Inner flow and free-surface movement characterization in an oscillating drop

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Introduction

- Motivation and objectives
- Droplet response under oscillation
- Experimental approaches
- Hologram reconstruction
- Results
- Summary and conclusions

Motivation

Search for the dynamical properties of liquid drops

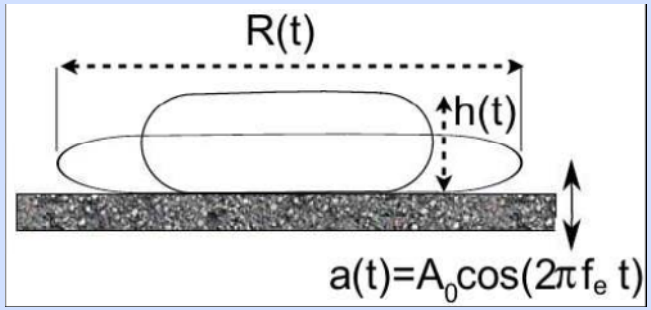
Sample analysis ⟷ "Coffee ring" effect

Droplet shaking

Objectives

- Measurement of the inner droplet flow under shaking
- Transition between pinned and unpinned contact line
- Generation of the star droplet: axisymmetry break up
- Study of the free-surface movement under shaking

Droplet response under shaking

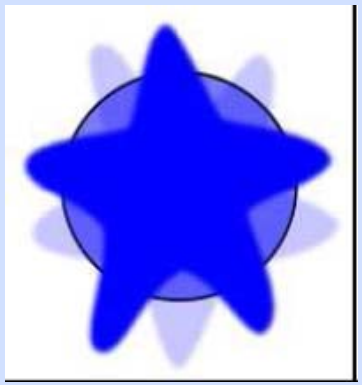


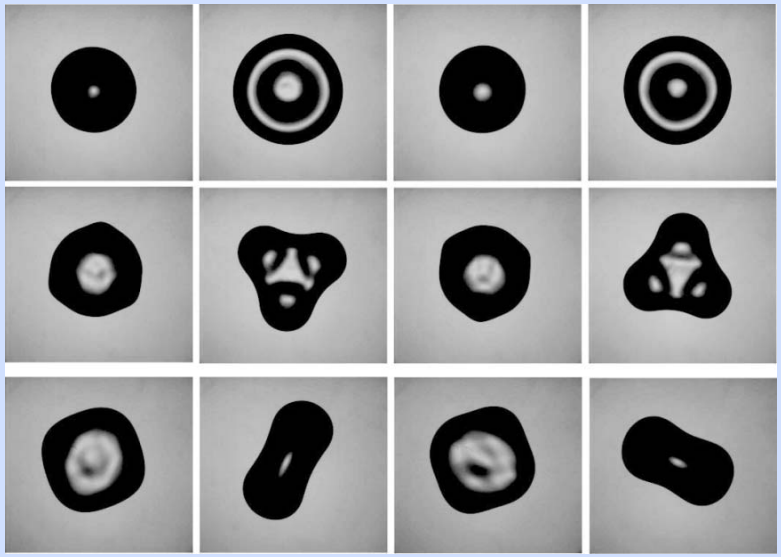
Resonance frequency

$$f_n = \frac{1}{2\pi}\left(\frac{n(n^2-1)\sigma}{\rho R^3}\right)^{1/2}$$

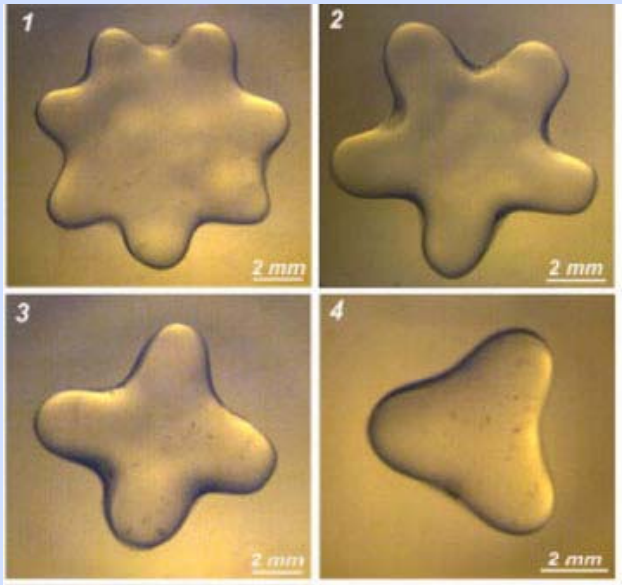
R drop radius, σ surface tension
ρ density

Takaki R, Adachi K (1985) J. Phys. Soc. Jap. 54, 2462-2469





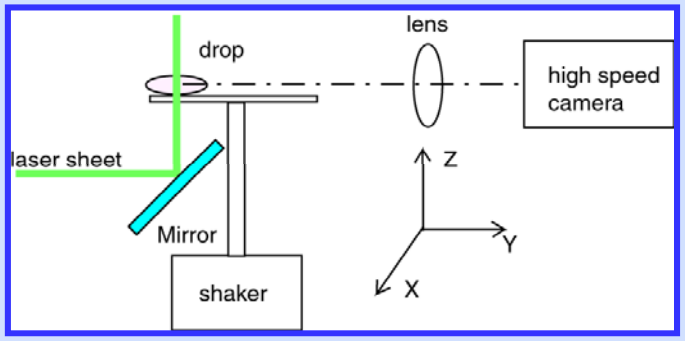
«Triplons»
*X. Noblin, A. Buguin, and F. Brochard-Wyart. PRL **94**, 166102 (2005).*

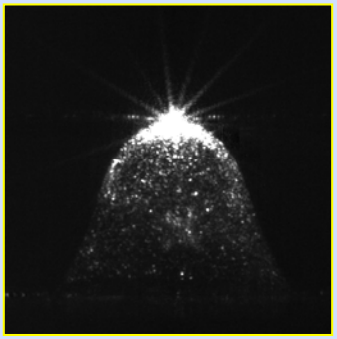


A. Snezhko, E. Ben Jacob, I.S. Aranson, New J. Phys. 10, 043034 (2008)

Experimental approaches

LATERAL VIEW

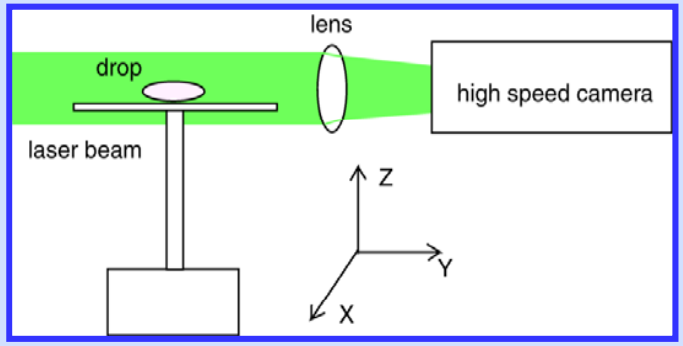


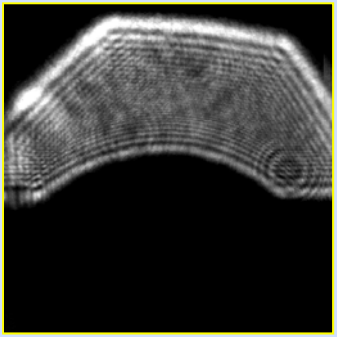


PIV approach

A droplet plane is illuminated

Reflections in the drop surface due to the change in the refractive index



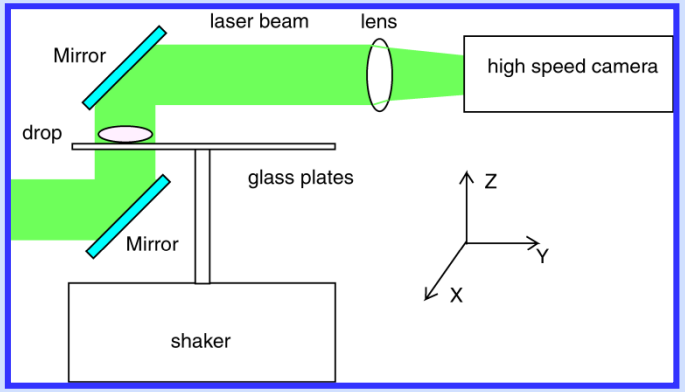


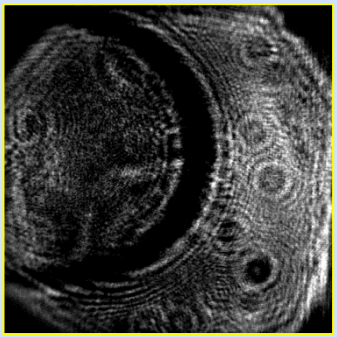
Digital Holography approach

The whole droplet is illuminated.

The complex surface shape prevents from a complete visualization within the droplet and introduces optical aberrations

TOP VIEW



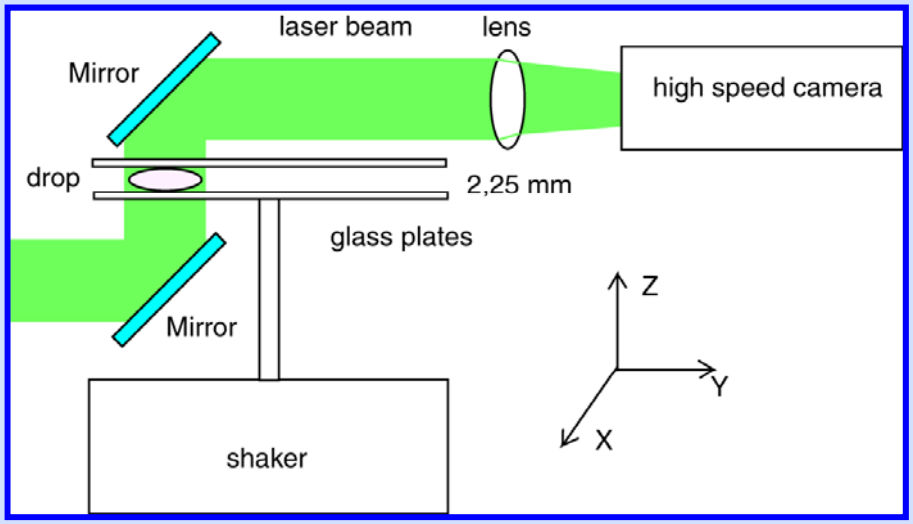


Experimental approaches

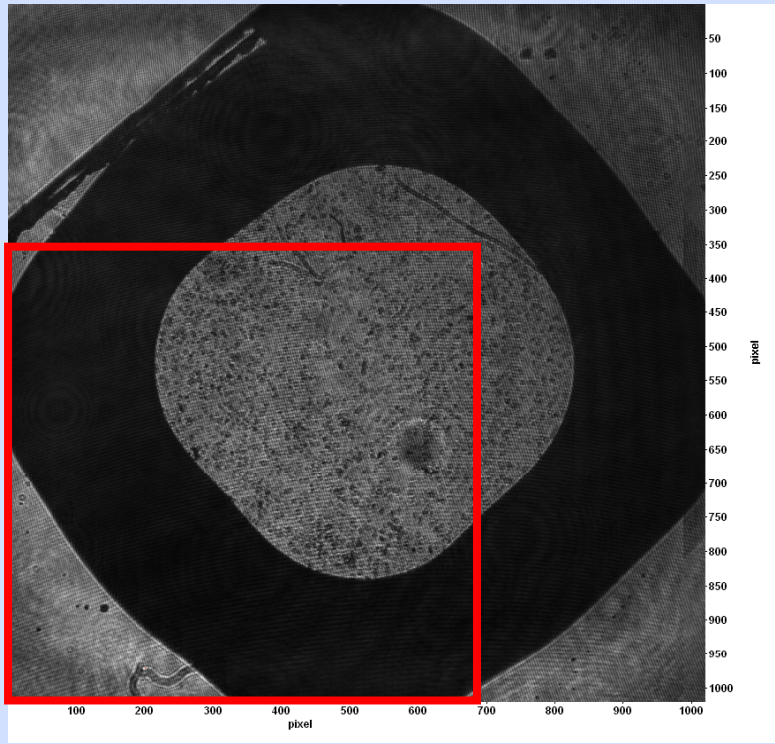
Final solution

Digital Holography approach

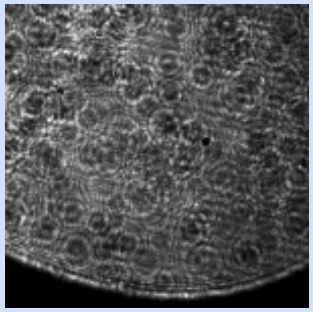
The droplet is sandwiched between two glass plates



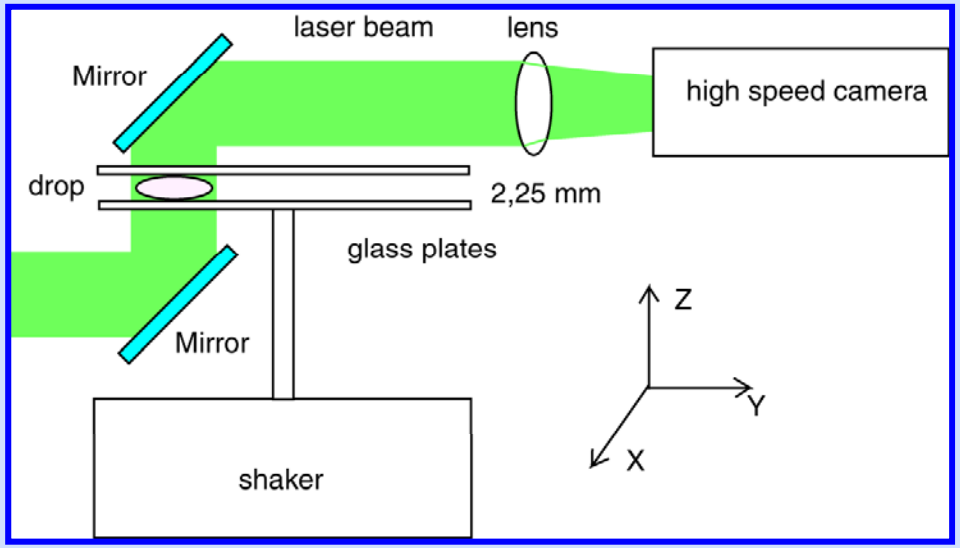
Hologram



Hologram close-up



Digital in-line holographic set-up



Hologram recording

- One illuminating beam
- Object beam: light diffracted by seeding inside the droplet
- Reference beam: direct light

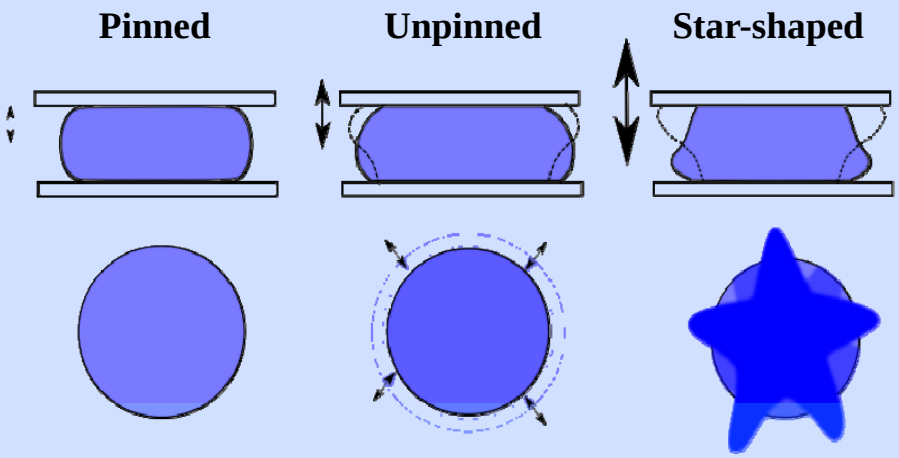
- High speed camera: Highspeedstar 5, CMOS, 10 bits, 1024x1024, 3000 Hz
- Lens, f'= 55 mm, f#= 2.8
- Continuous laser 532 nm 200 mW
- Oscillation frequency= 54,8 Hz

Mechanical shaker

- Loudspeaker
- Function generator: wide range of frequency and amplitude

- Two slightly hydrophobic plates:
  - Contact angle ~ 90º
  - hysteresis ~ 10º

Drop: Water seeded with 10 μm latex particles



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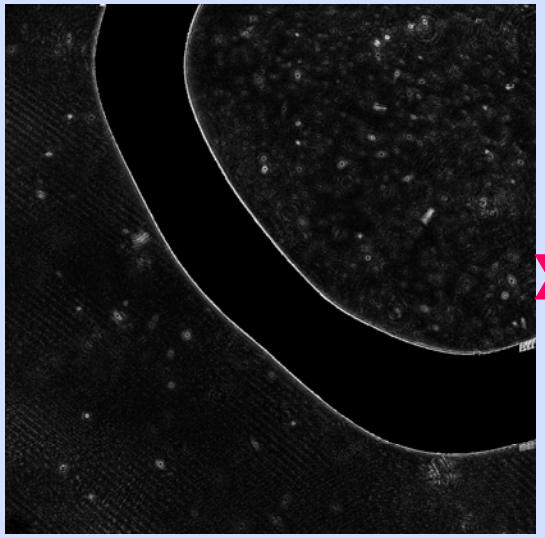
Contact line

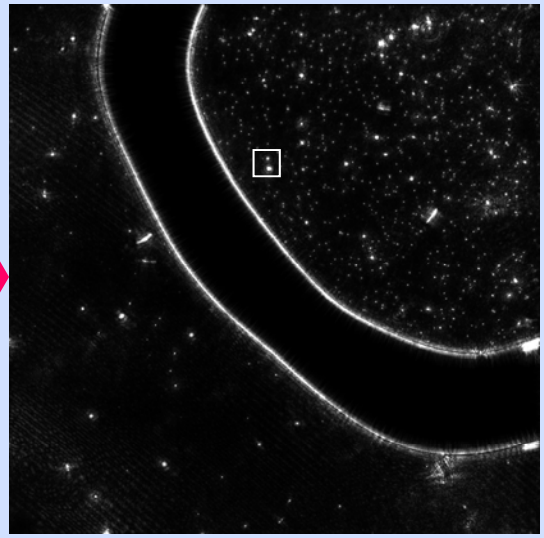
	Pinned	Unpinned Axisymmetric drop	Unpinned Break up of axisymmetry	Star-shaped drop
Lateral view (Plane ZY)				
Top view (Plane XY)				
Contact line motion				

Reconstructed in-line hologram

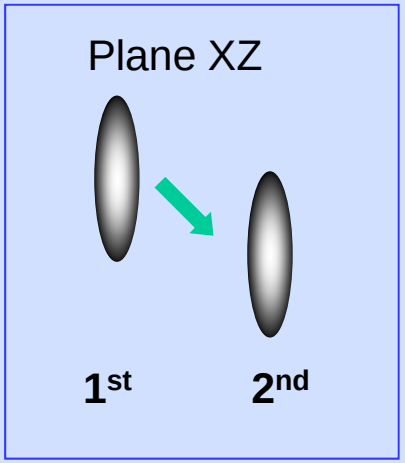
Plane XY



Hologram with the reference subtracted



Reconstructed hologram, middle plane

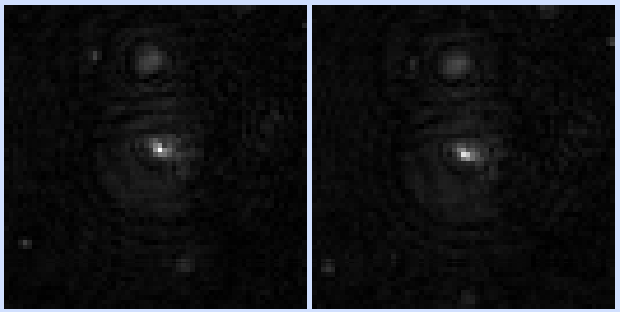


The reconstructed image of a sphere is an ellipsoid

3D cross-correlation

- Iterative procedure
- Particle location: maximum intensity
- Window selection

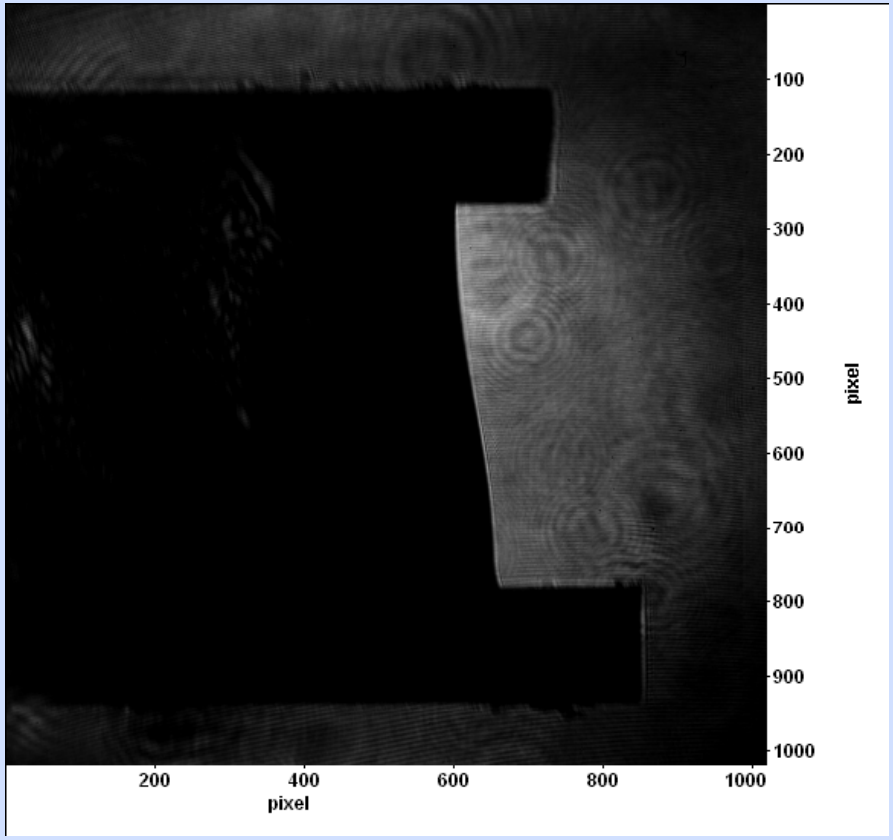
First exposure 2nd exposure



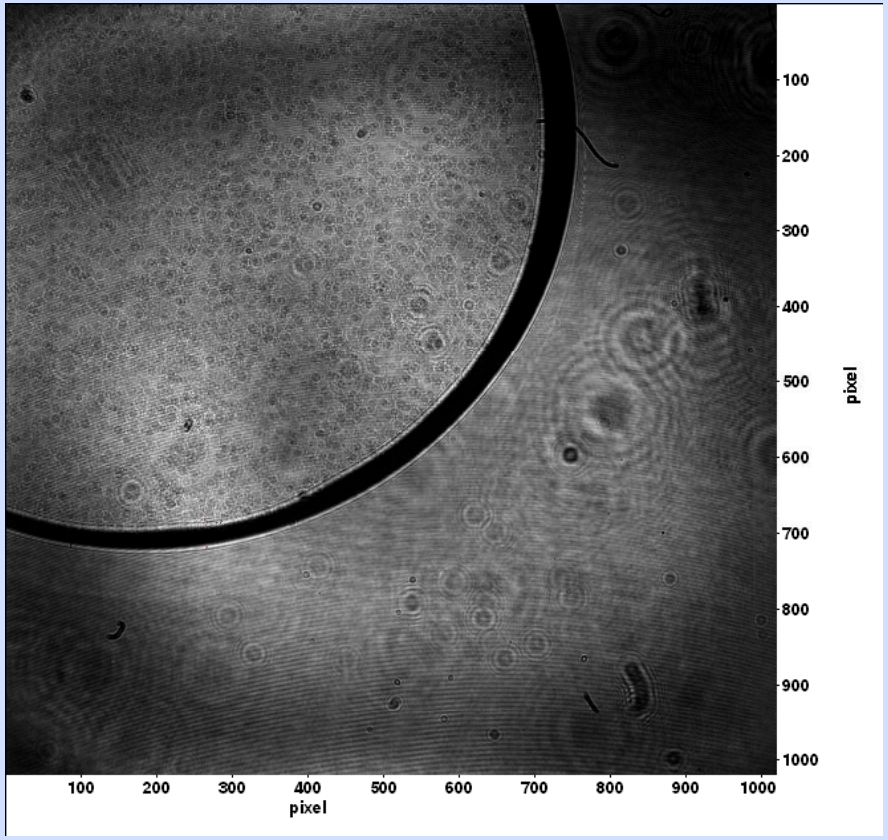
Contact line pinned

A= 0,24 mm

Lateral view



Top view

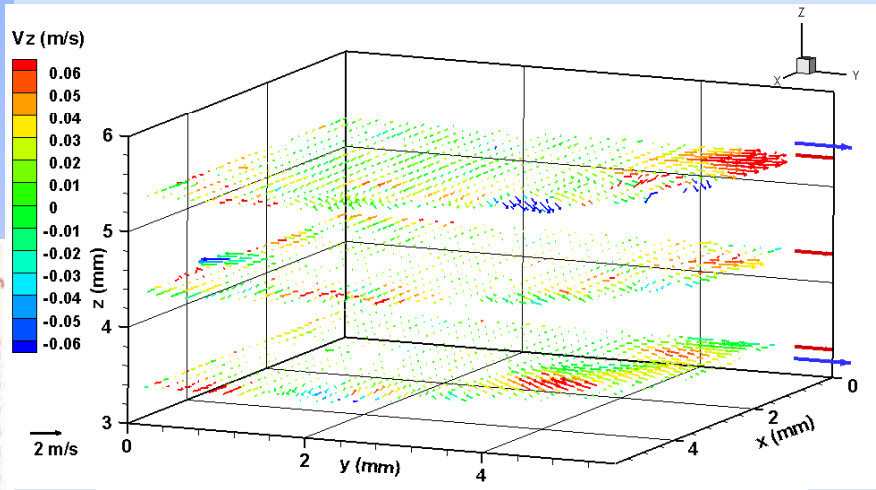


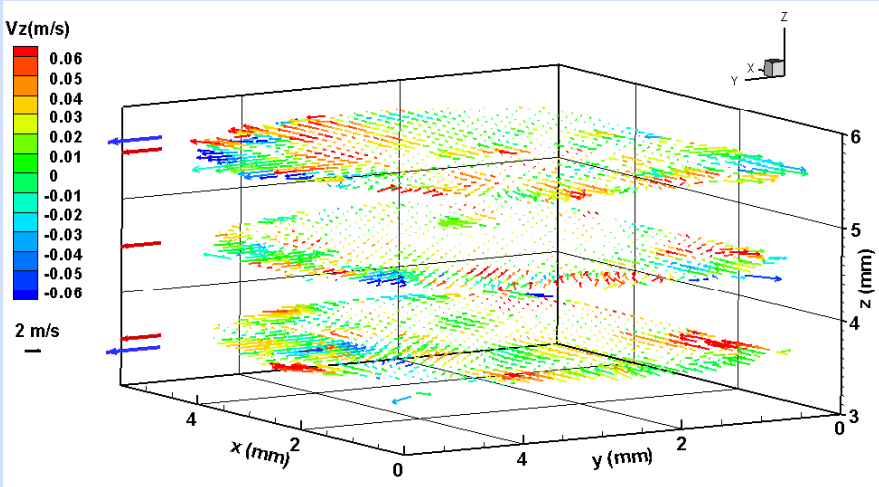
Velocity vector maps

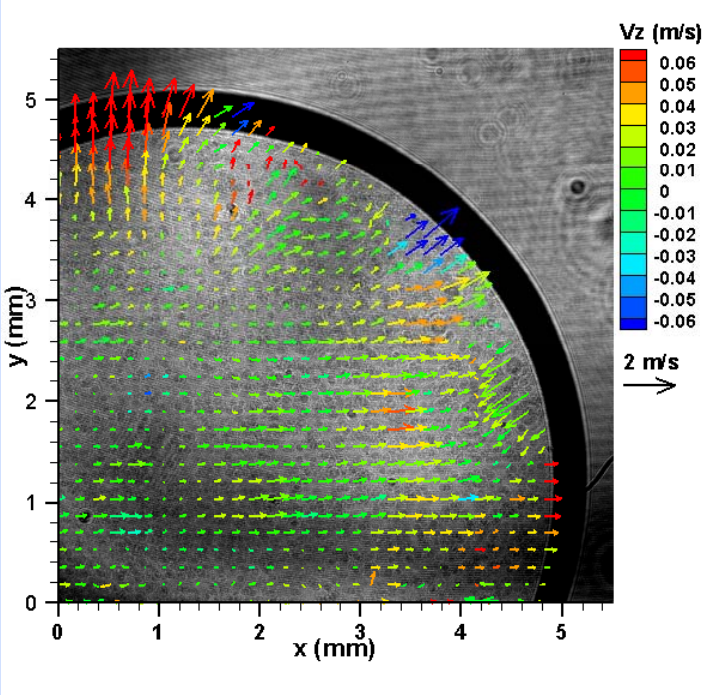
Contact line pinned

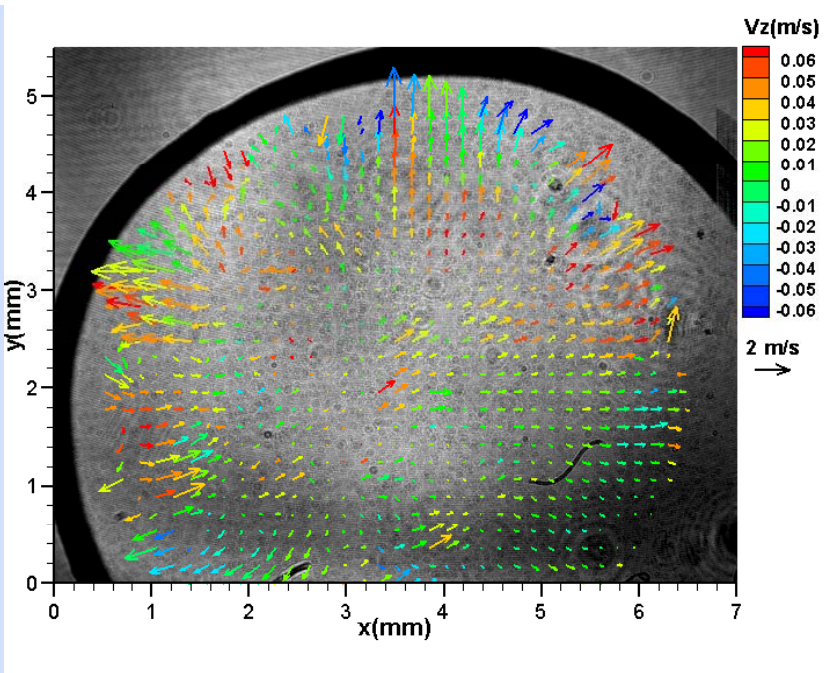
Contact line unpinned, axisymmetry

3D velocity vector maps





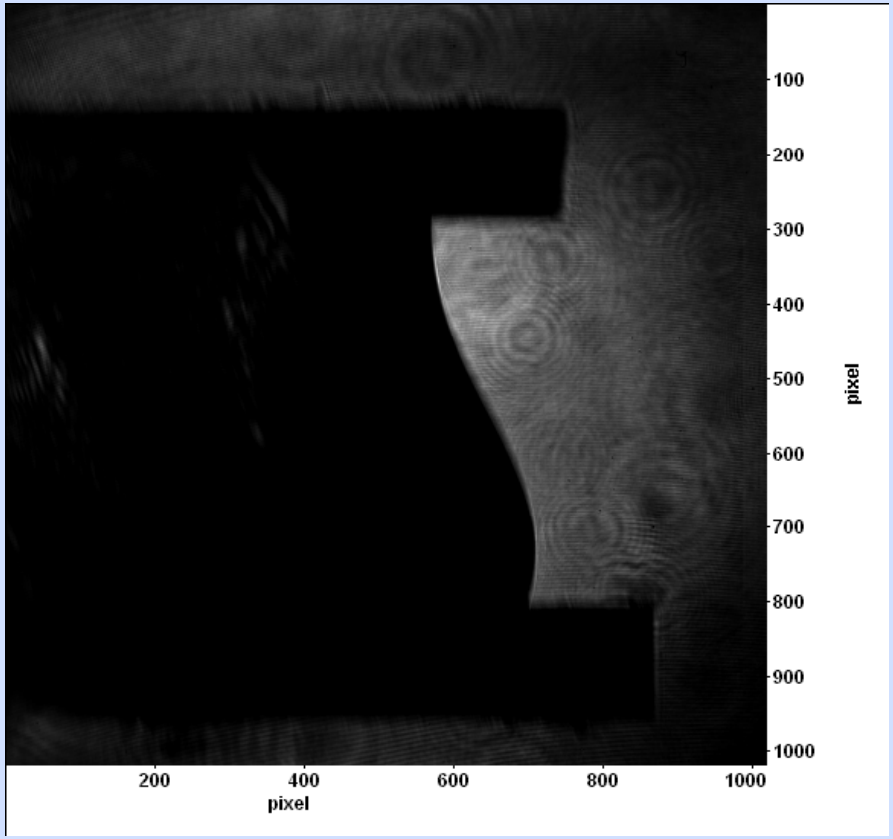


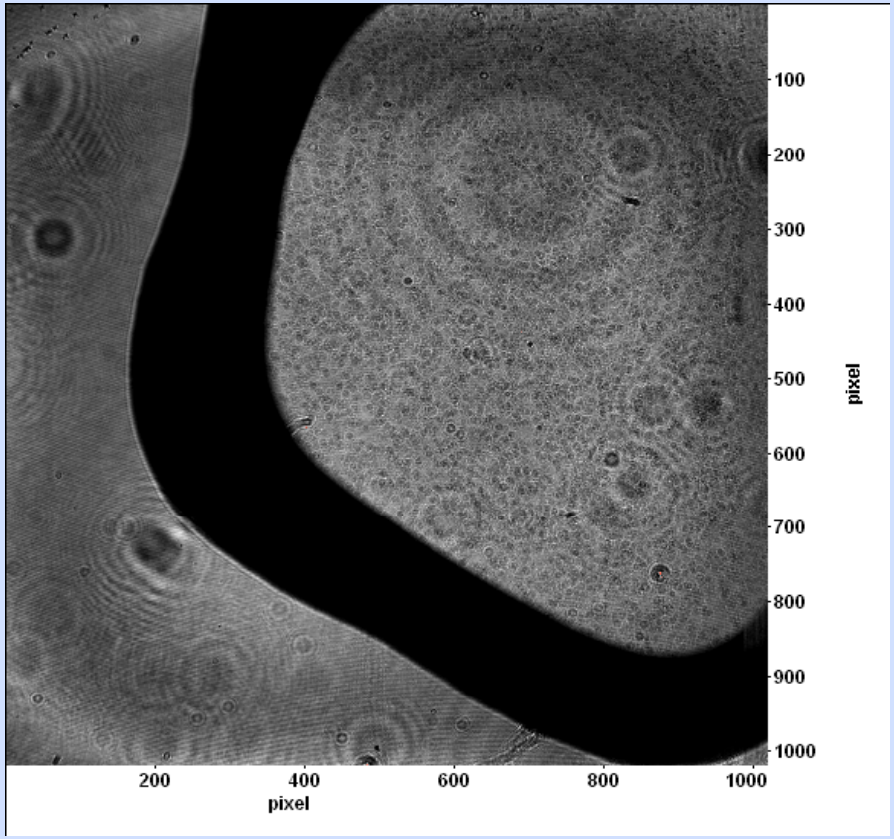


Contact line unpinned

Axisymmetry break-up

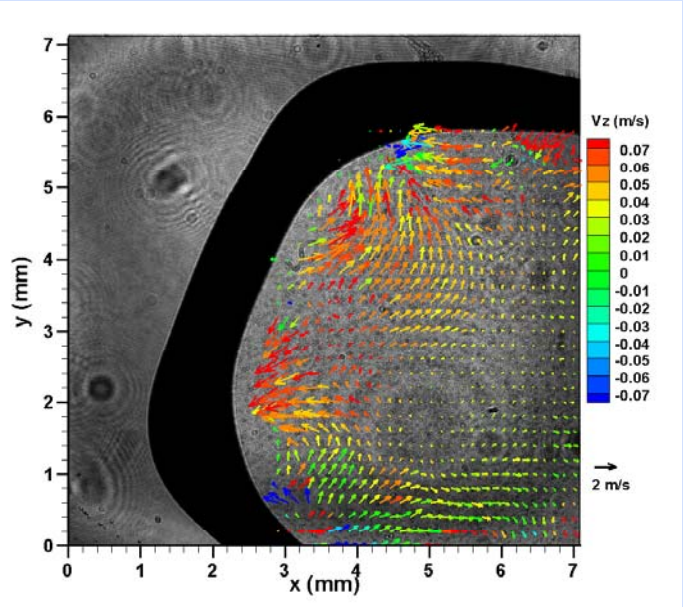
A= 1 mm

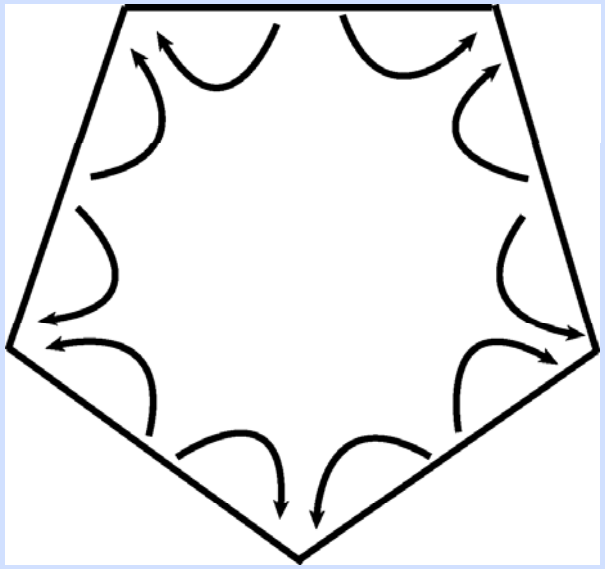




Contact line unpinned

Axisymmetry break-up

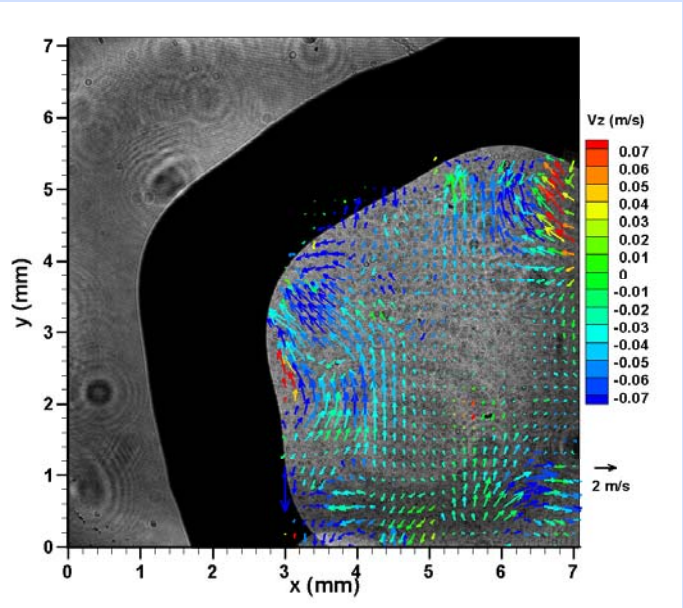


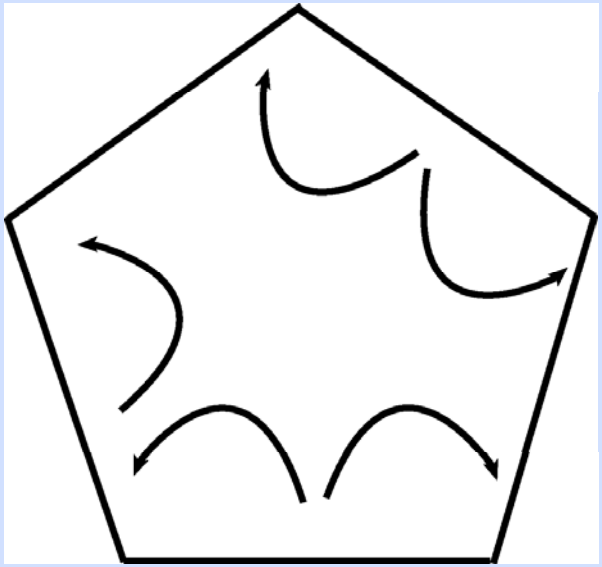


Defined 2D structures

Azimuthal standing waves

Half a period between each structure

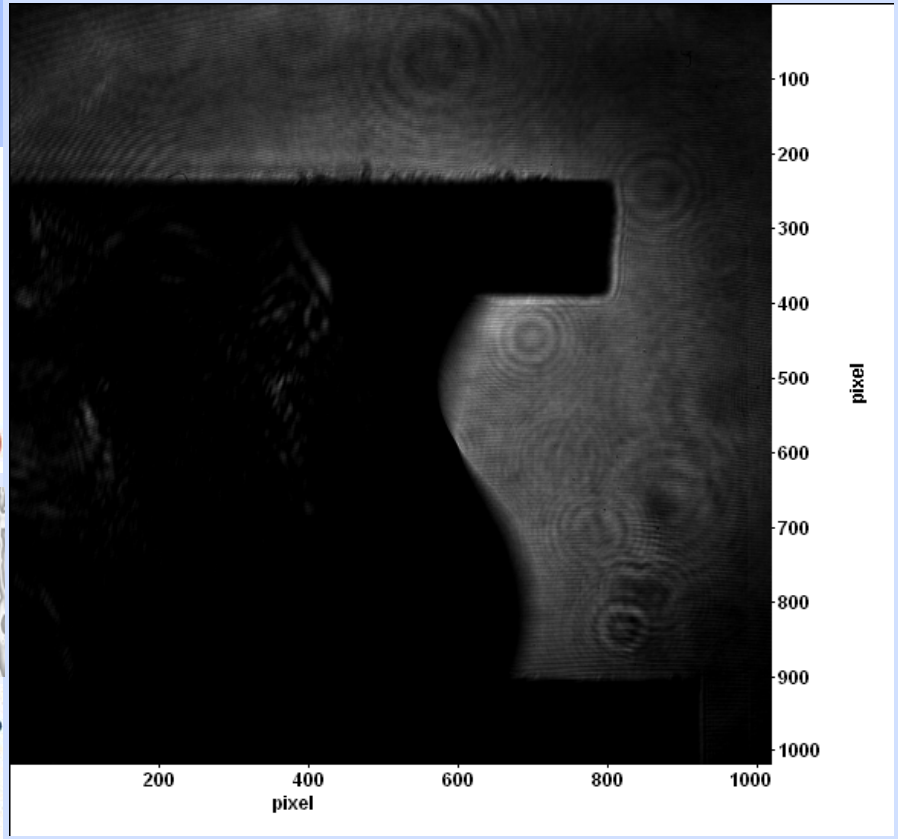


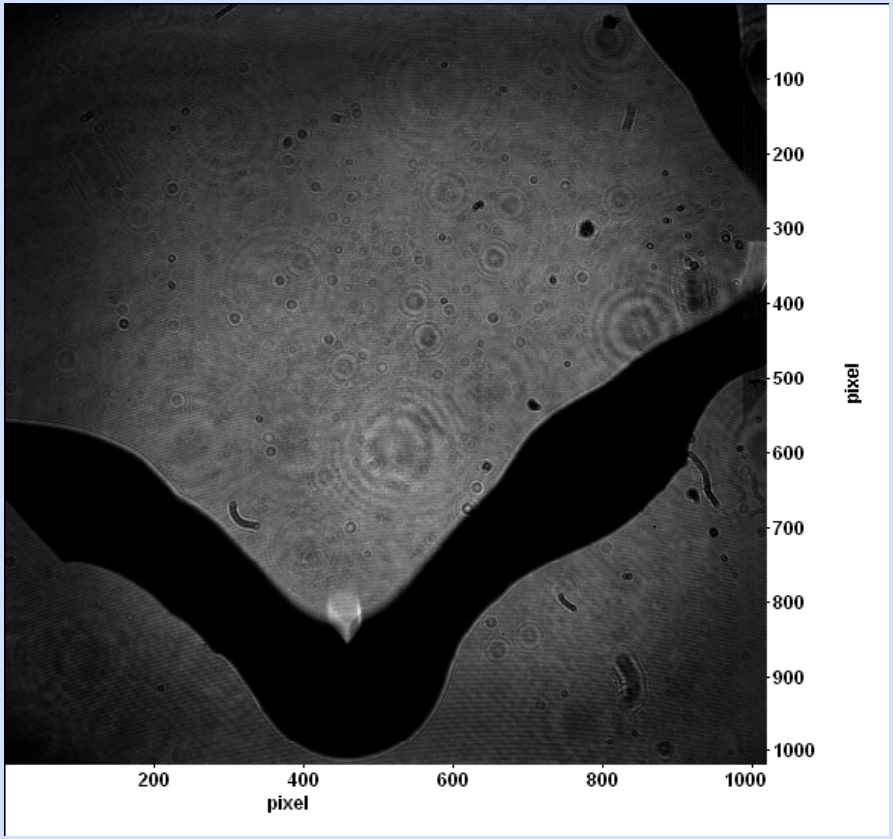


Contact line unpinned

A= 1.34 mm

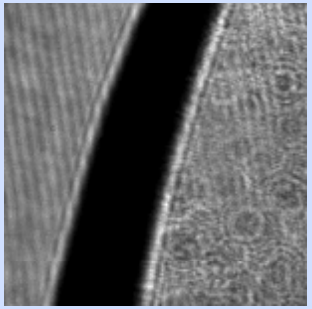
Star-shaped drop

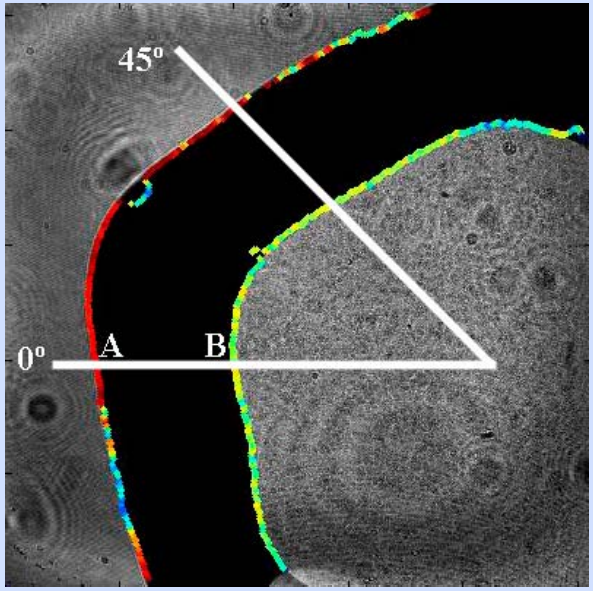


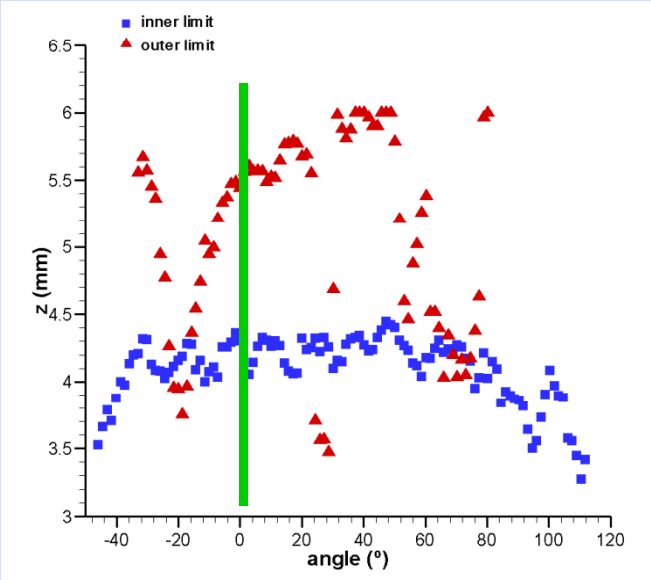


Free-surface movement

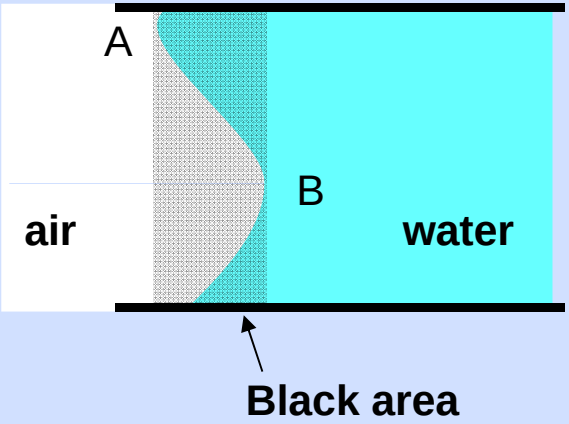
Hologram close-up



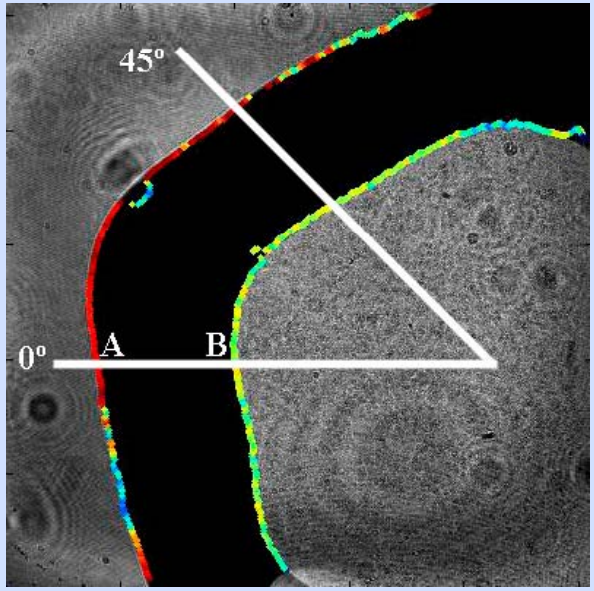


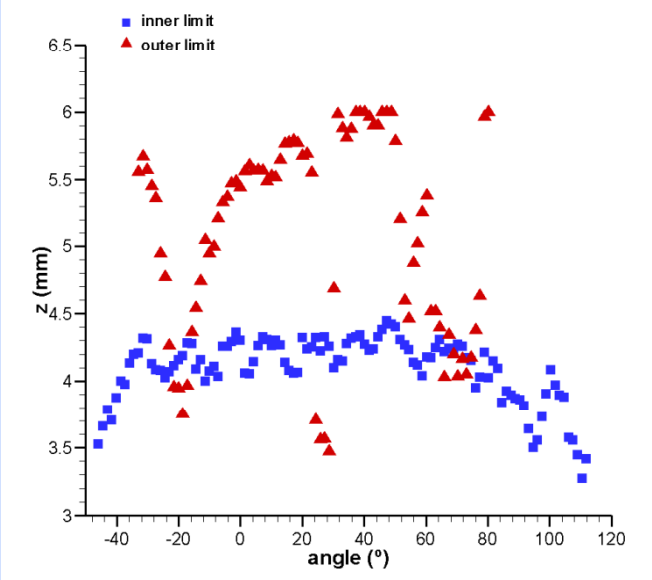


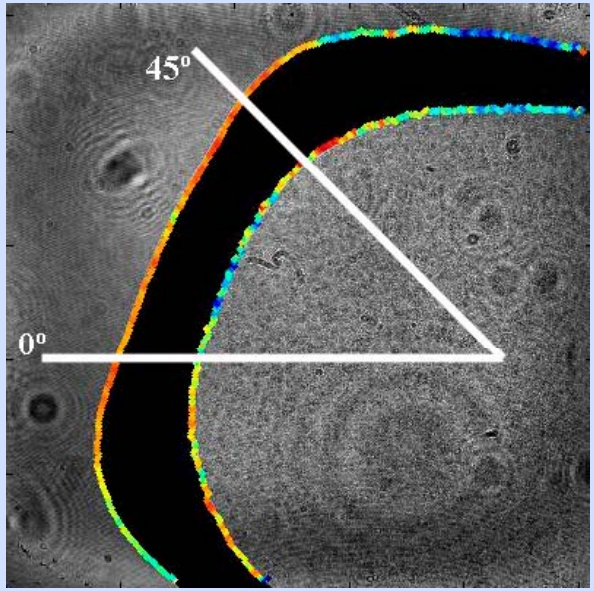
LATERAL VIEW

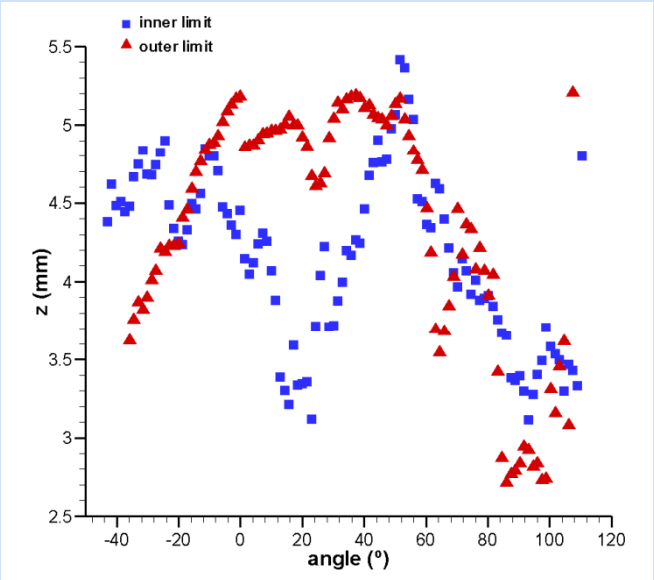


Free-surface movement









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Conclusions

- The inner flow of a droplet under shaking has been measured
- Transition between pinned and unpinned contact line was visualized
- Internal structures related to the break-up of axisymmetry
- Generation of the star droplet: axisymmetry break up
- Digital holography allows to measure the free-surface movement