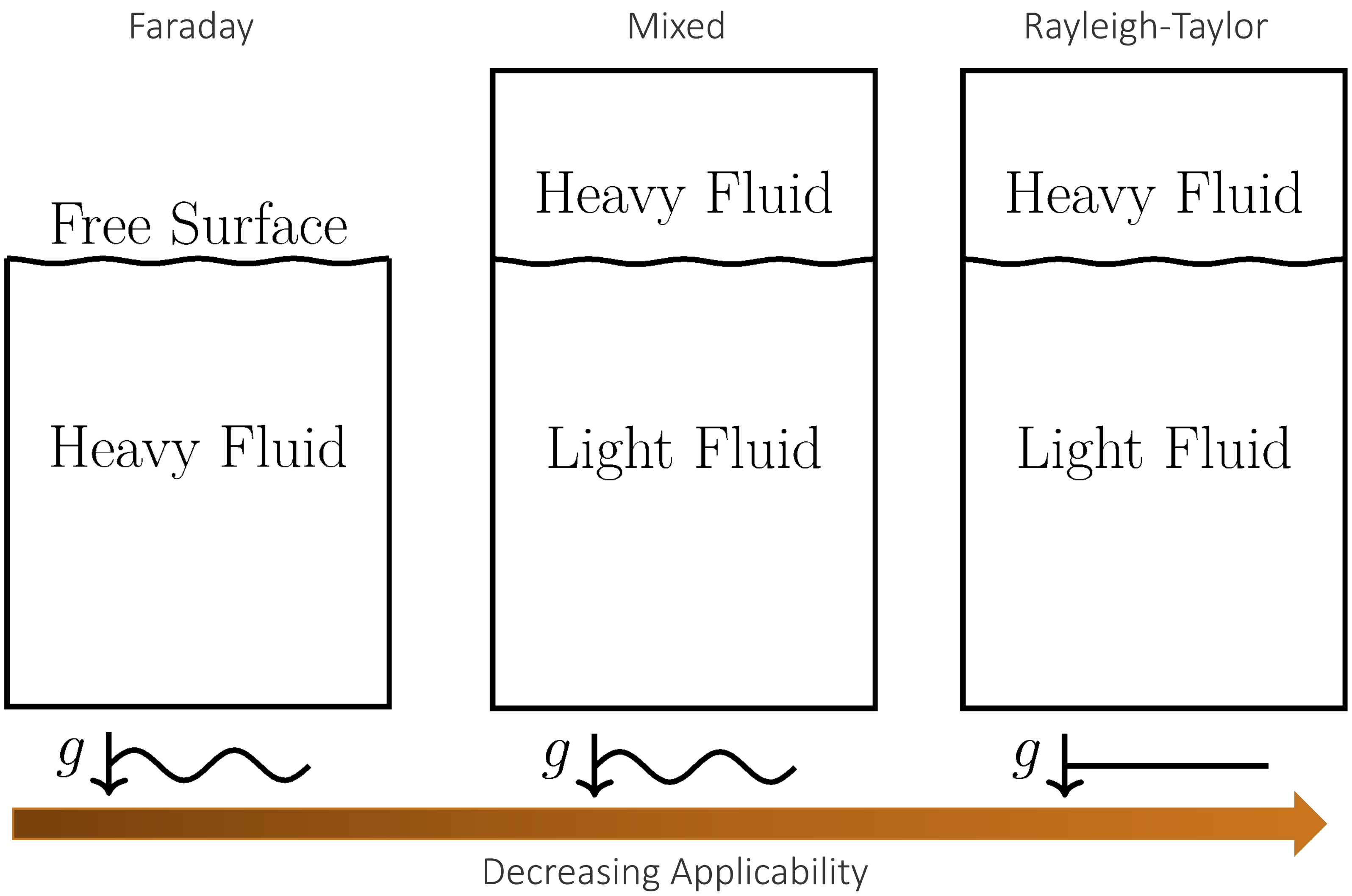
CPC Computational Physics Group

Introduction

- Gas Injection
  - Changes hydrodynamic properties
  - Changes in liquid-gas mixture
- Dependent on Initial Breakup
  - Not yet well-understood
- Requires DNS

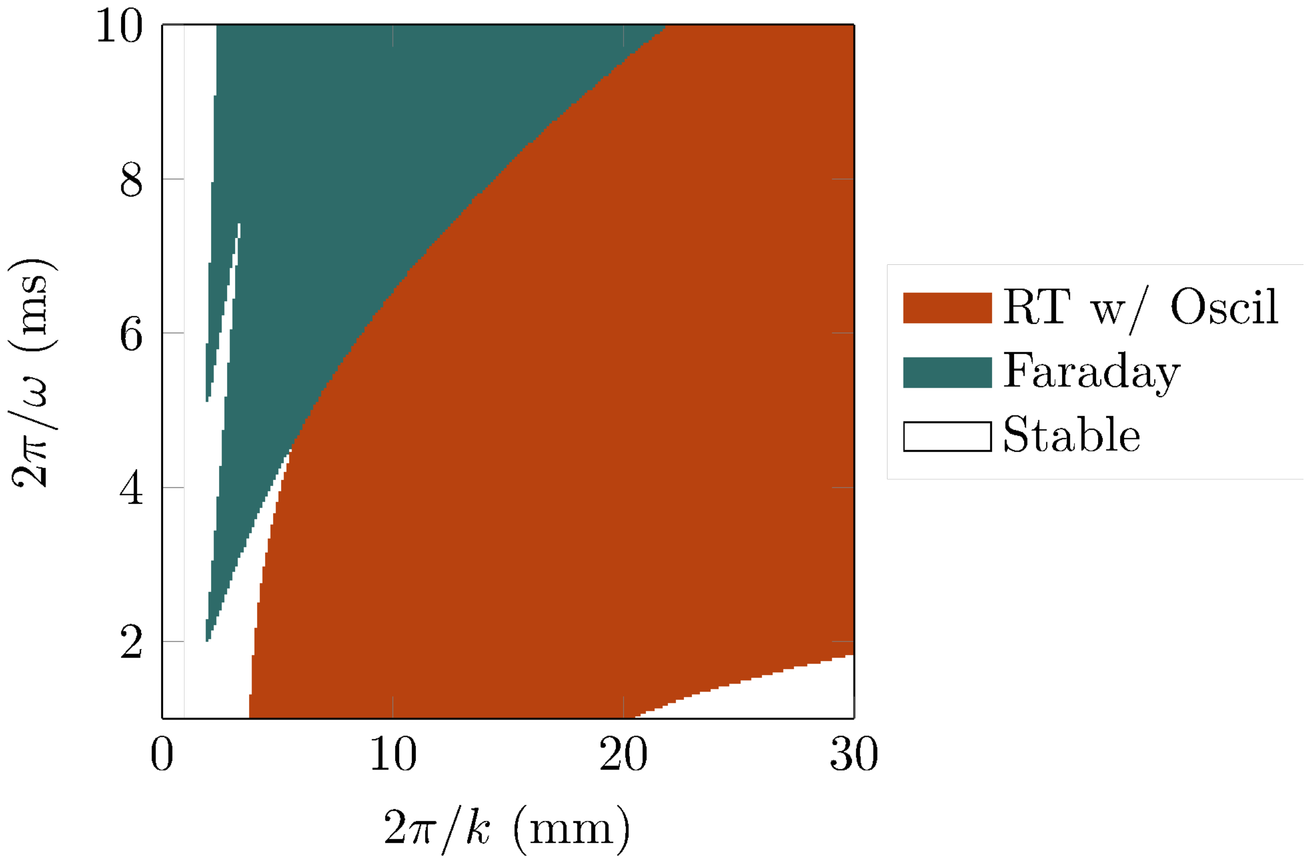


Three Primary Modes of Instability



Linear Stability Analysis

- **Three Modes of Instability**
  - Rayleigh-Taylor (RT)
  - RT with Oscillation
  - Faraday Instability
- **Outcomes**
  - Dominant instability changes
  - Problem dependent



Model and Numerics

- Compressible and Multiphase
- Diffuse Interface Method
  - Baer-Nunziato-like 6-eqn
- **Finite Volume:** WENO3
  - Shock Capturing
- **Riemann Solve:** HLLC
- **Time Stepping:** Explicit RK
- **Extra Physics:**
  - Surface-tension and body forces

$$\frac{\partial \alpha_i \rho_i}{\partial t} + \nabla \cdot (\alpha_i \rho_i \boldsymbol{u}) = 0$$

$$\frac{\partial \rho \boldsymbol{u}}{\partial t} + \nabla \cdot (\rho \boldsymbol{u}\boldsymbol{u} + p\boldsymbol{I} + \boldsymbol{\Omega}) = -\rho \boldsymbol{g}$$

$$\frac{\partial \alpha_1 \rho_1 e_1}{\partial t} + \nabla \cdot (\alpha_1 \rho_1 e_1 \boldsymbol{u}) + \alpha_1 p_1 \cdot \nabla \boldsymbol{u} = -\mu p_I \delta P$$

$$\frac{\partial \alpha_2 \rho_2 e_2}{\partial t} + \nabla \cdot (\alpha_1 \rho_2 e_2 \boldsymbol{u}) + \alpha_2 p_2 \cdot \nabla \boldsymbol{u} = \mu p_I \delta P$$

$$\frac{\partial (\rho E + \varepsilon_0)}{\partial t} + \nabla \cdot ((\rho E + \varepsilon_0 + P)\boldsymbol{u} + \boldsymbol{\Omega} \cdot \boldsymbol{u}) = -\rho(\boldsymbol{u} \cdot \boldsymbol{g})$$

$$\frac{\partial \alpha_1}{\partial t} + \boldsymbol{u} \cdot \nabla \alpha_1 = \mu(p_1 - p_2)$$

$$\frac{\partial c}{\partial t} + \boldsymbol{u} \cdot \nabla c = 0$$

Problem Statement and QOI

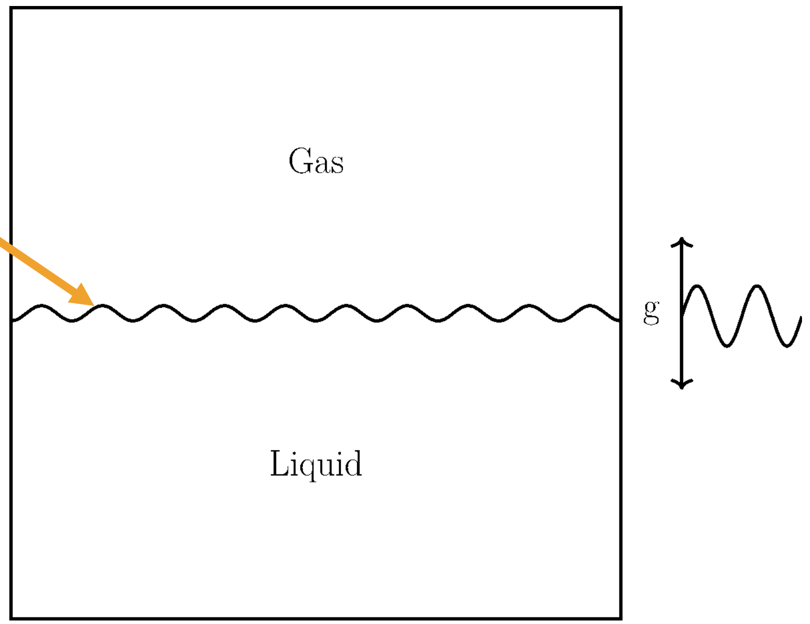
Problem Statement

Small Initial Perturbation

(a) $f_1(x) = a \sin\left(\frac{2\pi x}{\lambda} - \frac{\pi}{2}\right)$

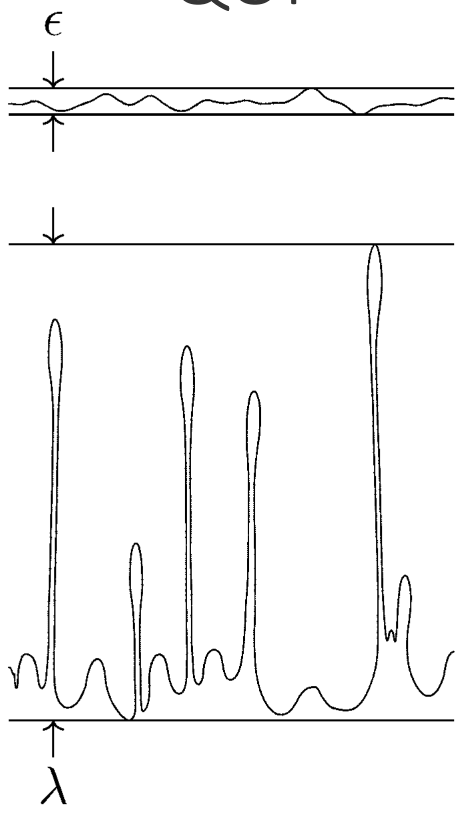
(b) $f_2(x) = a \exp\left[\sin\left(\frac{2\pi x}{\lambda} - \frac{\pi}{2}\right)\right] + b$

(c) Perlin Noise



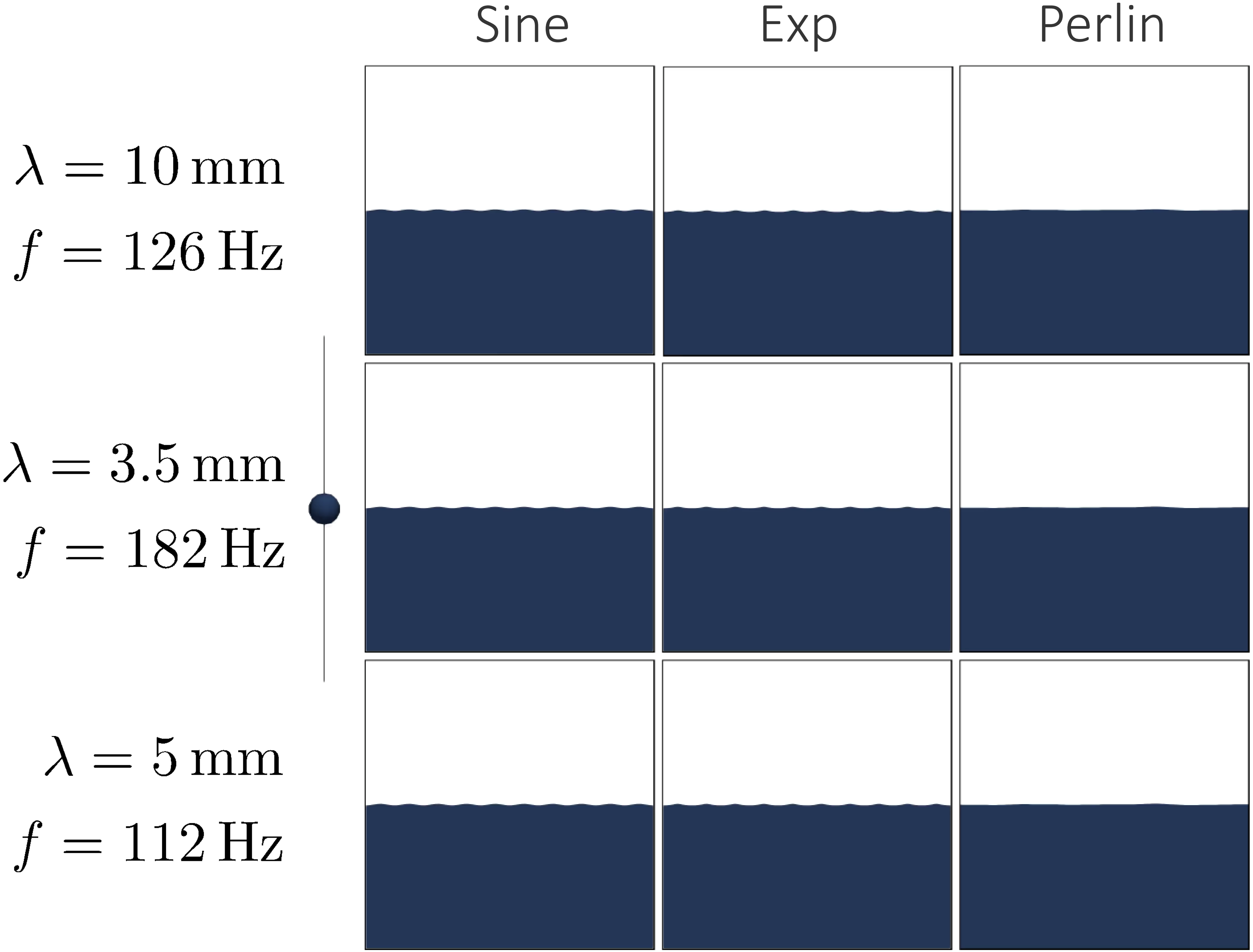
Simulations performed at three combinations of wavelength and frequency

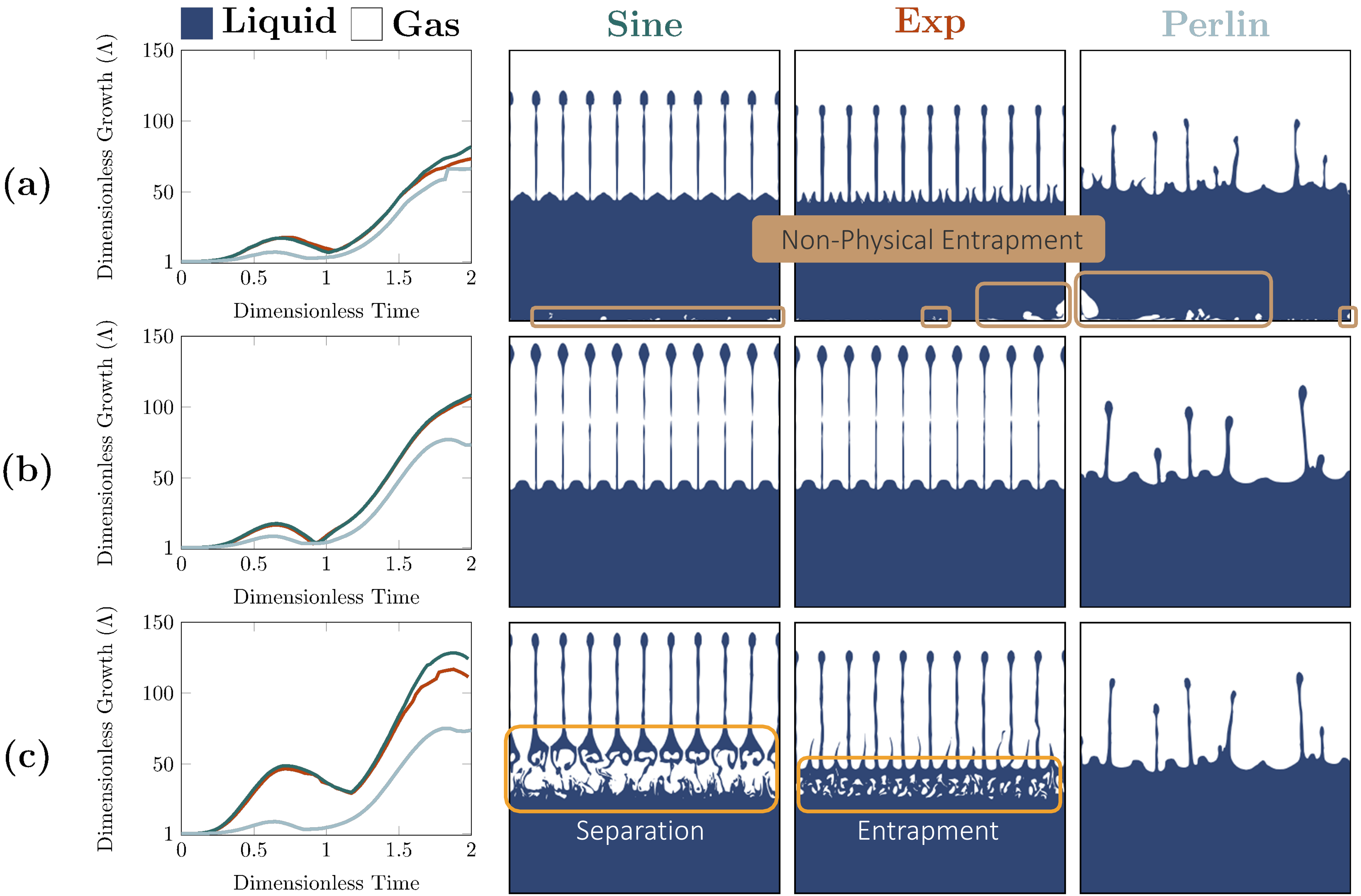
QOI



Dimensionless Growth $\Lambda = \frac{\lambda}{\epsilon}$

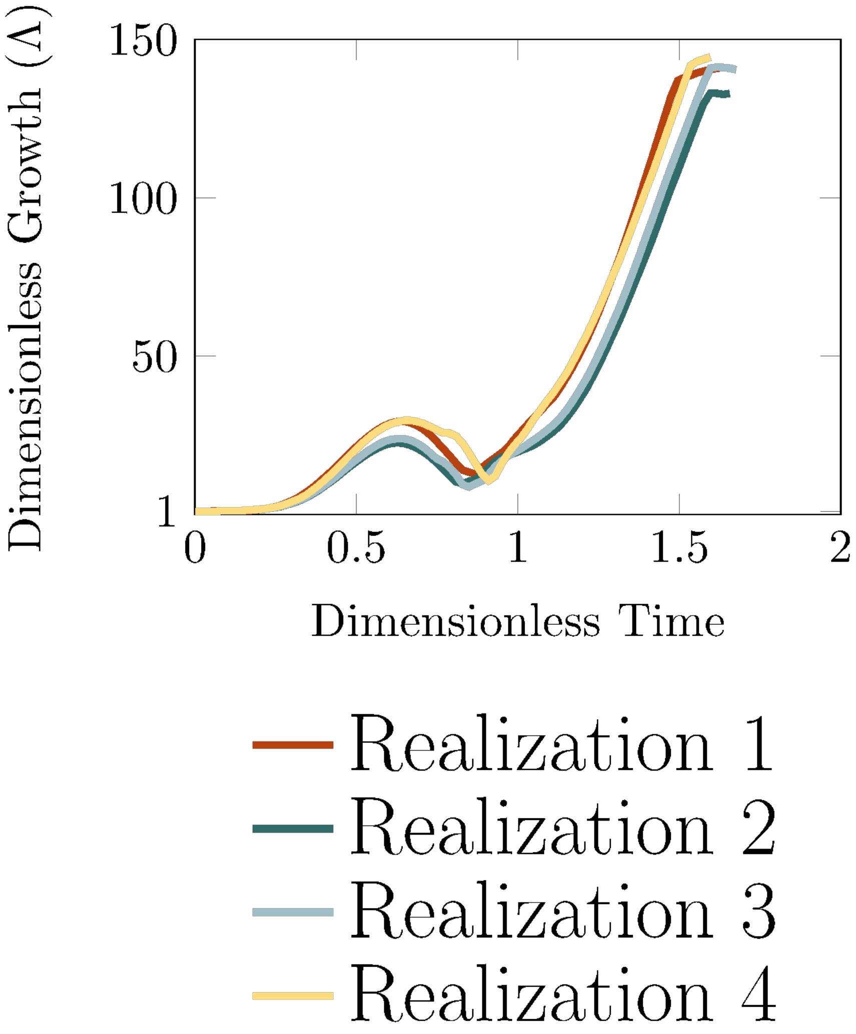
Interface Breakup at 64g

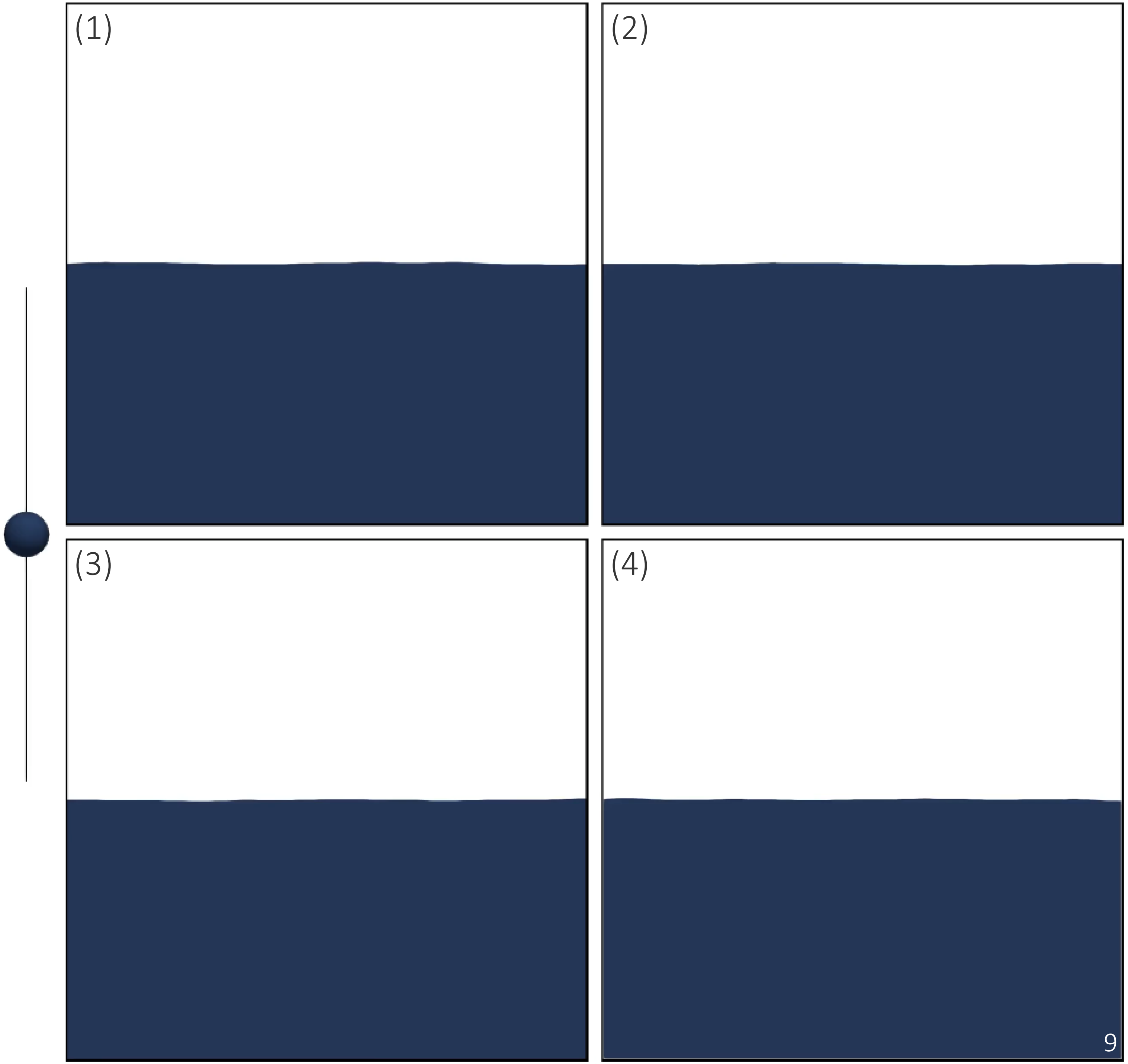




Liquid
Gas
Sine
Exp
Perlin
(a)
(b)
(c)
Dimensionless Growth (Λ)
Dimensionless Time
150
100
50
1
0
0.5
1
1.5
2
Non-Physical Entrapment
Separation
Entrapment

Results are Independent of Random ICs





Takeaways

- **Gas Injection**
  - Potentially harmful in hydrodynamic systems
  - Strongly dependent on early breakup
- **Compressible multiphase simulations**
  - Show independence to random perturbations
- **Next steps**
  - More detailed linear stability analysis
  - Extension to 3D

MFC

mflowcode.github.io

Thank you!

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