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Title:	Direct Numerical Simulation of Tilted Rayleigh-Taylor Instability
Author(s):	Tie Wei and Daniel Livescu
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Direct Numerical Simulation of Tilted Rayleigh-Taylor Instability

Tie Wei and Daniel Livescu
CCS-2, Los Alamos National Lab

ABSTRACT

The tilted Rayleigh-Taylor instability, where the initial interface is not perpendicular to the driving acceleration, is investigated using Direct Numerical Simulations (DNS). In this configuration, the inclination of the initial interface results in a large-scale overturning motion in addition to the buoyancy driven instability. The DNS results are compared to the rocket-rig experiments of Smeeton and Youngs (AWE Report No. 35/87) at several Atwood numbers (A=0.267, 0.48, and 0.90). Since the initial conditions in these experiments are largely unknown, an extensive range of initial conditions have been explored to match the mixing layer growth between DNS and experiments. The evolution of the mixing layer was found to be strongly influenced, for the duration of the experiments, by the initial spectrum shape and peak location, as well as the perturbation amplitude. A set of initial conditions matching the experimental growth rates has been determined. Results are also presented on the interaction between shear and buoyancy, including the parameters influencing the overturning and mixing.

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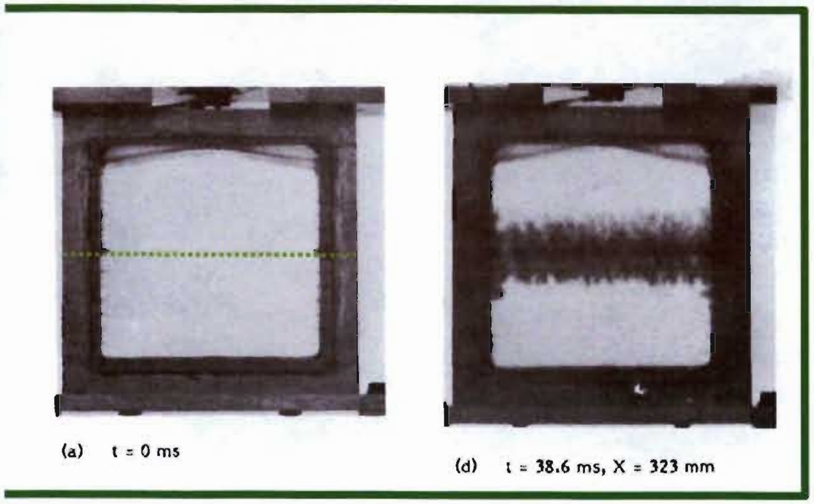
Los Alamos National Lab

Outline

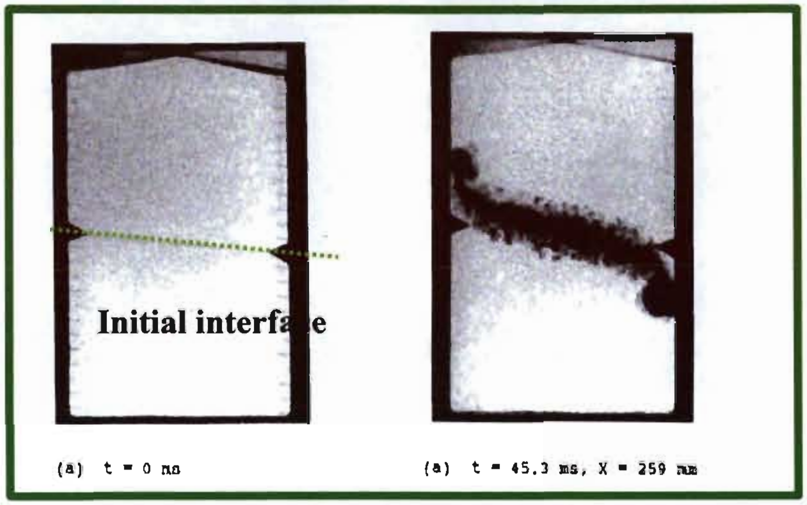
- Tilted Rayleigh-Taylor instability
- Experimental studies
- DNS of tilted RTI
  - Effect of initial perturbation shape
  - Effect of initial perturbation amplitude

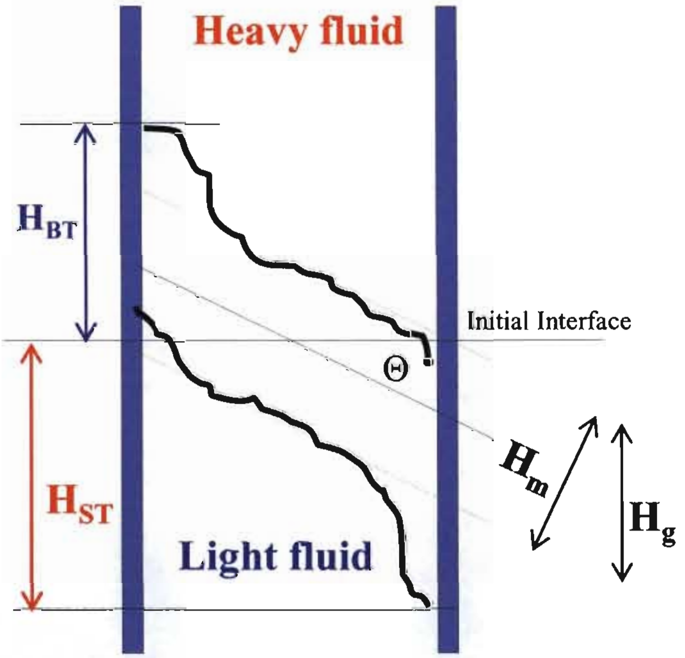
Rayleigh-Taylor Instability

Flat interface



Tilted interface



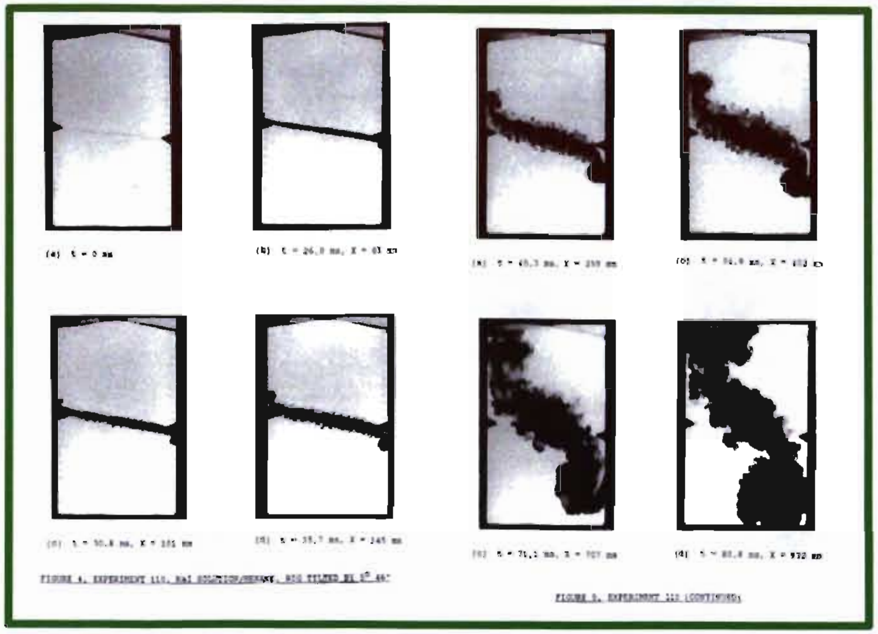


Motivations:

- **In practice, interface is rarely perfectly flat, especially with low wave number perturbations.**
- **2D mean flow is an interesting case to test modeling.**
- **Shear and buoyancy generations of turbulence.**

Experimental studies of tilted RTI

Rocket-Rig (Smeeton and Youngs 1987)



SOM (Ptitzyna et al. 1993)

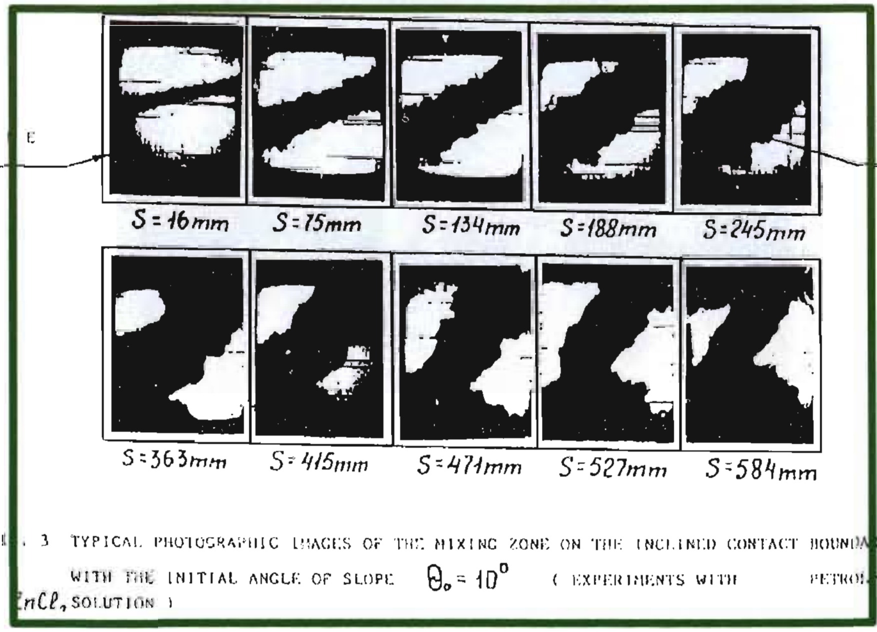
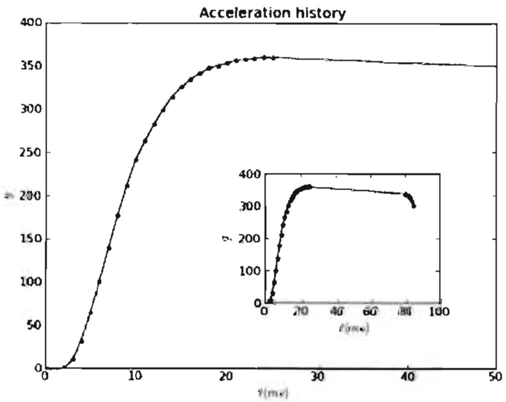


FIG. 3 TYPICAL PHOTOGRAPHIC IMAGES OF THE MIXING ZONE ON THE INCLINED CONTACT BOUNDARY WITH THE INITIAL ANGLE OF SLOPE $\theta_0 = 10^\circ$ (EXPERIMENTS WITH PETROL – ZnCl, SOLUTION)

Variable acceleration



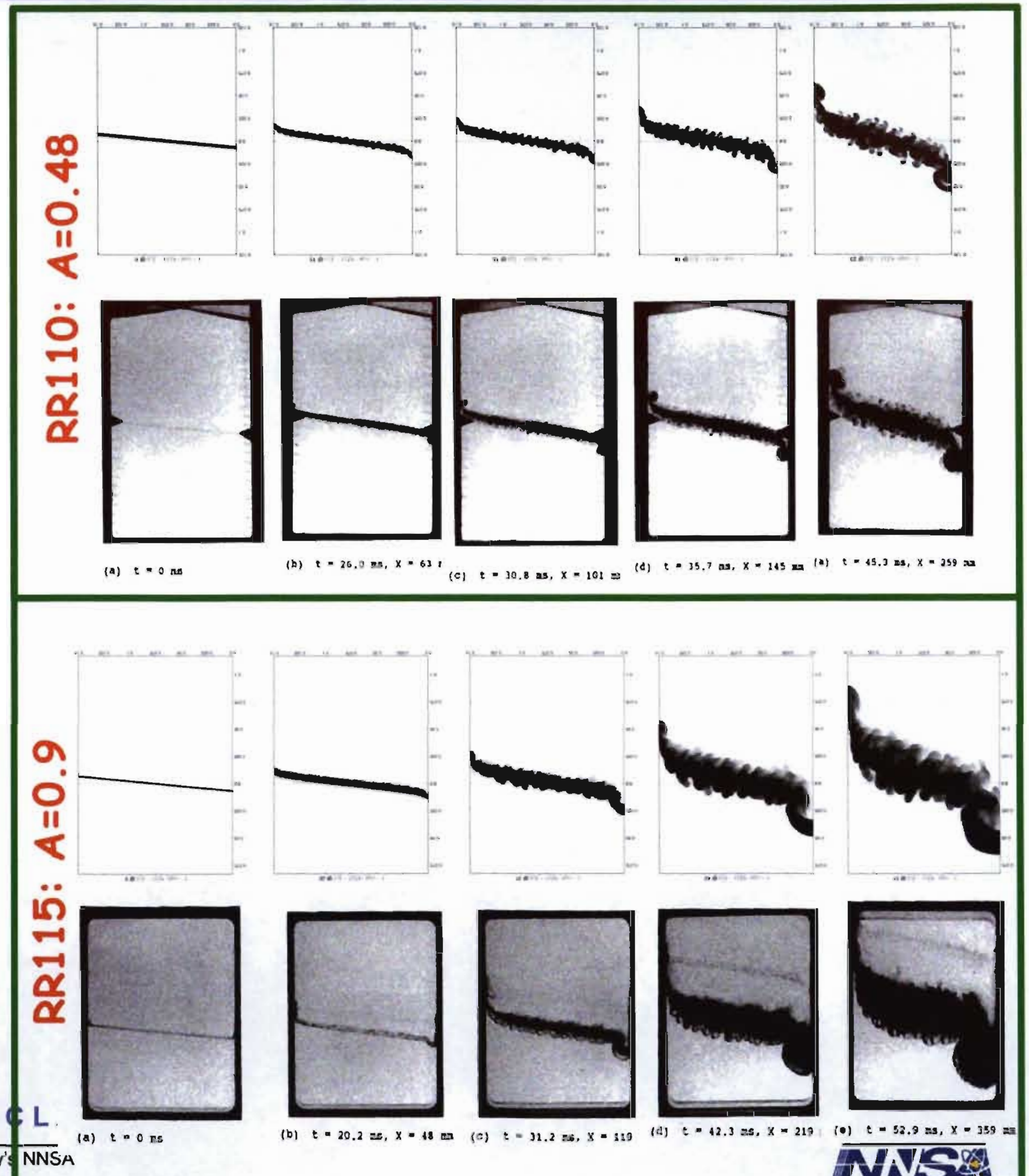
Challenges to simulations:

- **Initial conditions in experiments are largely unknown.**
- **Effects of top and bottom walls**

DNS of Rocket-Rig case 110 and 115

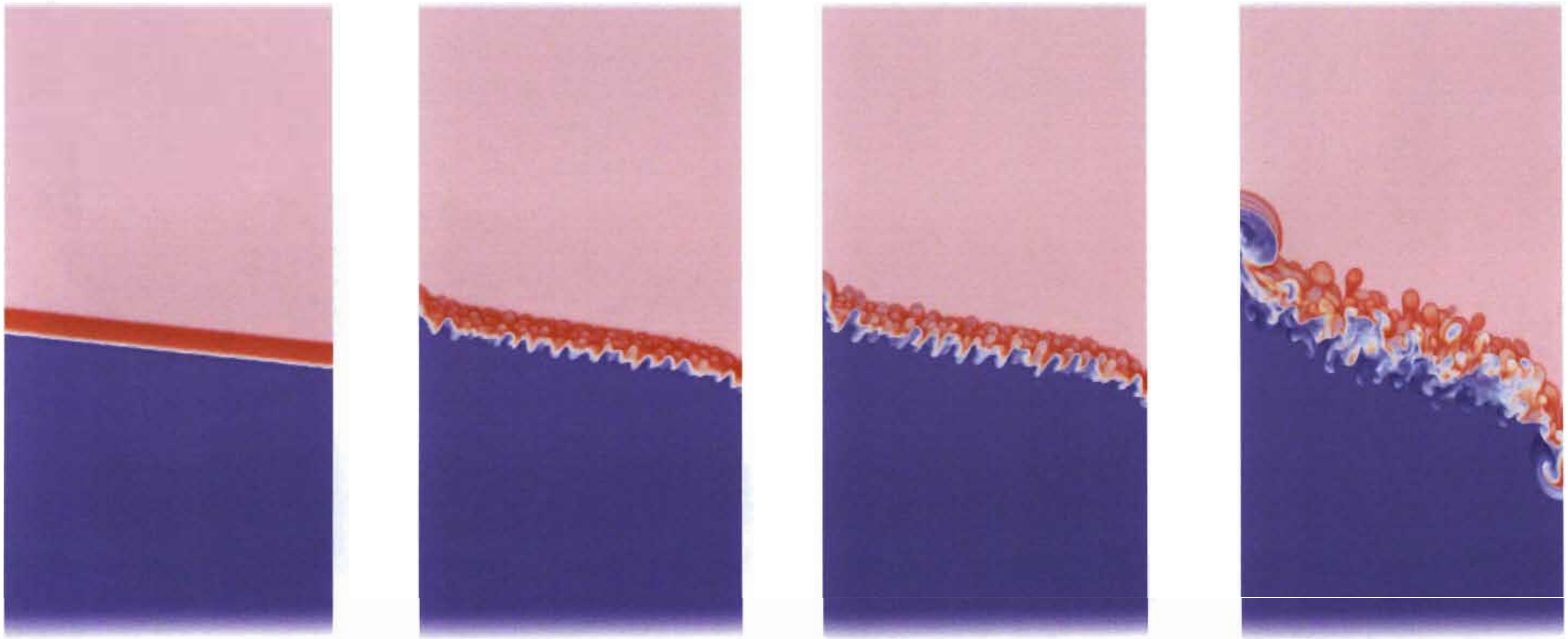
DNS of Rocket Rig experiments

- RR96: A=0.267
- RR110: A=0.48
- RR115: A=0.9



Using proper initial perturbations, we have good agreement between experiments and DNS, both the rotation of interface and mixing layer width.

Direct numerical simulation of titled RTI: 3D view



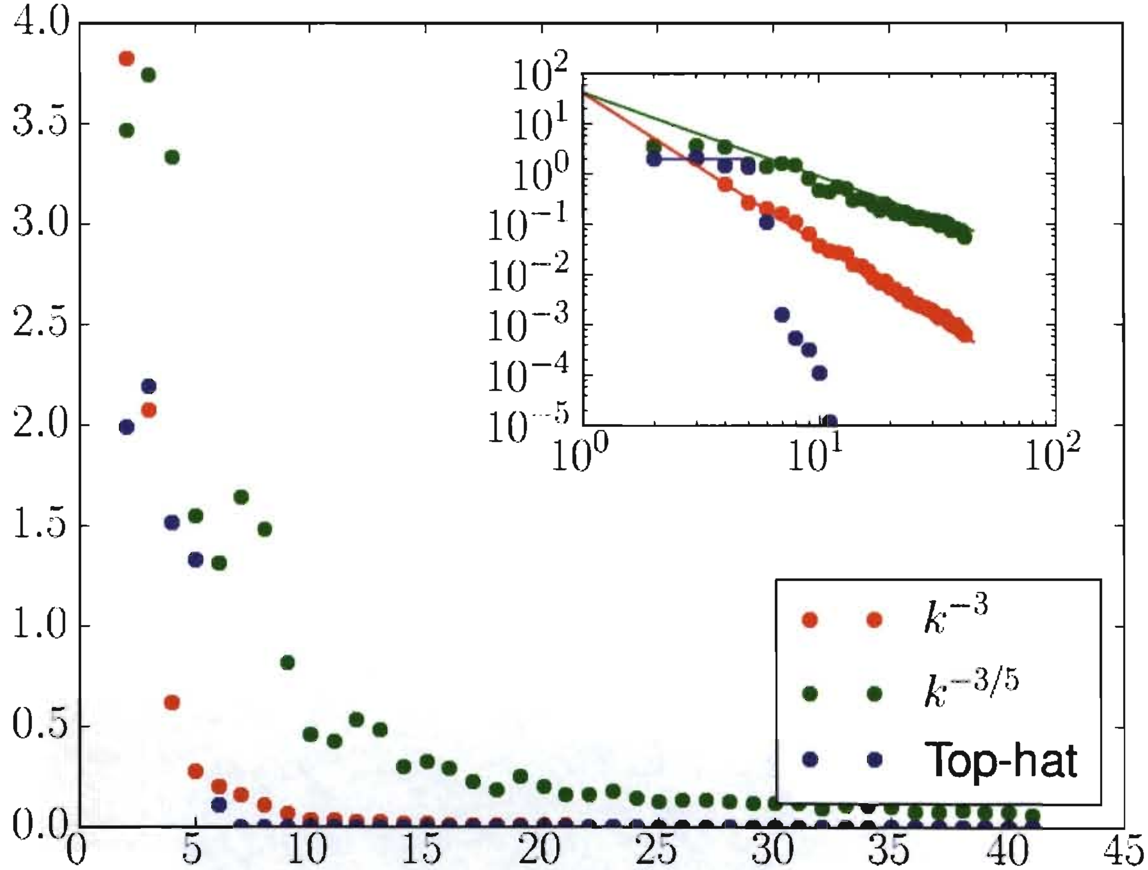
Code used: CFDNS (Livescu et al. LA-CC-09-100)
Mixed FFTs-6th order compact finite difference
Slip walls

Domain size: 250X150X25mm (matching experiment)

Meshes: 1024X512X96

DNS of RR110: 3 ICs

	IC-1	IC-2	IC-3
Spectra shape	K^-3	k^-5/3	Top-hat
Location	K0=1	k0=1	k=2-5
Initial perturbation height/Lh	0.00277	0.003333	0.00277
Initial diffusion height/Lh	0.0183	0.007	0.0183

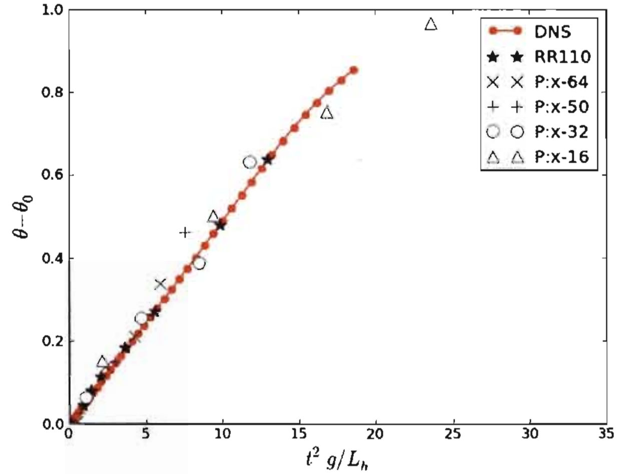


Effect of initial perturbation spectra

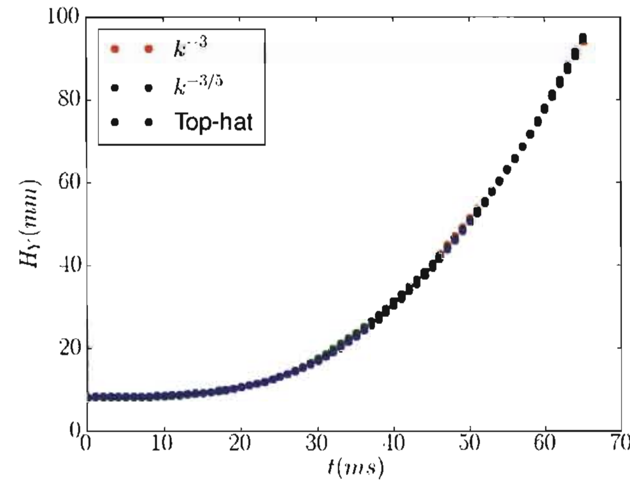
Perturbation spectra has small effects on:

- Rotation of the interface;
- Mixing layer width;
- Side-wall bubble/spike growth.

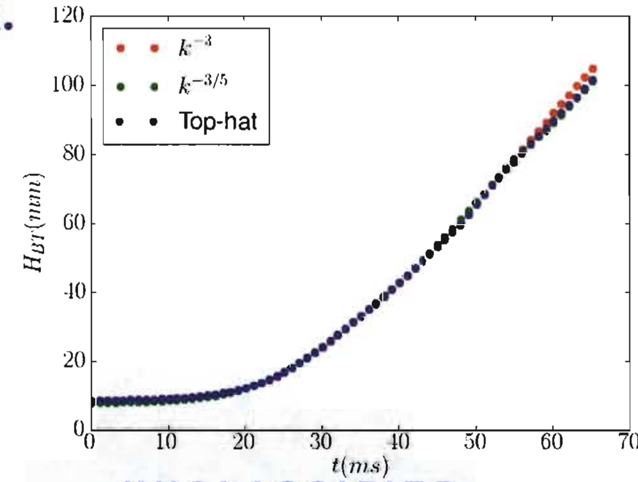
Interface angle



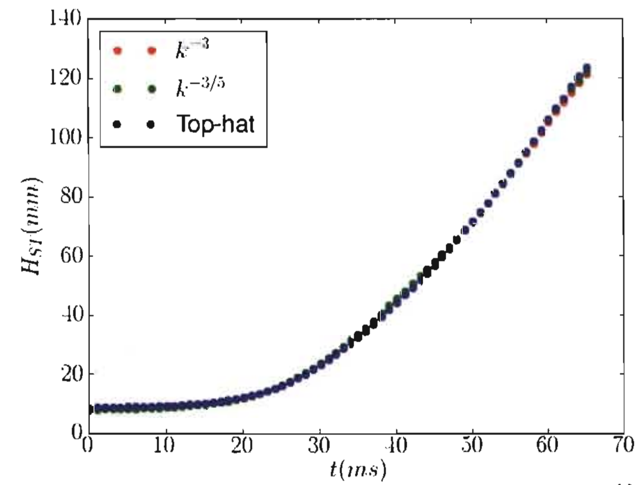
Mixing layer width



Side wall bubble height



Side wall spike height



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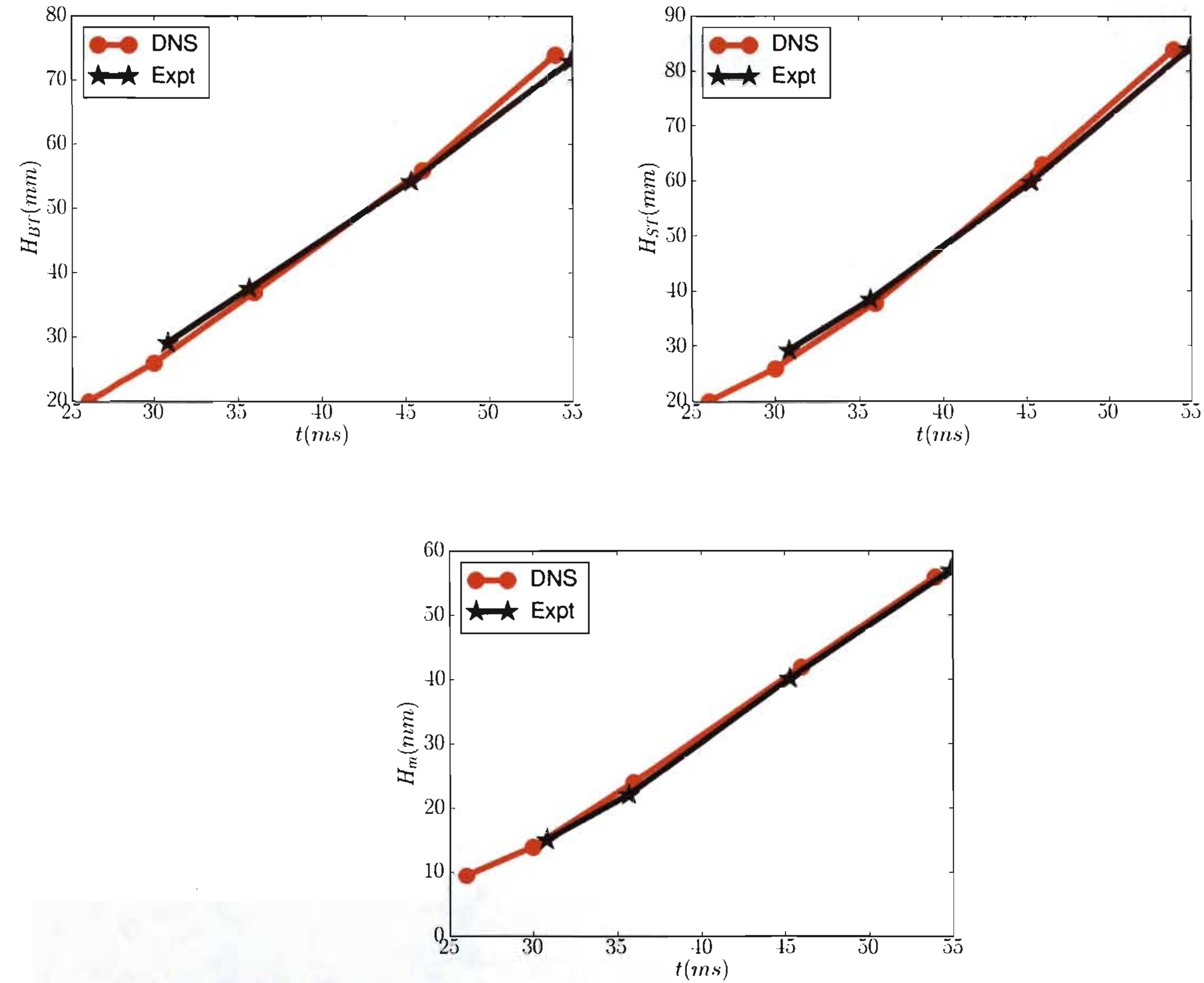
DNS of RR110: comparison



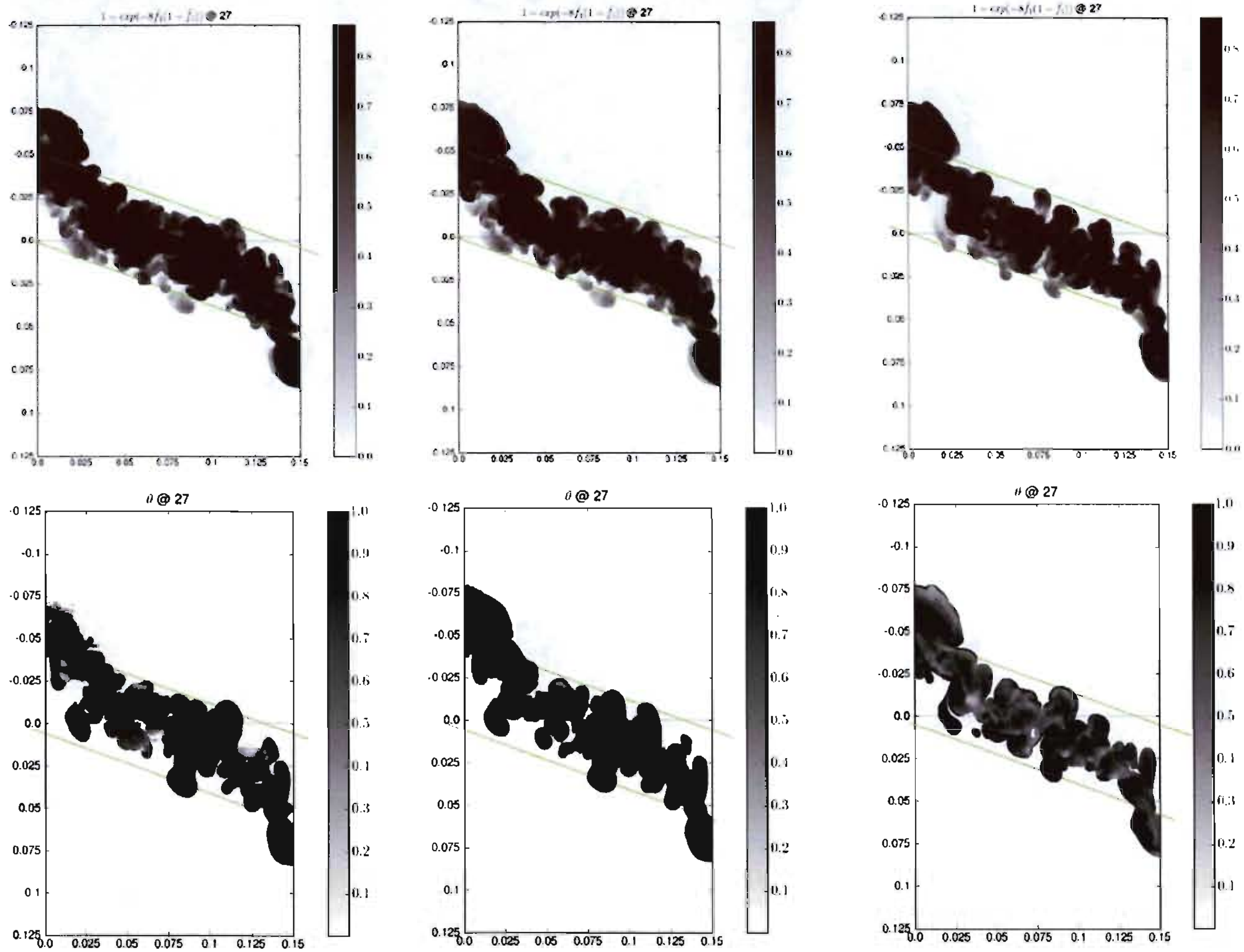
Effect of initial perturbation spectra

Refractive index:

$$1-\exp(-8f_1f_2)$$

(b) t = 54.9 ms, X = 402 mm

k^-3 k^-5/3 Tophat



Mixing metric: $\theta \equiv \dfrac{\langle f_1 f_2 \rangle}{\langle f_1 \rangle \langle f_2 \rangle}$

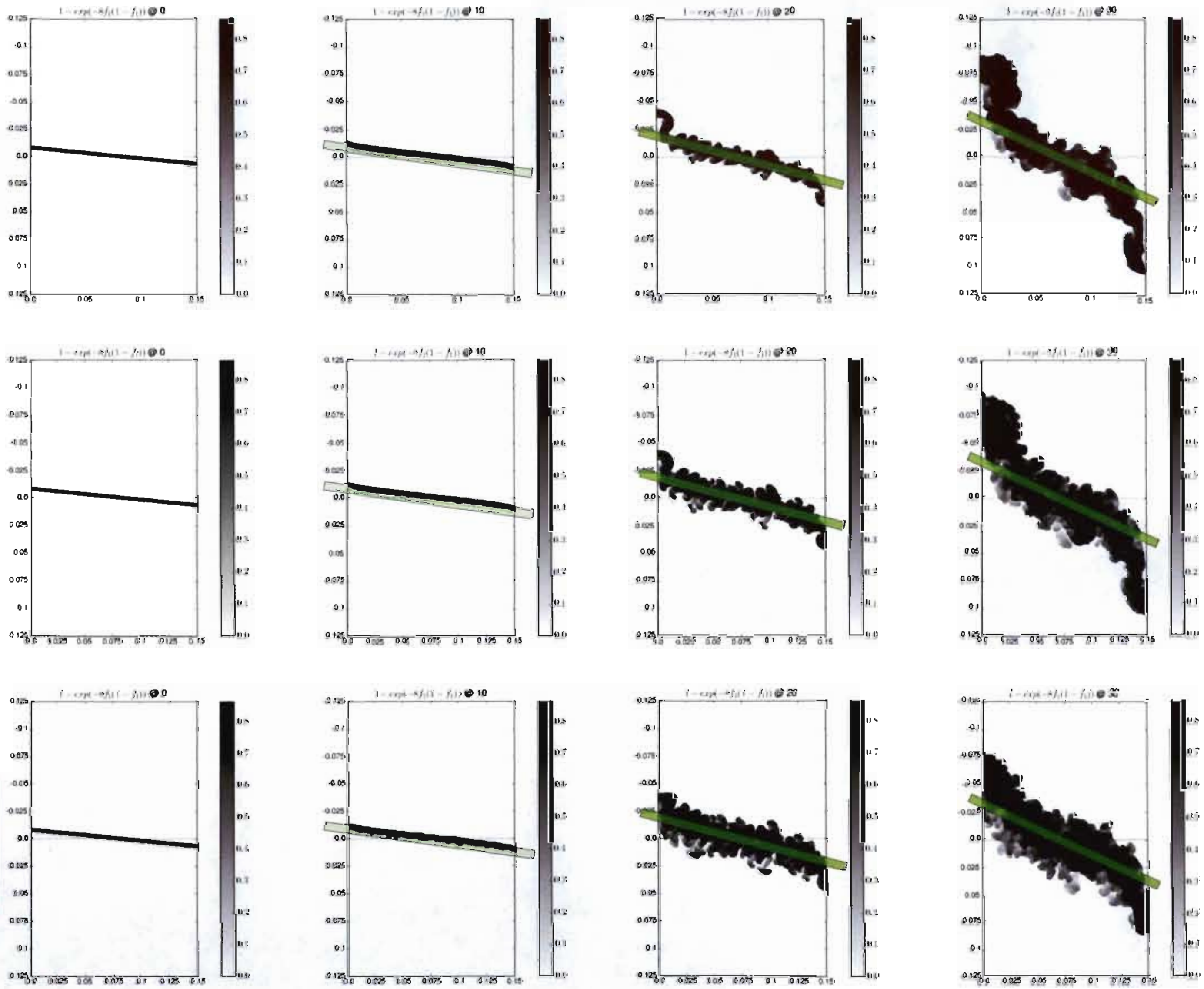
$$f_1 = (\rho - \rho_1)/(\rho_2 - \rho_1),\ f_2 = 1 - f_1$$

Effect of IC-initial perturbation amplitude

$$\frac{\delta_{p0}}{L_h} = 0.27\%$$

$$\frac{\delta_{p0}}{L_h} = 0.55\%$$

$$\frac{\delta_{p0}}{L_h} = 1.1\%$$

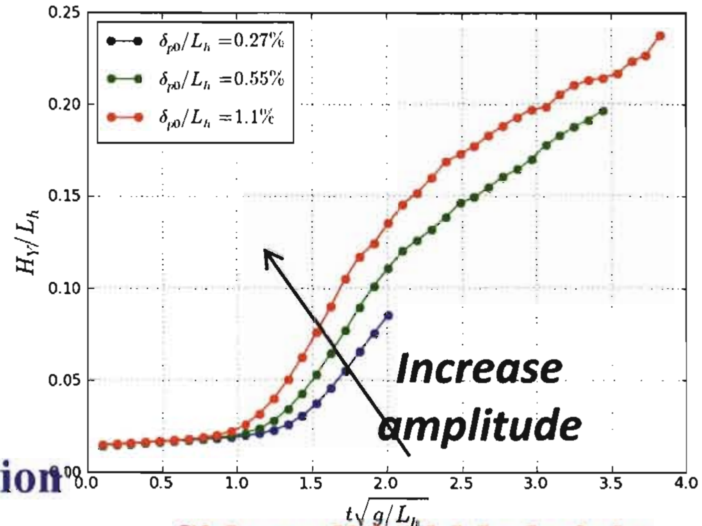


Effect of IC-initial perturbation amplitude

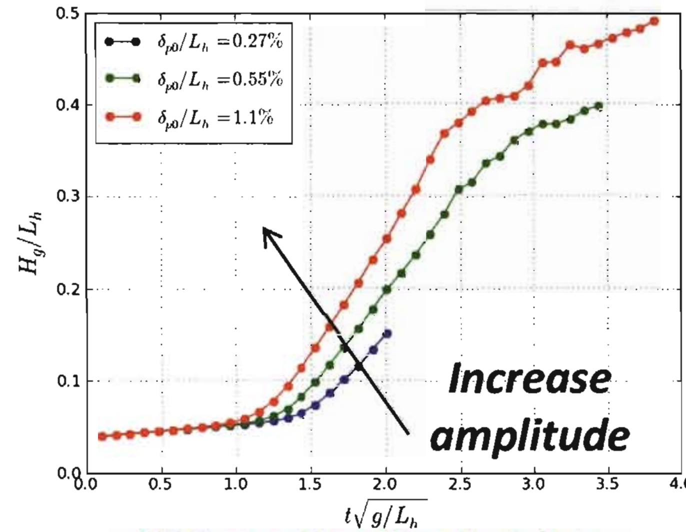
Initial perturbation amplitude:

- causes time-shifting in the development of mixing layer.
- has small effect on the rotation of interface.
- has small effect on the side wall bubble/spike growth.

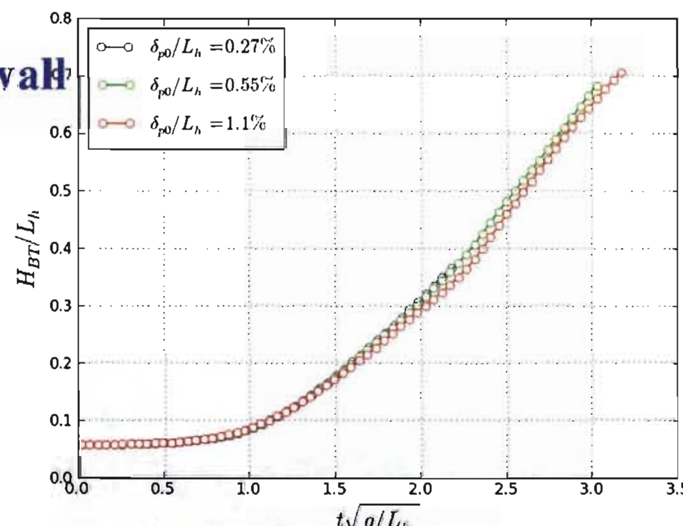
Mixing layer width: H_Y



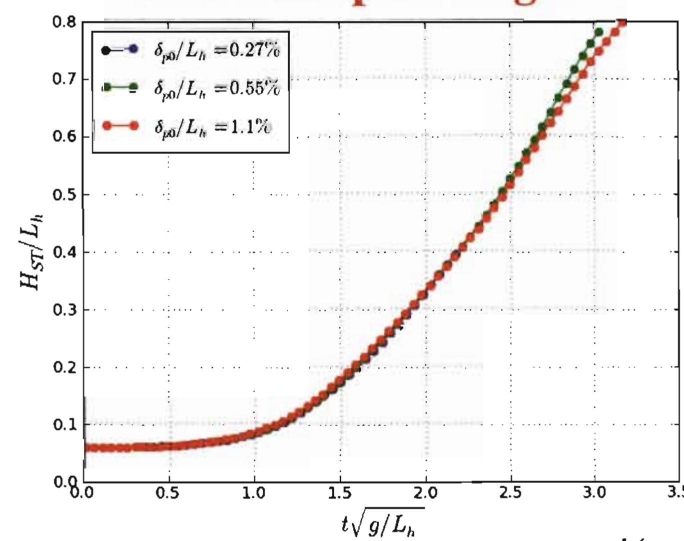
Mixing layer width: H_g



Side wall bubble height



Side wall spike height



Summaries

- Global measures are matched between experiments and Direct Numerical Simulations using different initial conditions.
- Initial perturbation spectra and amplitude affect the mixing layer growth, but have little influence on the rotation of interface.