SAPIENZA
UNIVERSITÀ DI ROMA

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PRACE

C.M. CASCIOLA

DIPARTIMENTO DI INGEGNERIA MECCANICA E AEROSPAZIALE
SAPIENZA

12 - Febbraio - 2017

Componenti del Gruppo

Linee di Ricerca ERC - BIC

1. Microscale Wetting & Cavitation

M. Amabili (AR), A. Giacomello (RTD-A), E. Lisi (PhD), S. Marchio (PhD), S. Meloni (RTD-A

Collaborazioni: C. Valeriani (Universidad Complutense de Madrid)

---

2. Mesoscale Cavitation & Multiphase Flow Physics

M. Gallo (PhD), F. Magaletti (AR), L. Marino (PA)

---

3. Macroscale Cavitation & Multiphase Flows

D. Pimponi (AR)

Collaborazioni: S. Chibbaro, S. Popinét (UPMC/Sorbonne)

---

4. Bubble Dynamics & Turbulent Transport

F. Battista (RTD-A), P. Gualtieri (RC), J.-P. Mollicone (AR)

---

5. Laser Induced Cavitation

D. Caprini (PhD), L. Marino (PA), A. Occhicone (PhD), G. Sinibaldi (AR)

Collaborazioni: M. Chinappi (RTD-B Tor Vergata), F. Michelotti (PA SBAI), F. Pereira (INSEA

---

6. Cavitation in Biochips

D. Caprini (PhD), L. Marino (PA), C. Scognamiglio (PhD), G. Silvani (PhD), G. Sinibaldi (AR

Collaborazioni: D. Durando (INRIM - Ultrasound Lab.), M. Kiani (Temple University), G. Peruzzi (CLNS@IIT)

Altre Linee di Ricerca

7. Experimental Microfluidics

D. Caprini (PhD), L. Marino (PA), C. Scognamiglio (PhD), G. Sinibaldi (AR)

Collaborazioni: M. Chinappi (RTD-B Tor Vergata), X. Noblin (CNRS-LPMC), A. Nascetti (DI

---

8. After Implant Hemodynamics

G. Finesi (MS), F. Battista (RTD-A), P. Gualtieri (RC)

Collaborazioni: M. Taurino (PO Medicina Clinica e Molecolare & AO S. Andrea)

---

9. Microcombustors

F. Battista (RTD-A)

Collaborazioni: S. Chibbaro (UPMC/Sorbonne)

---

10. Fundamental Turbulence

F. Battista (RTD-A), P. Gualtieri (RC), J.-P. Mollicone (AR)

Consistenza del gruppo: 1 PO, 1 PA, 1 RC, 3 RTD-A, 5 AR, 8 PhD S., 1 MS

Collaborazioni: Univ. Complutense Madrid, UPMS/Sorbonne Paris, Tor Ver

UNIVERSIDAD COMPLUTENSE MADRID

C. Valeriani

TEMPLE UNIVERSITY®

M. Kiani

SBAI - Dipartimento di Scienze di Base Applicate all'Ingegneria

F. Michelotti

DIET - Dipartimento di Ingegneria Elettrica e Telecomunicazioni

A. Nascetti

Université Nice Sophia Antipolis

LPMC

X. Noblin

UPMC SORBONNE UNIVERSITÉS

S. Chibbaro

S. Popinét

The Italian Ship Model Basin INSEAN

Francisco Pereira

Dipartimento di Ingegneria Industriale

Tor Vergata

M. Chinappi

INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

G. Durando

DMCM - Dipartimento di Medicina Clinica e Molecolare

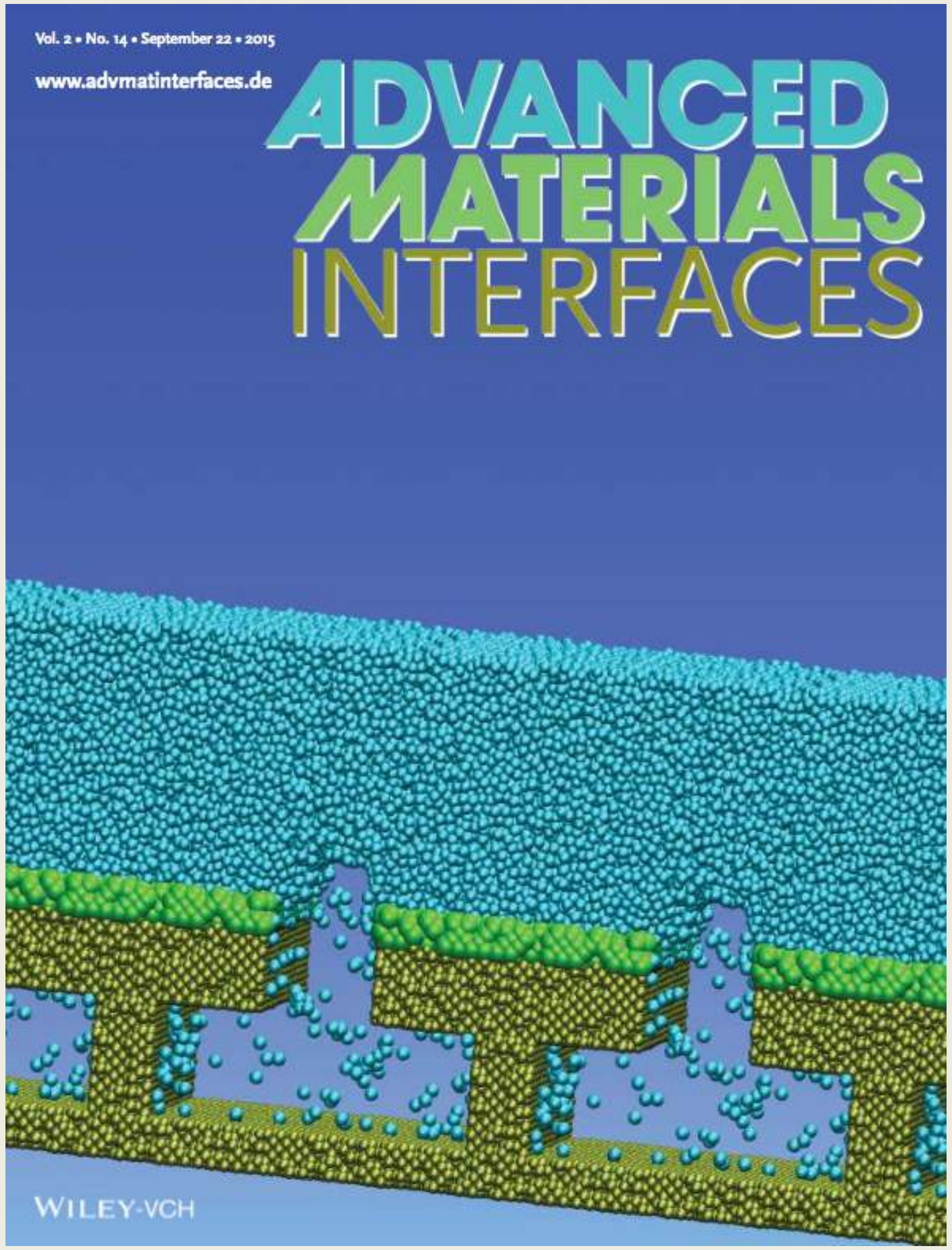
M. Taurino

iit @SAPIENZA

Giovanna Peruzzi

35 Pubblicazioni 2013 -

Phys. Rev. Fluids (2s)
J. Fluid Mech. (1s, 9)
Phys. Rev. Let. (2)
J. Phys: Cond. Mat. (1)
J. Chem. Phys. (3)
J. Mult. Phase Flows. (1)
Soft Matter (1)
New J. Phys. (1)
Adv. Mat. Int. (1)
Flow. Turb. Comb. (1)
Europ. Phys. Let. (1)
J. Phys.: Conf. S. (2)
Phys. Fluids (2)
Langmuir (2)
Microfluidics & Nano. (2)
Int. J. Heat Mass Tr. (1)
Phys. Rev. E (1)
J. Phys. Chem. B (1)



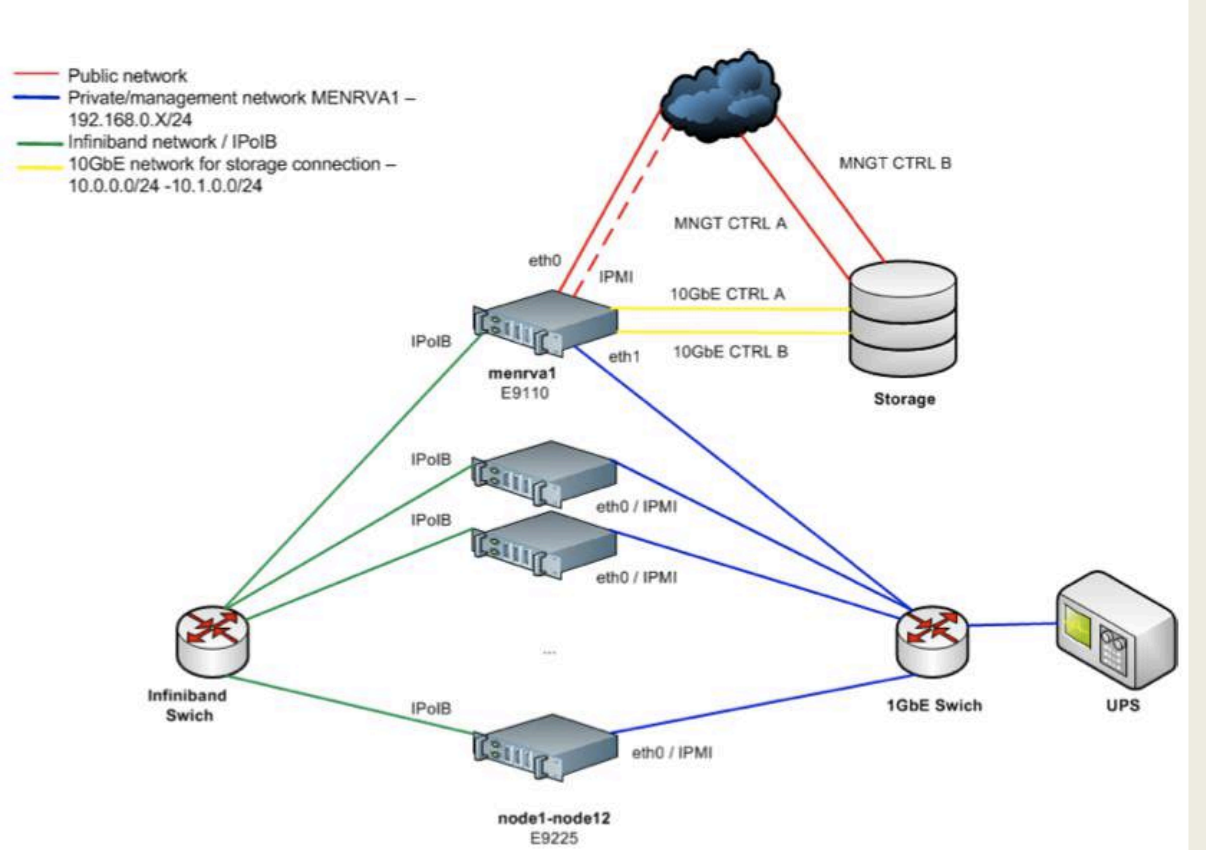
Fondi

- ERC Advanced Grant 2013: (BIC) Cavitation across scales - *F*ollowing
- Sapienza Awards 2014: Micro & Nanobubbles for Drug Delivery (53 k€)
- Grandi e Medie Attrezzature Sapienza: Cluster Menrva (120 k€)
- 5 PRACE Grants: CMC (2), P. Gualtieri (1), A. Giacomello (1, 2 year) *(*
- Grandi e Medie Attrezzature Sapienza 2012: Sistema per Microscopia a Correl
- Fondi Gestione Microfluidic Lab (IIT-CLNS@Sapienza) (40 k€/year)

Strutture & Attrezzature

- ## Cluster Menrva

12 Nodi x 2 eptacore = 192 cores
(CPU Intel Xeon E5-2650v2 2,6GHz, 64 Gb RAM)
Switch Infiniband E6345, 40 Gb/s
12 Dischi 3 TB SATA, configurazione RAID 6 (30 TB)



- ## Microfluidic Lab

IIT Center for Life Nanoscience@Sapienza

- ## Area Meccanica Applicata

DIMA

Sapienza Cluster: *Menrva*

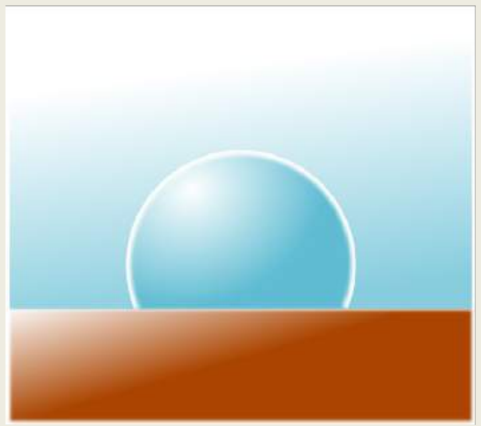
- Grandi e Medie attrezzature: 1.2E+5 €
- More than 120 participants
  - Engineering, Physics
  - Mathematics, Chemistry
  - Biology, Pharmacy
  - Medicine
- 12 compute nodes: 384 cores
  - 32 cores per node
  - 64 Gb per node
  - 48Tb storage
  - Intel E5-2650 v2 @ 2.60GHz
  - InfiniBan connection
- Hosted at DIMA

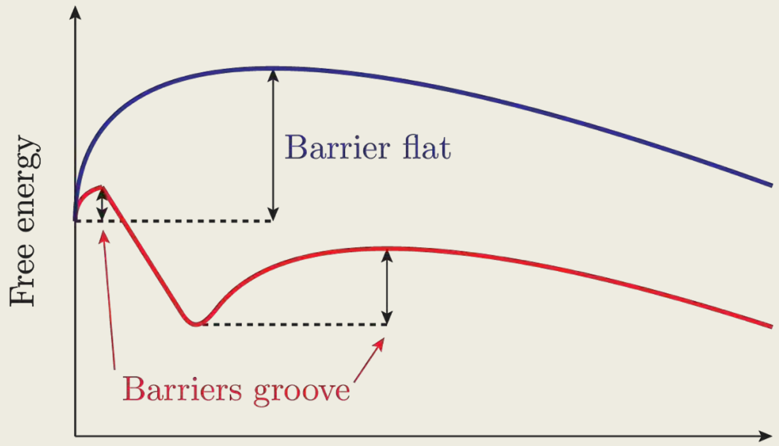
Menrva: Etruscan Godness of war, art, wisdom and health

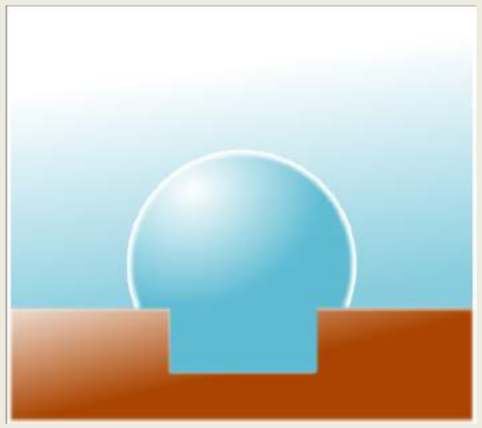
Microscale Wetting & Cavitation

Nanoscale wetting and cavitation

Origin of cavitation: homogeneous and heterogeneous nucleation



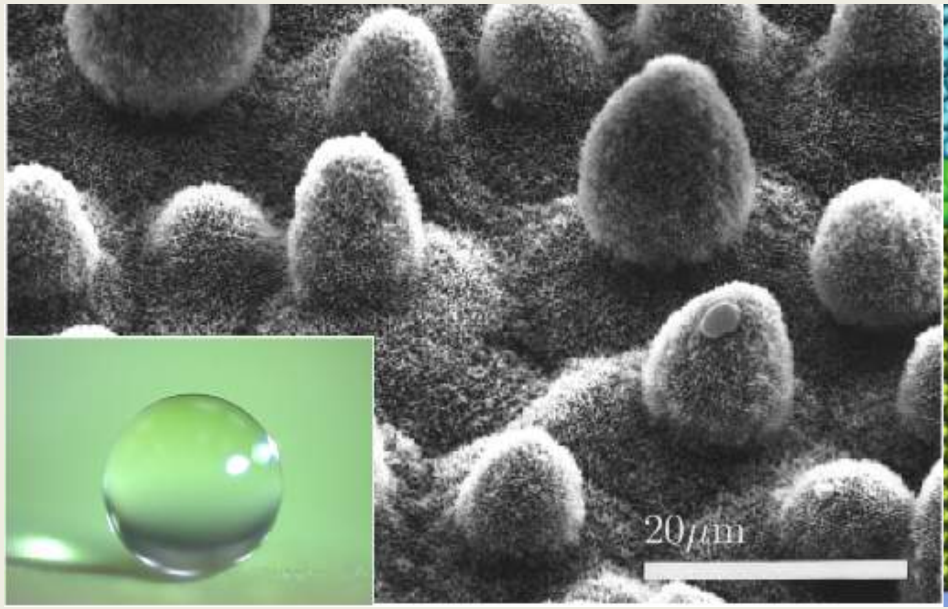


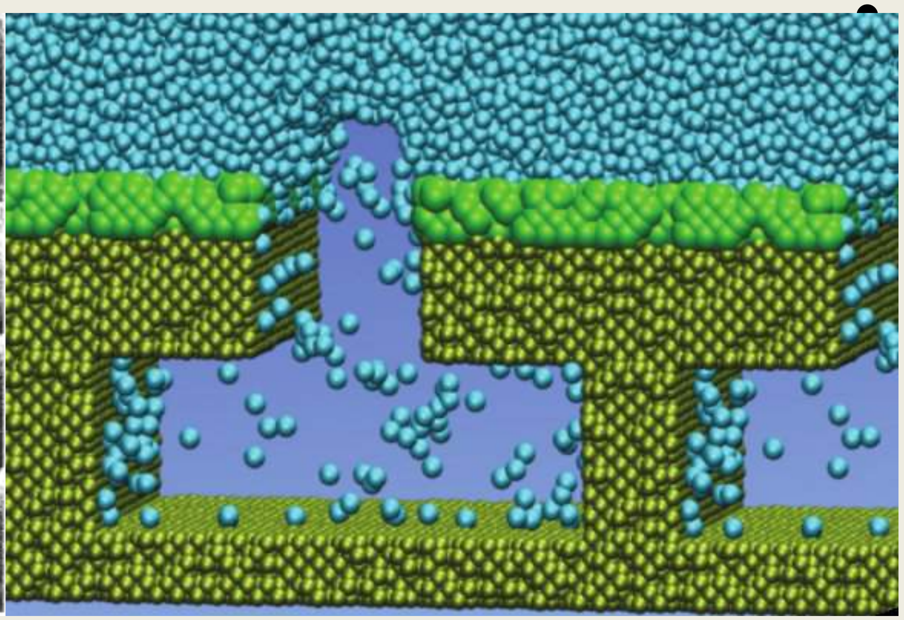


People:

- Simone Meloni
- Alberto Giacomello
- Matteo Amabili
- Emanuele Lisi
- Antonio Tinti
- Sara Marchio

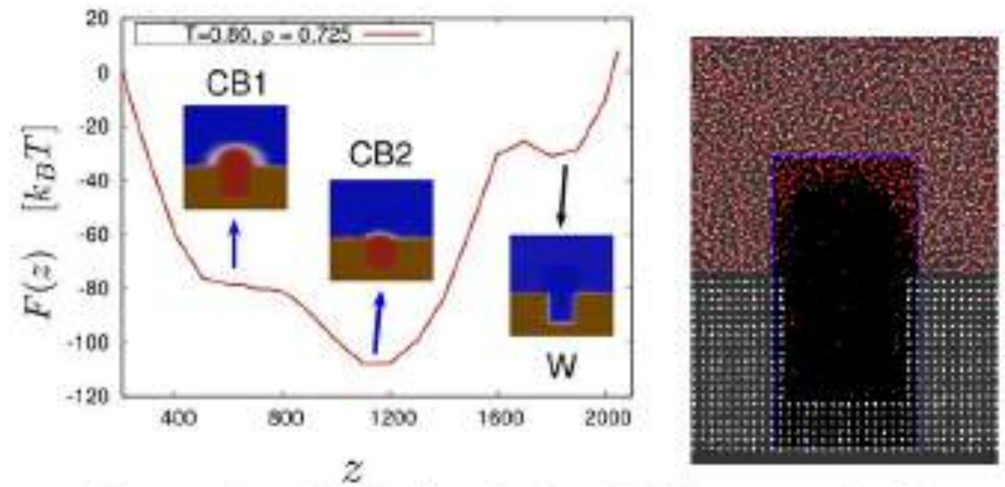
Superhydrophobic surfaces



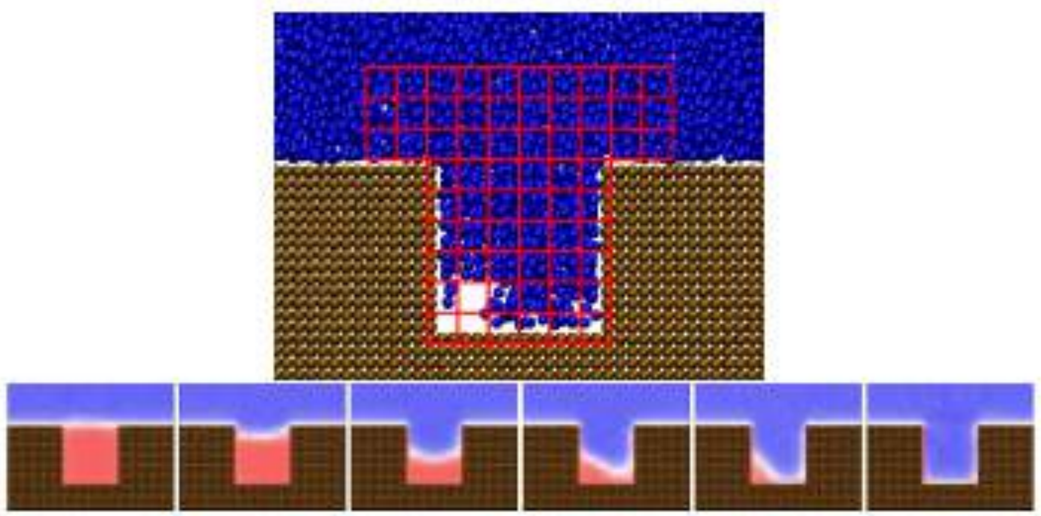


Methods

ATOMISTIC



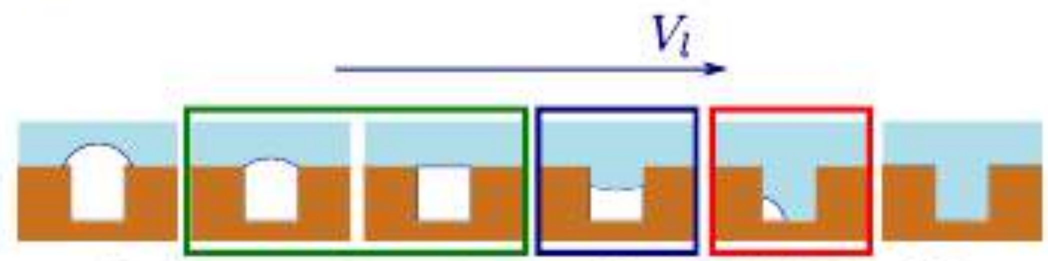
Restrained MD (and Parallel Tempering)
[Giacomello *et al.*, Langmuir 2012]



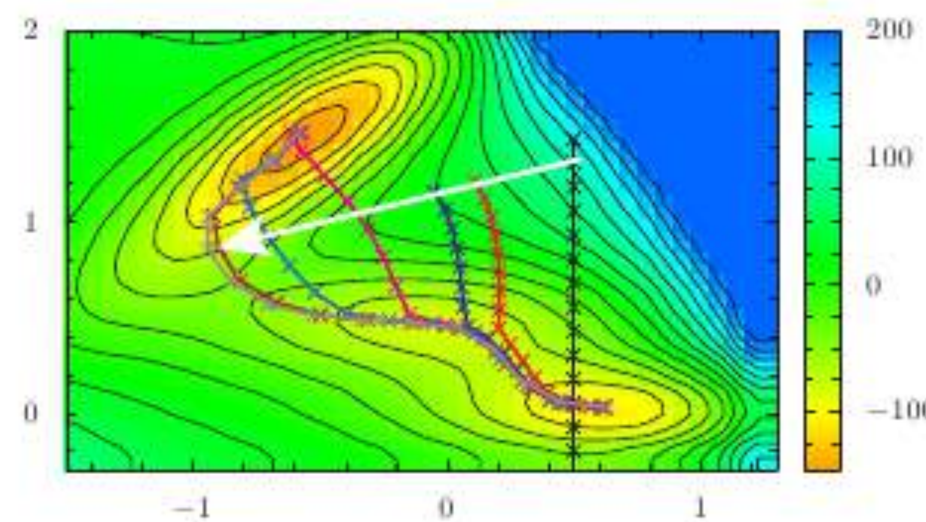
String method in collective variables
[Giacomello *et al.*, J. Chem. Phys 2015]

CONTINUUM

1. $P_l - P_v + \lambda = J\gamma_{lv}$ (mod. Laplace eq.)
2. $(\gamma_{sv} - \gamma_{sl})/\gamma_{lv} = \cos\theta$ (Young eq.)
3. $V_l = Z$ (constraint)



Continuum Rare Events Method (CREaM)
[Giacomello *et al.*, PRL 2012]

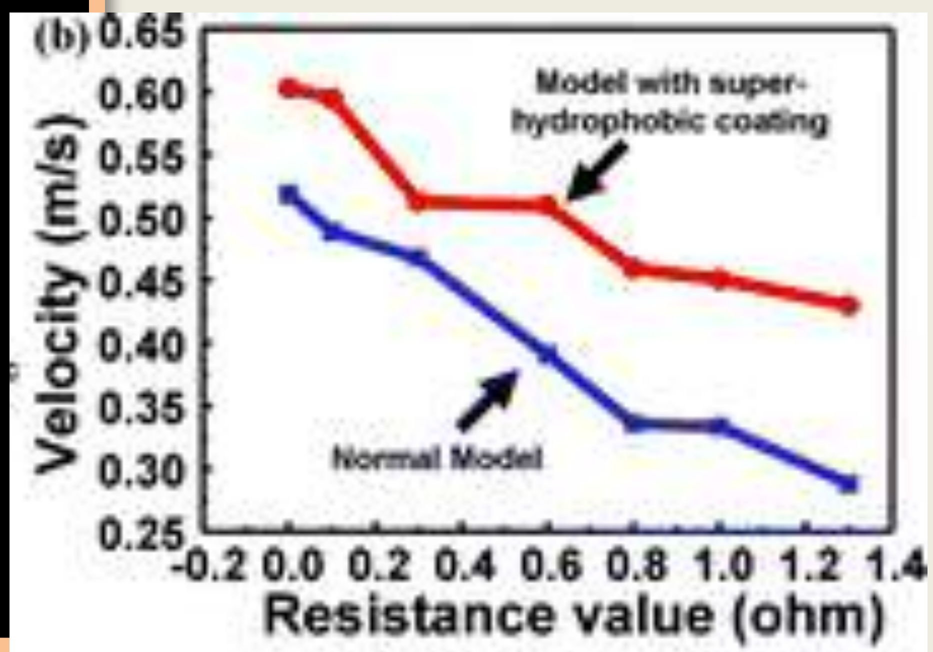


String method
[Giacomello *et al.*, J. Chem. Phys 2015]

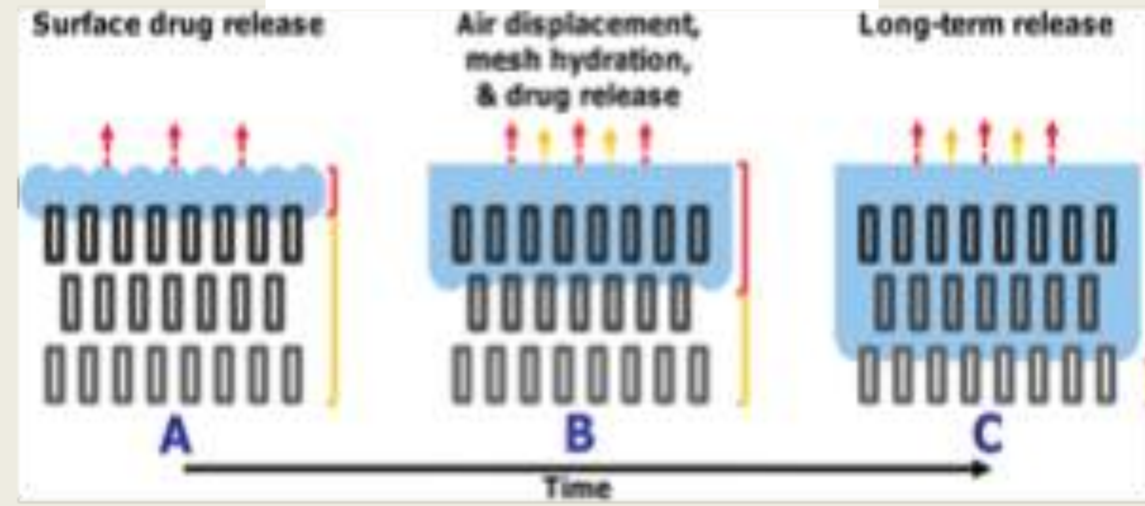
INCREASING LENGTH ⟶

Technological applications of superhydrophobic (submerged) surfaces

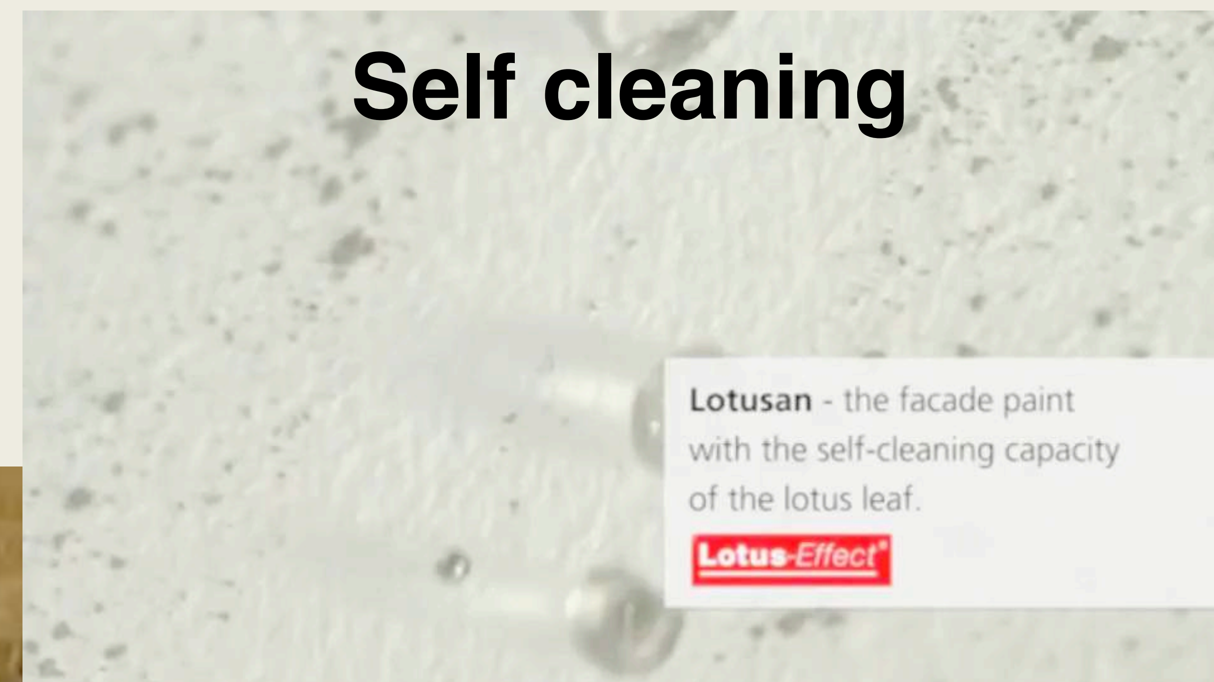
Drag reduction



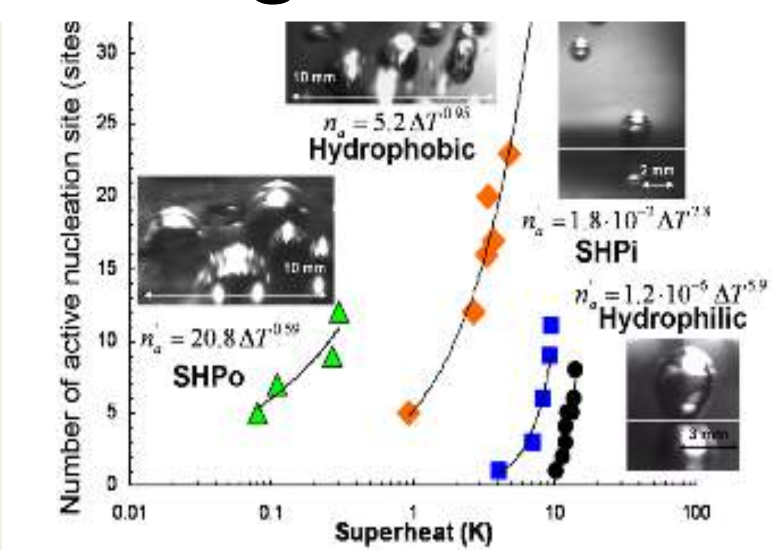
Drug delivery



Self cleaning



Boiling heat transfer



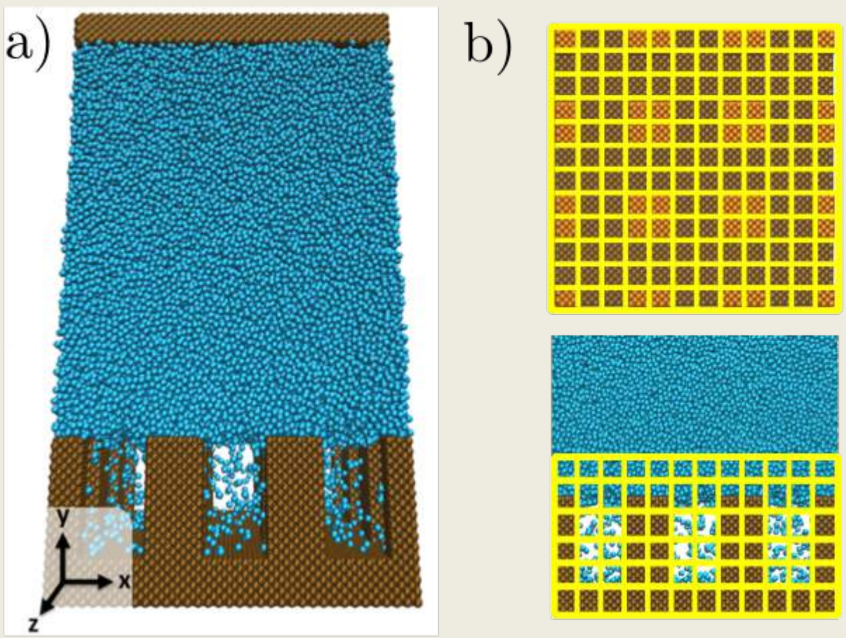
Anti-icing

Wetting/dewetting of nanopillared submerged surfaces: micro vs macro

- ➢Simple fluid on a simple solid
  - ➢Both are LJ
  - ➢Solid-fluid

$$v(r) = 4\epsilon\left(\left(\frac{\sigma}{r}\right)^{12} - c\left(\frac{\sigma}{r}\right)^{6})\right)$$

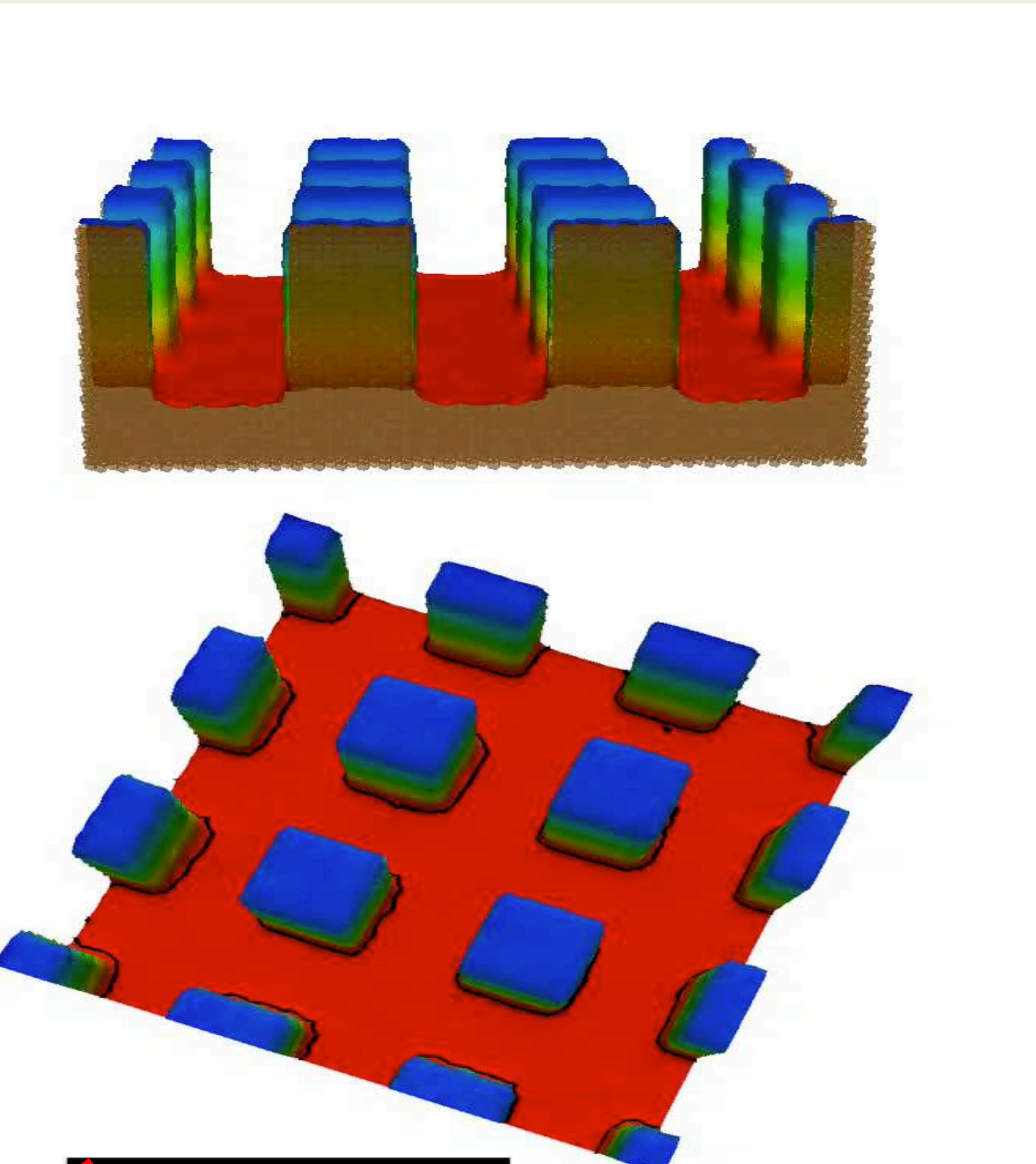
$$\theta_Y \sim 110^\circ$$

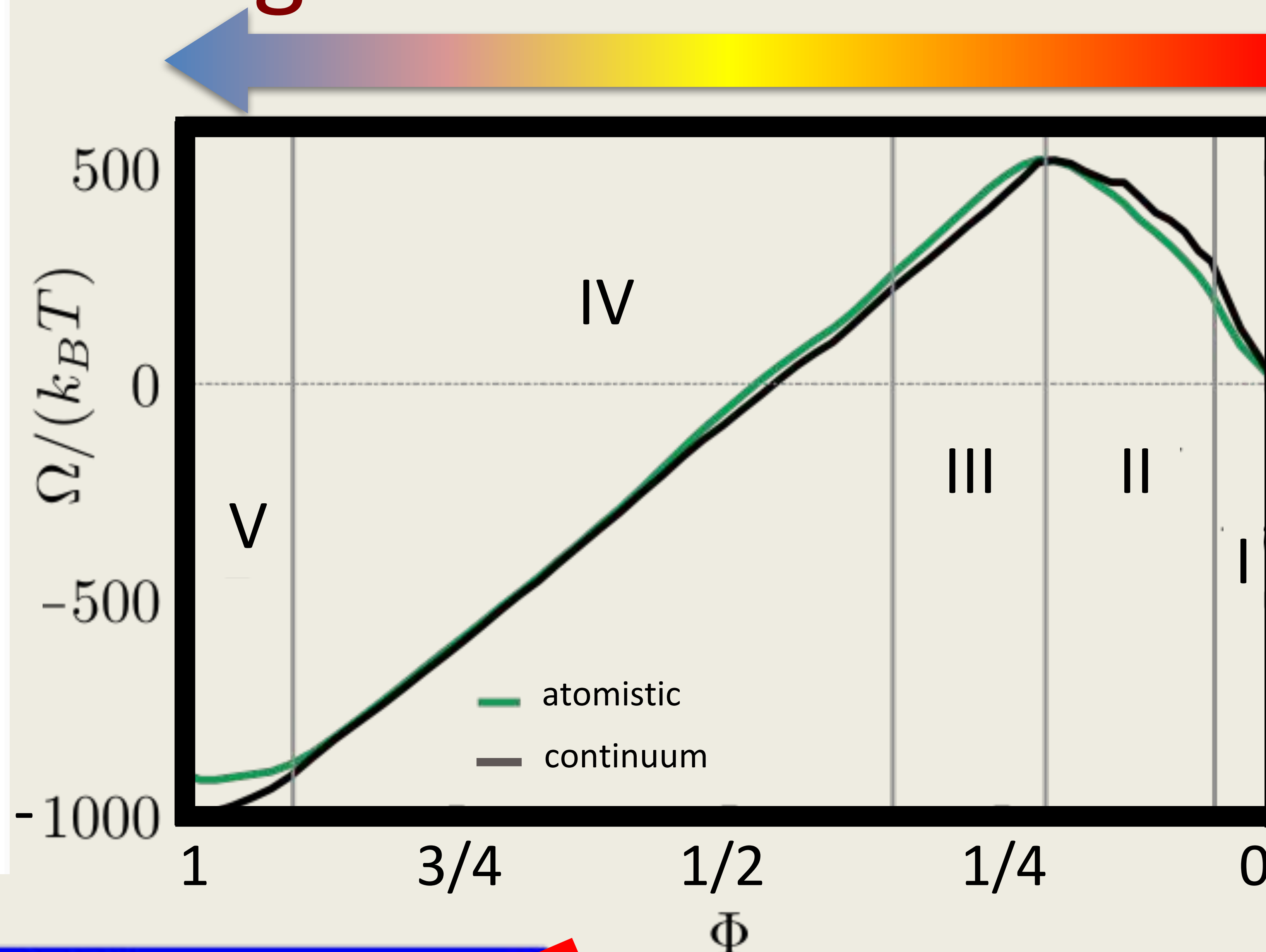


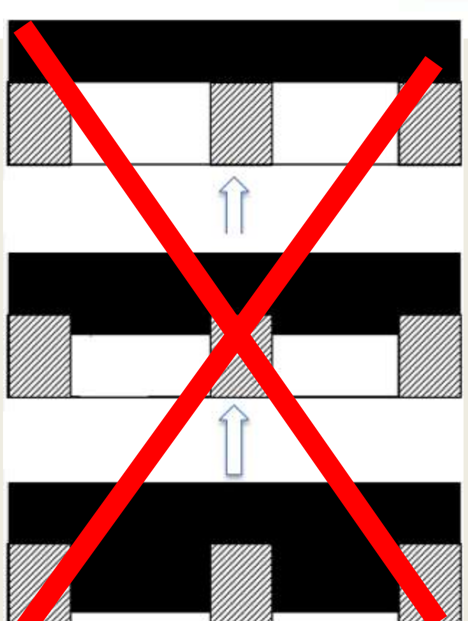
- ➢Most probable dewetting path as a function of the density field
  - ➢Not the usual observable vapor volume
  - ➢**Energetics**

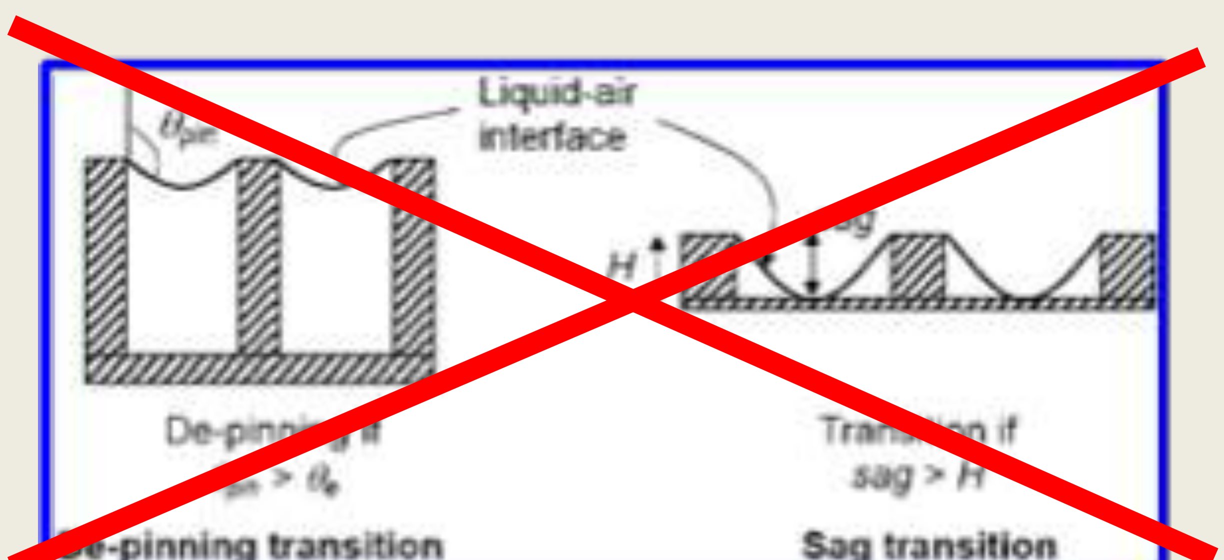
M. Amabili *et al*, submitted to Phys. Rev. Fluids

Atomistic dewetting Mechanism and energetics



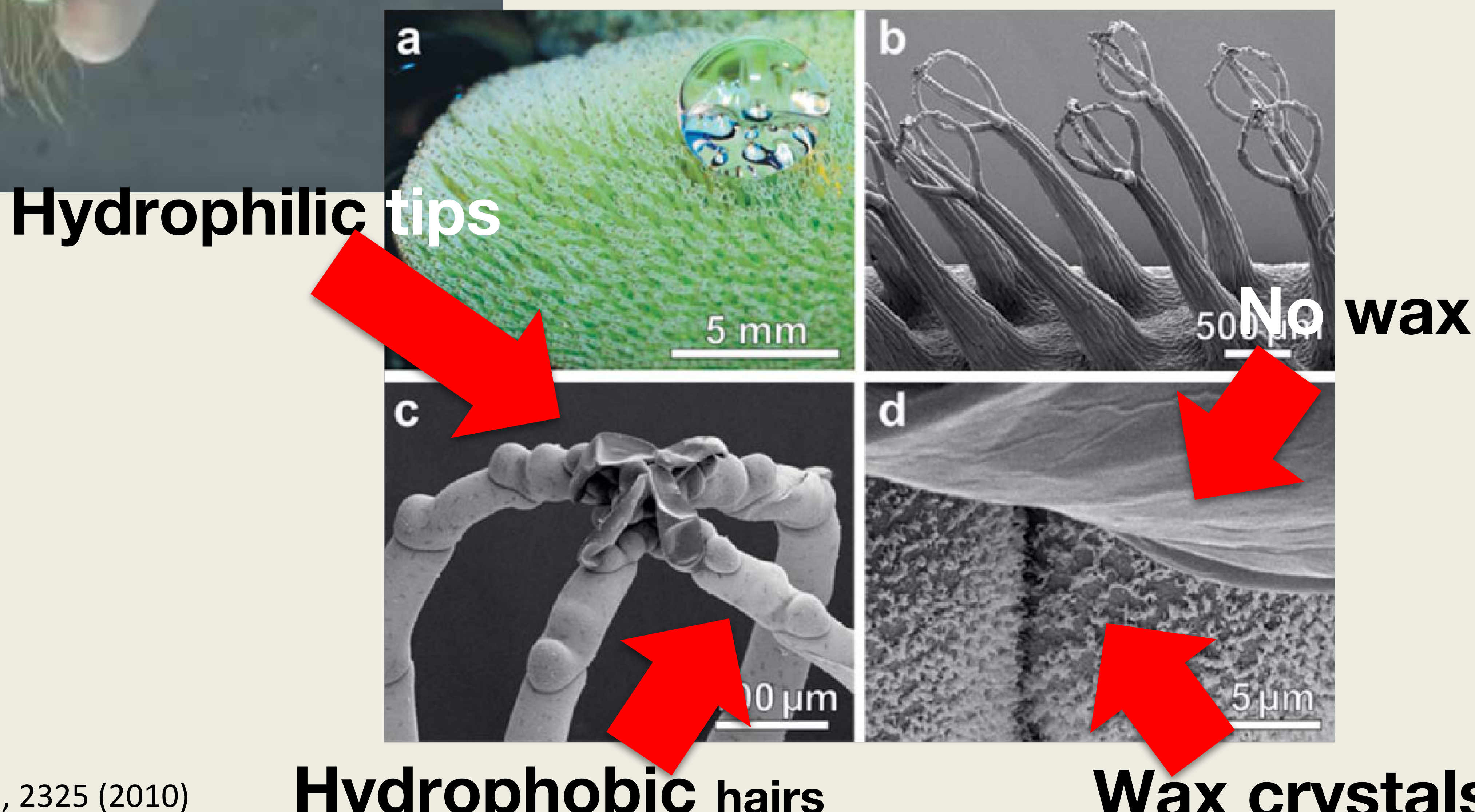






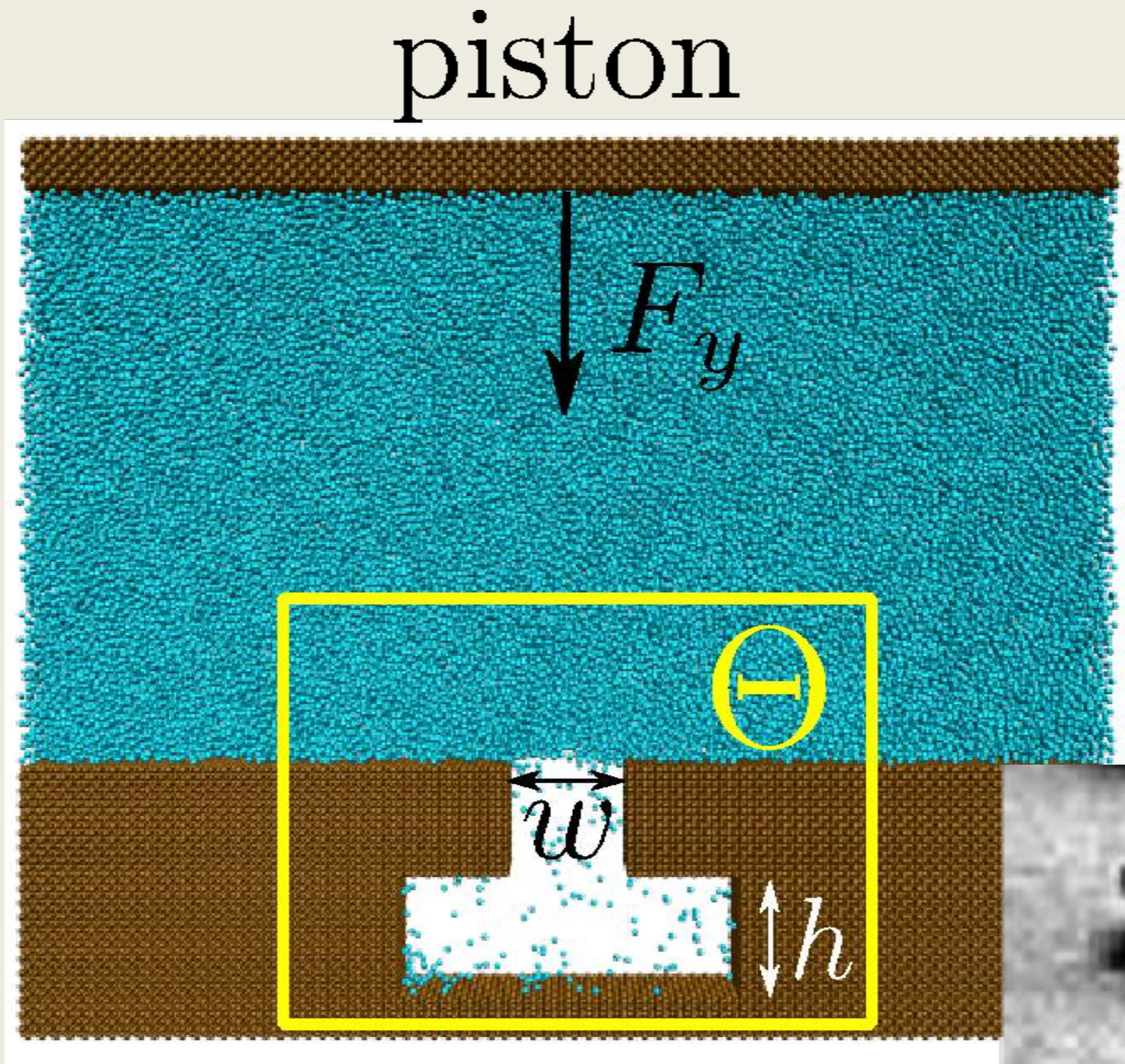
Patankar, Langmuir 20, 7097 (2004)
Patankar, Langmuir 26, 8941 (2010)

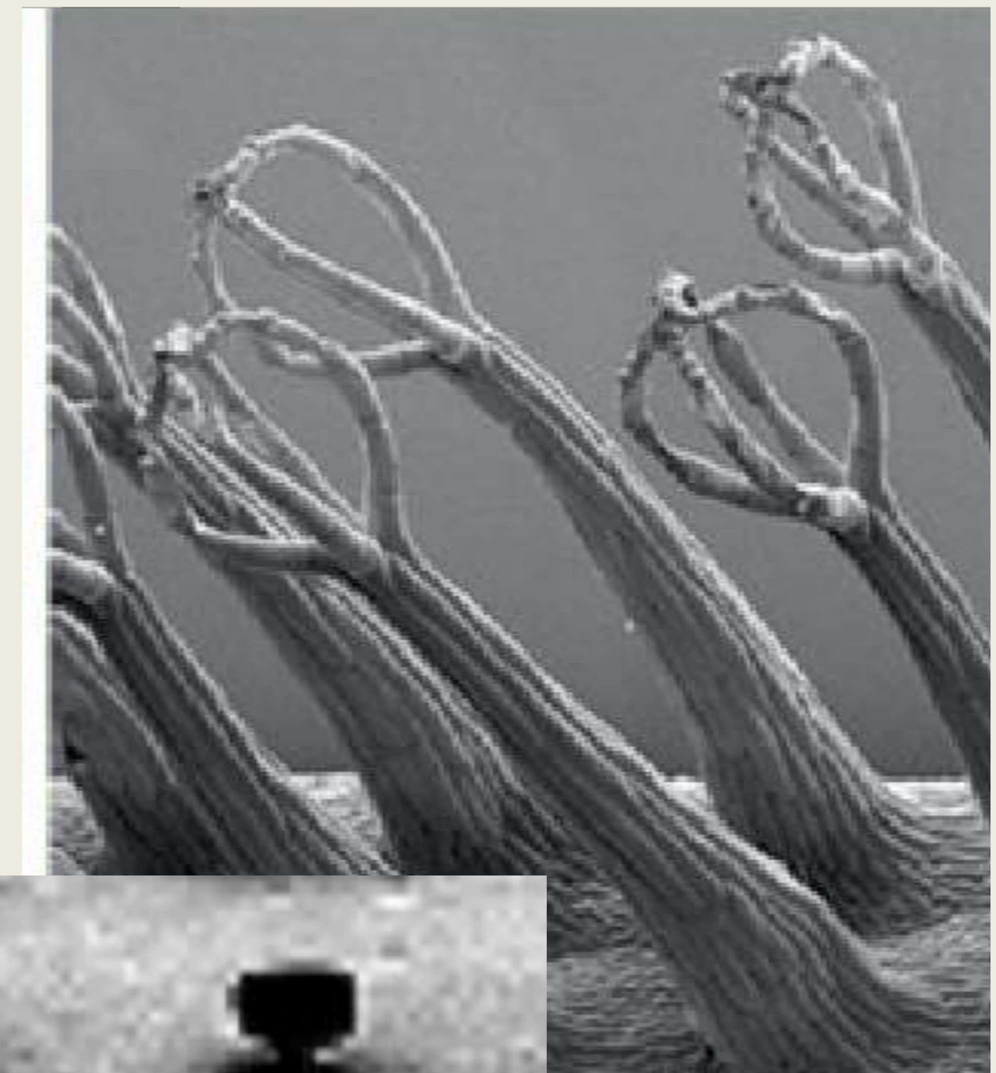
Robust Submerged Superhydrophibicity: Salvinia molesta

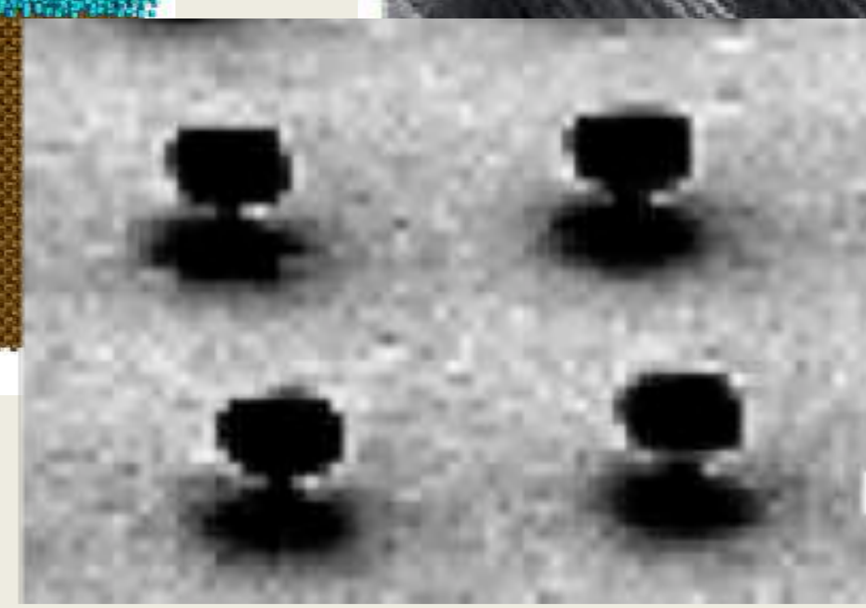


Barthlott et al, Adv. Mat. 22, 2325 (2010)

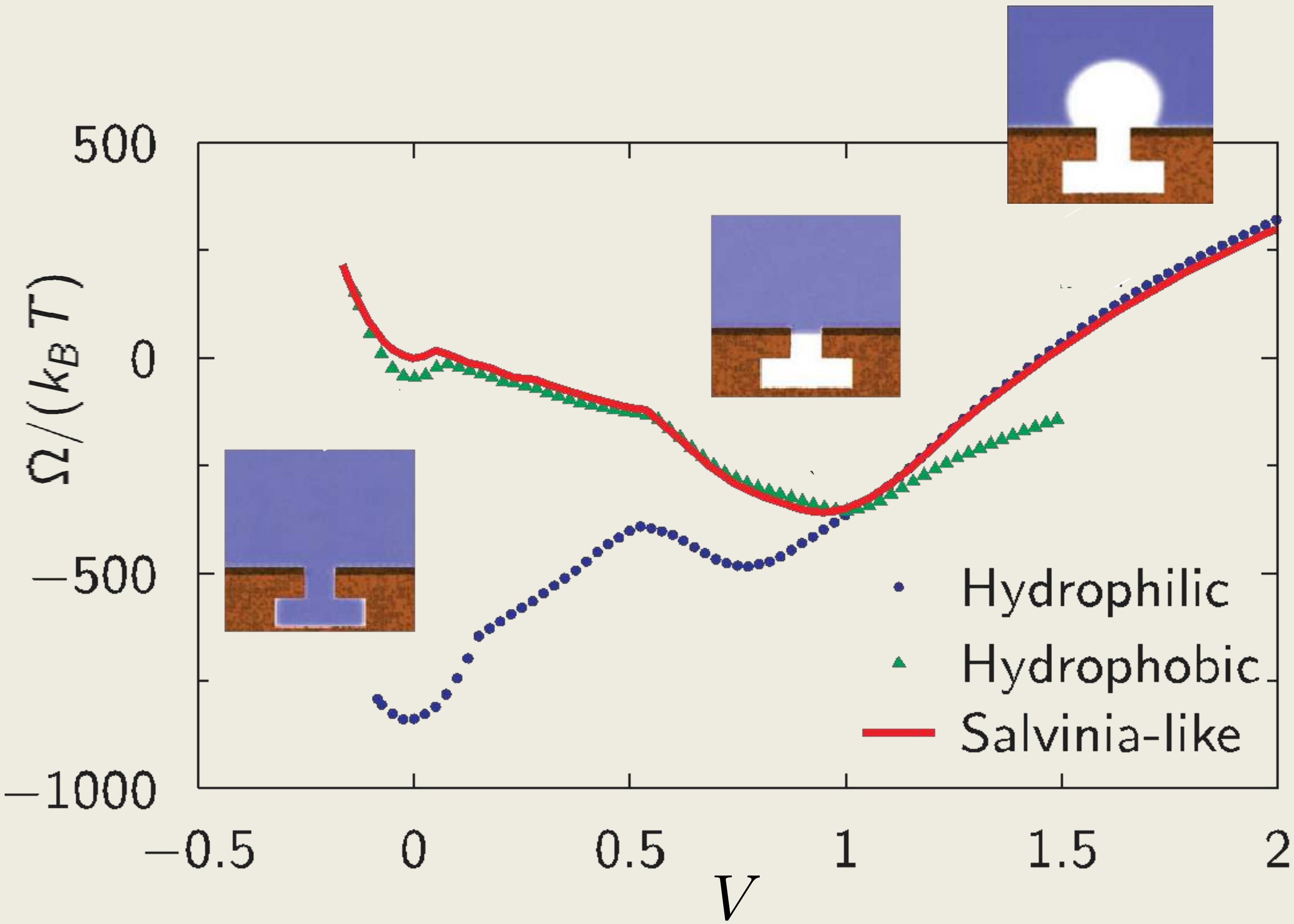
Model System

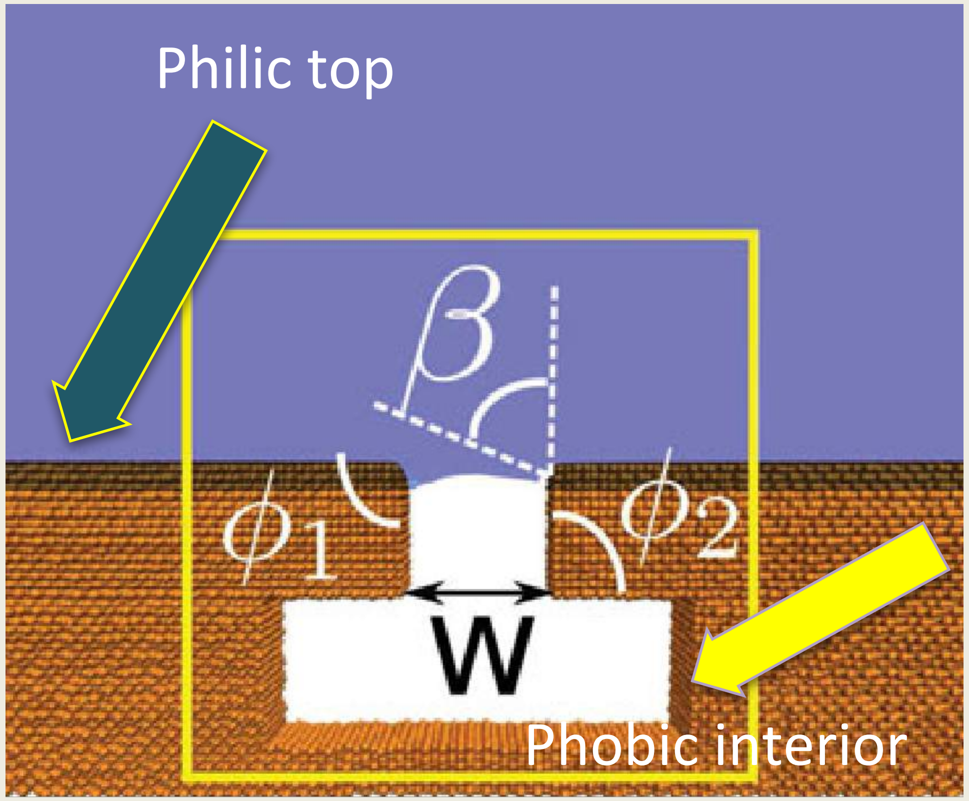






Combined chemistry model



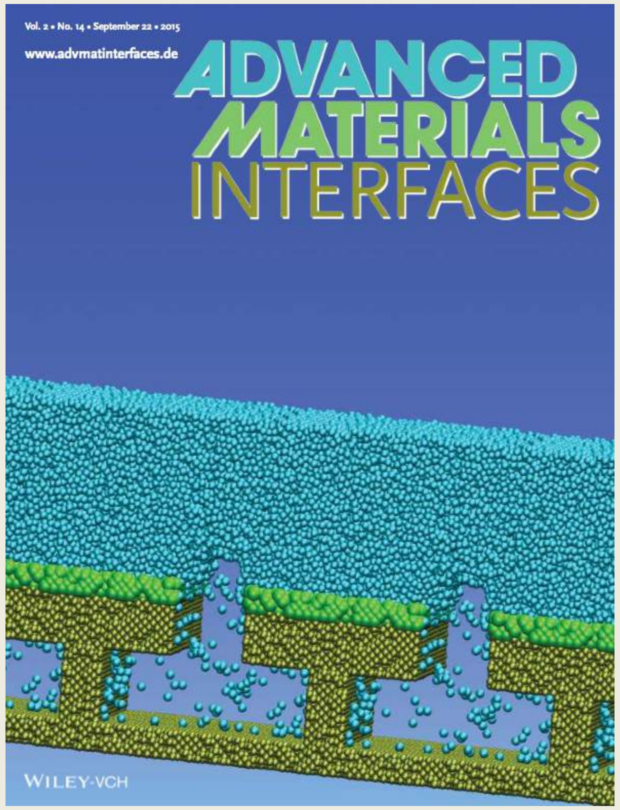


Materials Views
www.MaterialsViews.com

ADVANCED MATERIALS INTERFACES
www.advmatinterfaces.de

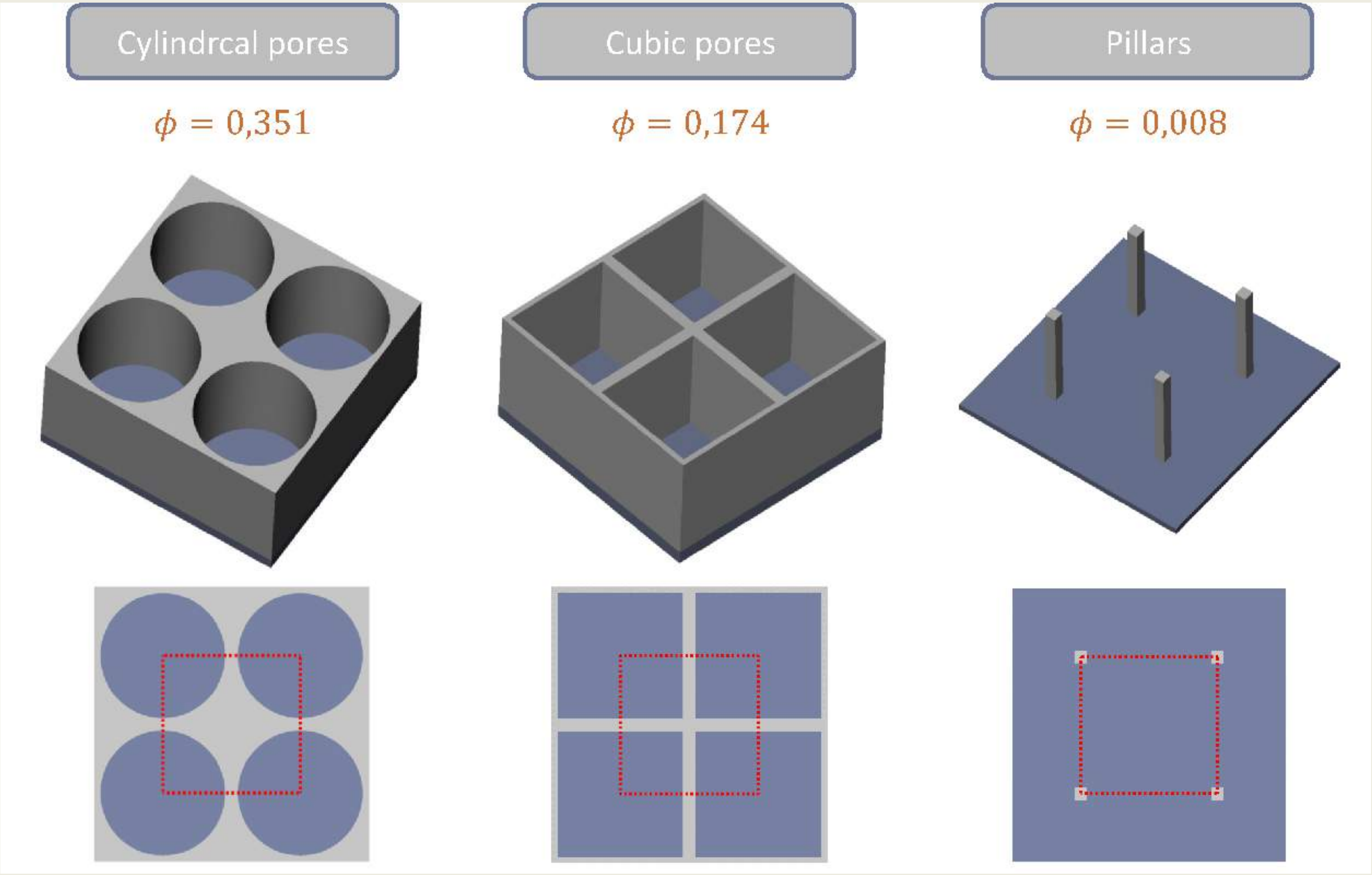
Unraveling the Salvinia Paradox: Design Principles for Submerged Superhydrophobicity

M. Amabili, A. Giacomello, S. Meloni, and C. M. Casciola*



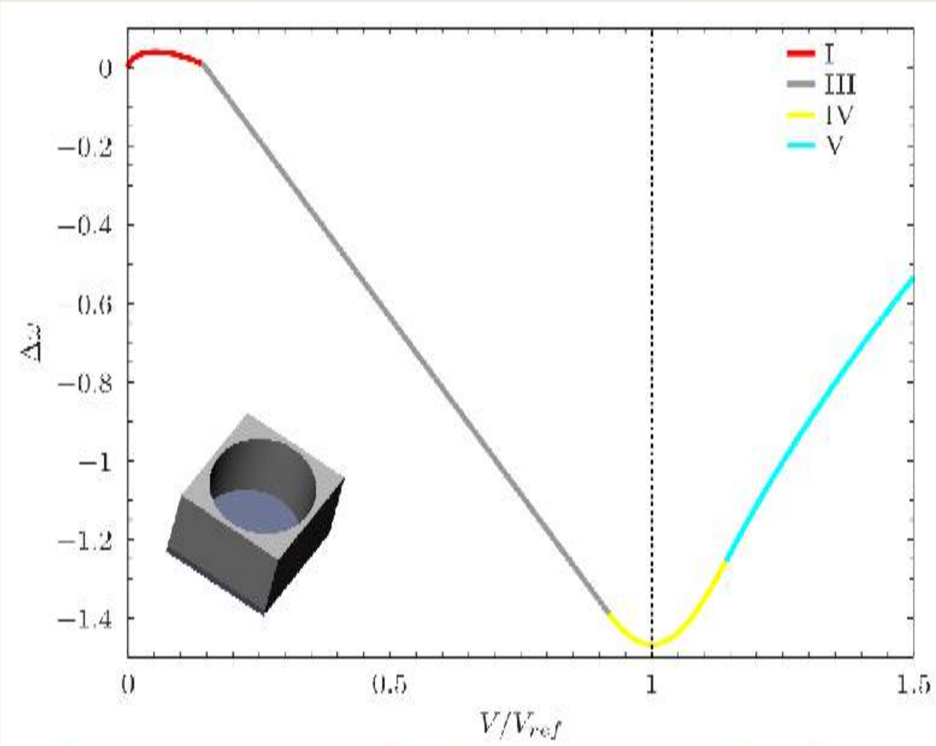
Design principles for self-recovery superhydrophobic surfaces

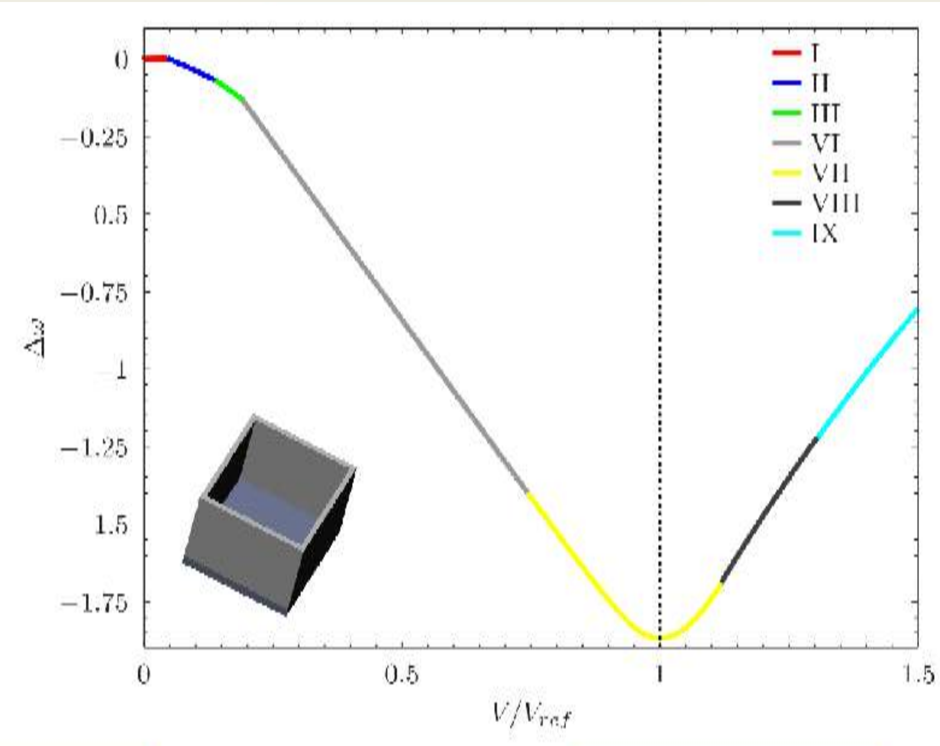
- **Self-recovery**
- **Minimal solid fraction**



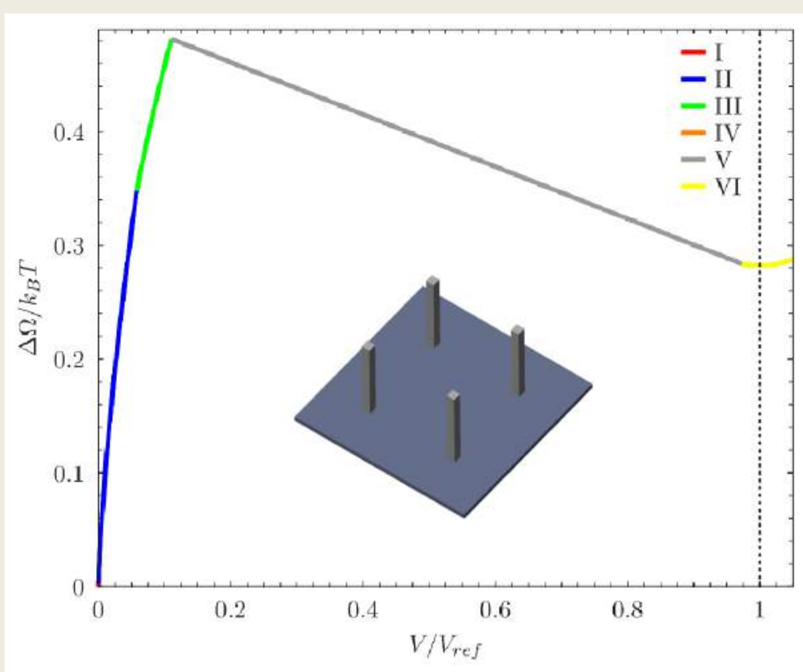
Design principles of self-recovery surfaces for drag reduction

self-recovery

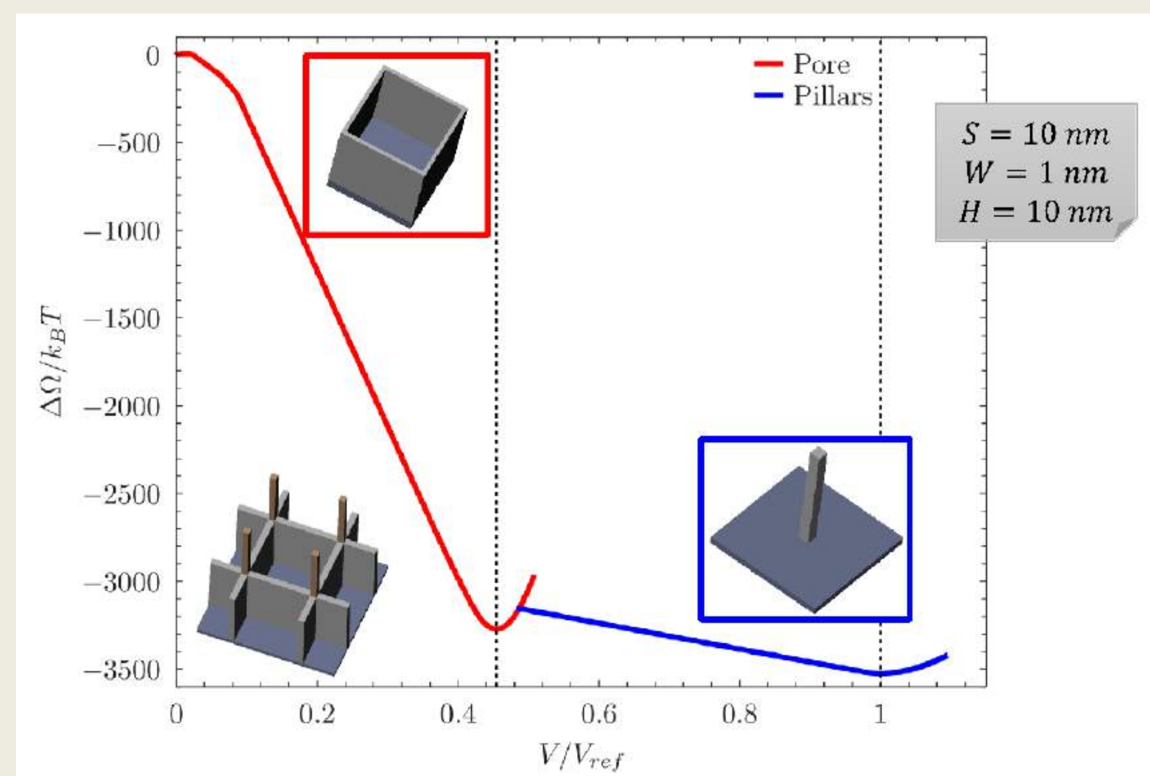




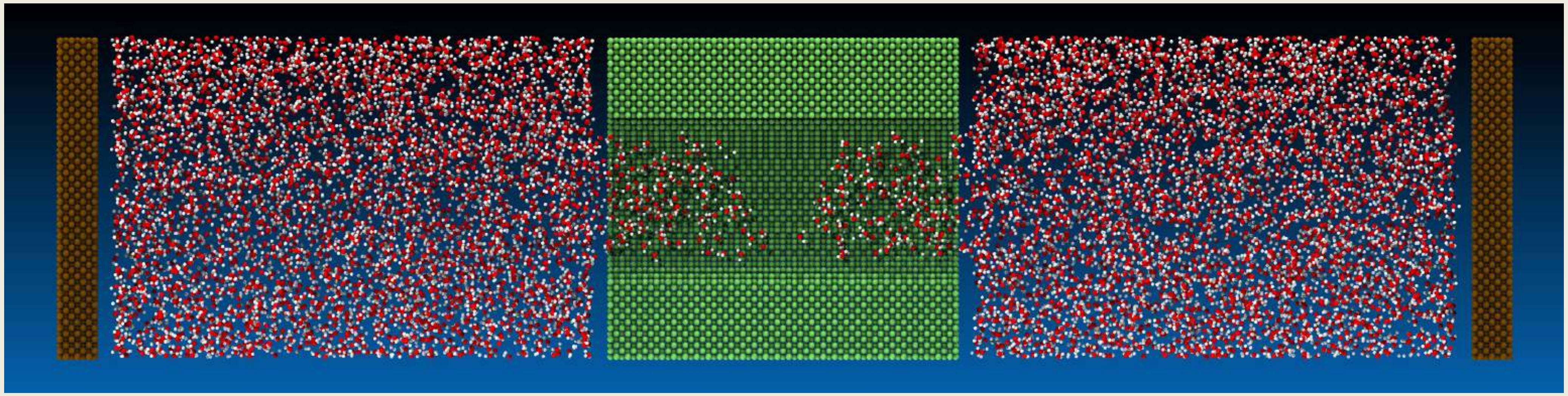
Drag reduction

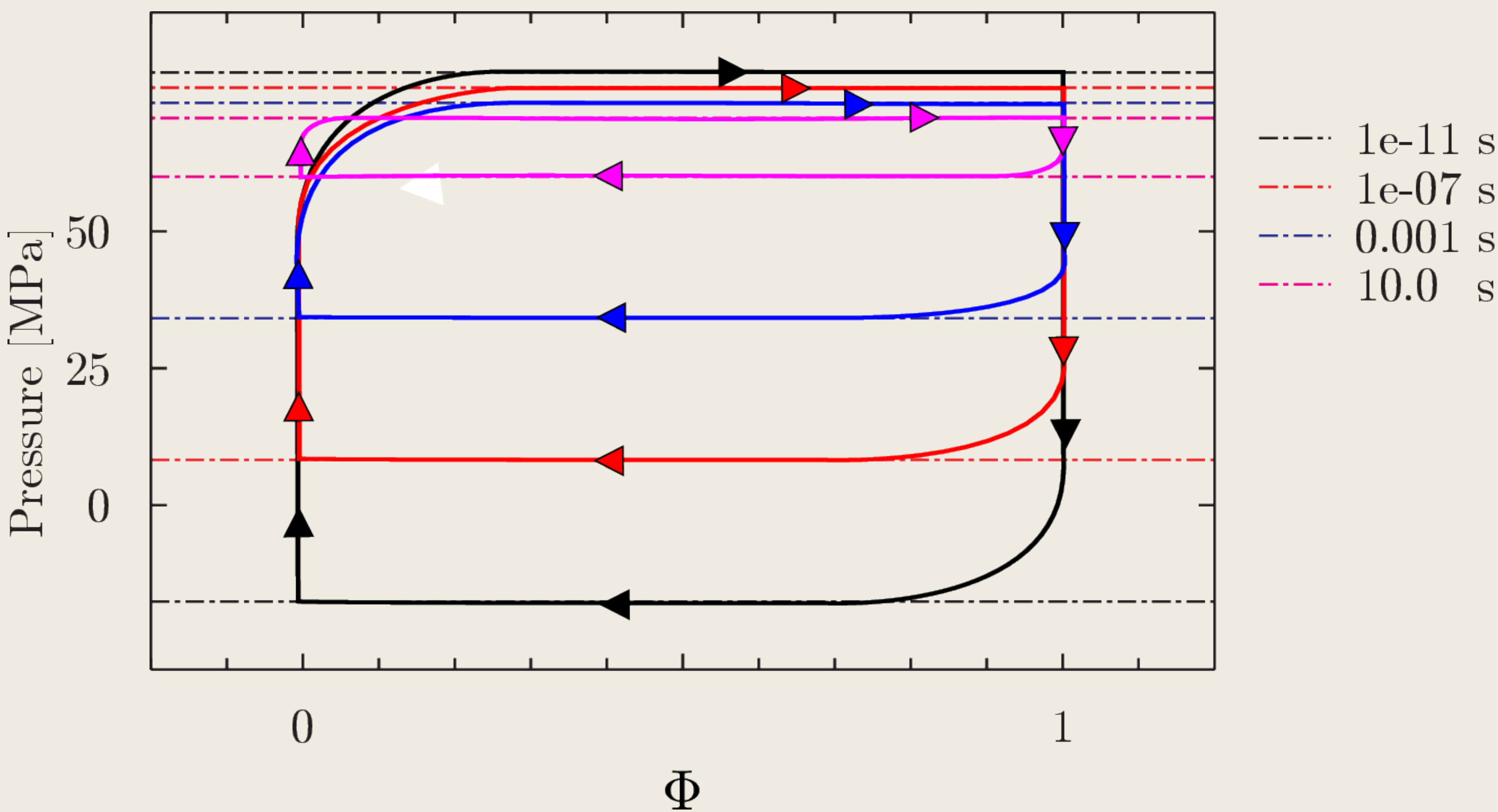


Combined

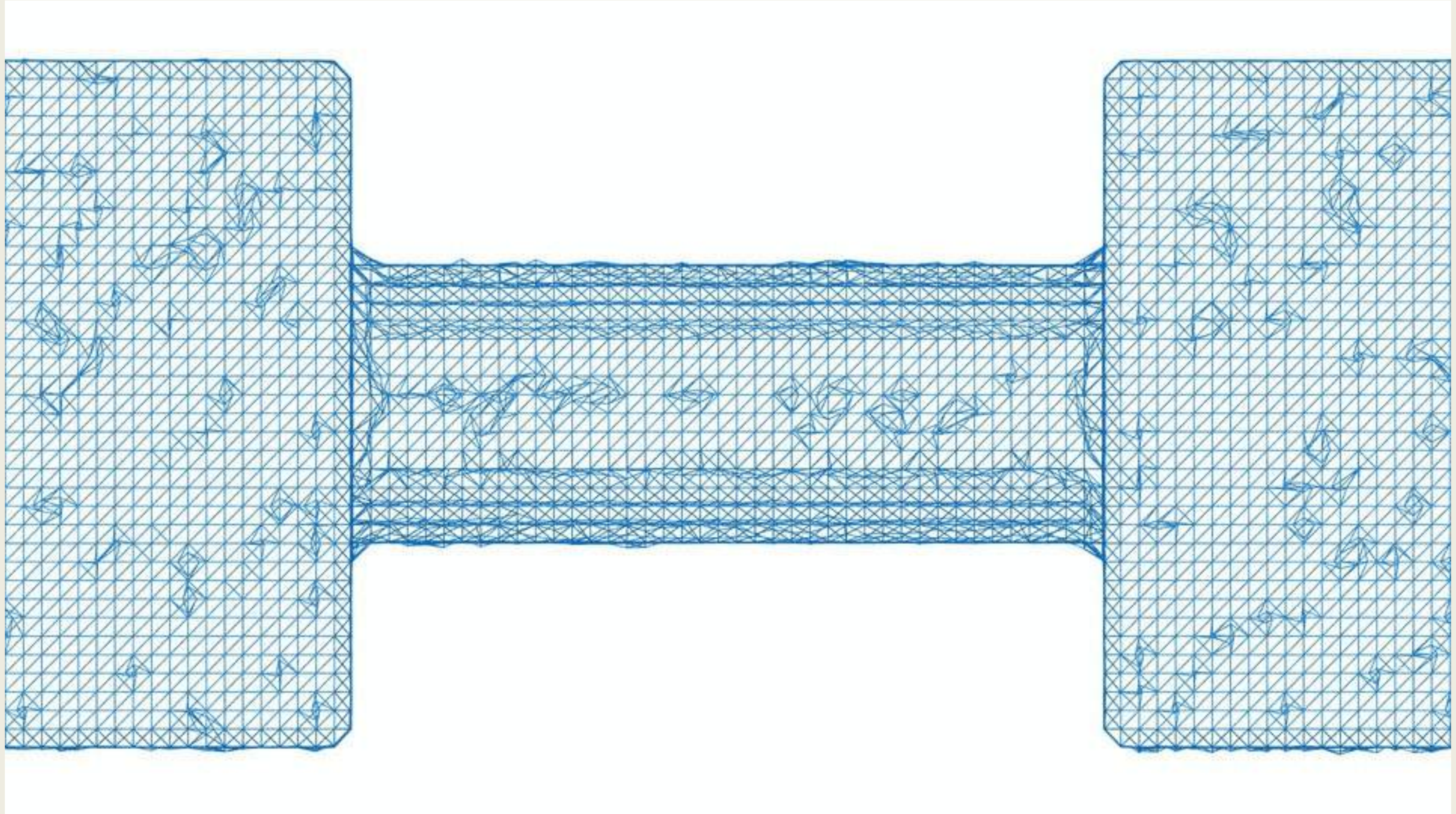


Cavitation in nanoporous materials





Rare event MD: cavitation in a nanopore



Physics of nanoconfined water (D=2 nm):

- cavitation at P=20 MPa
- intrusion at P=80 MPa
- hysteresis in intrusion/extrusion cycles

Applications of hydrophobic nanopores + water:

- energy storage: surface energy
- dampers: dissipation in intrusion/extrusion cycles

Cavitation at the Mesoscale & Multiphase Flow Physics

Diffuse interface model for liquid-vapor phase transitions

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0$$

$$\frac{\partial \rho \mathbf{u}}{\partial t} + \nabla \cdot (\rho \mathbf{u} \otimes \mathbf{u}) = \nabla \cdot \boldsymbol{T}$$

$$\frac{\partial \hat{e}}{\partial t} + \nabla \cdot (\mathbf{u}\hat{e}) = \nabla \cdot (\boldsymbol{T} \cdot \mathbf{u}) - \nabla \cdot \mathbf{q}_e$$

Francesco Magaletti (DIMA)
Mirko Gallo (DIMA)
Luca Marino (DIMA)

The free-energy functional $F = \int_{\mathcal{D}} \hat{f}\, dV = \int_{\mathcal{D}} \left(\hat{f}_0(\rho, \theta) + \frac{\lambda}{2} |\nabla \rho|^2 \right) dV$

leads to the constitutive equations:

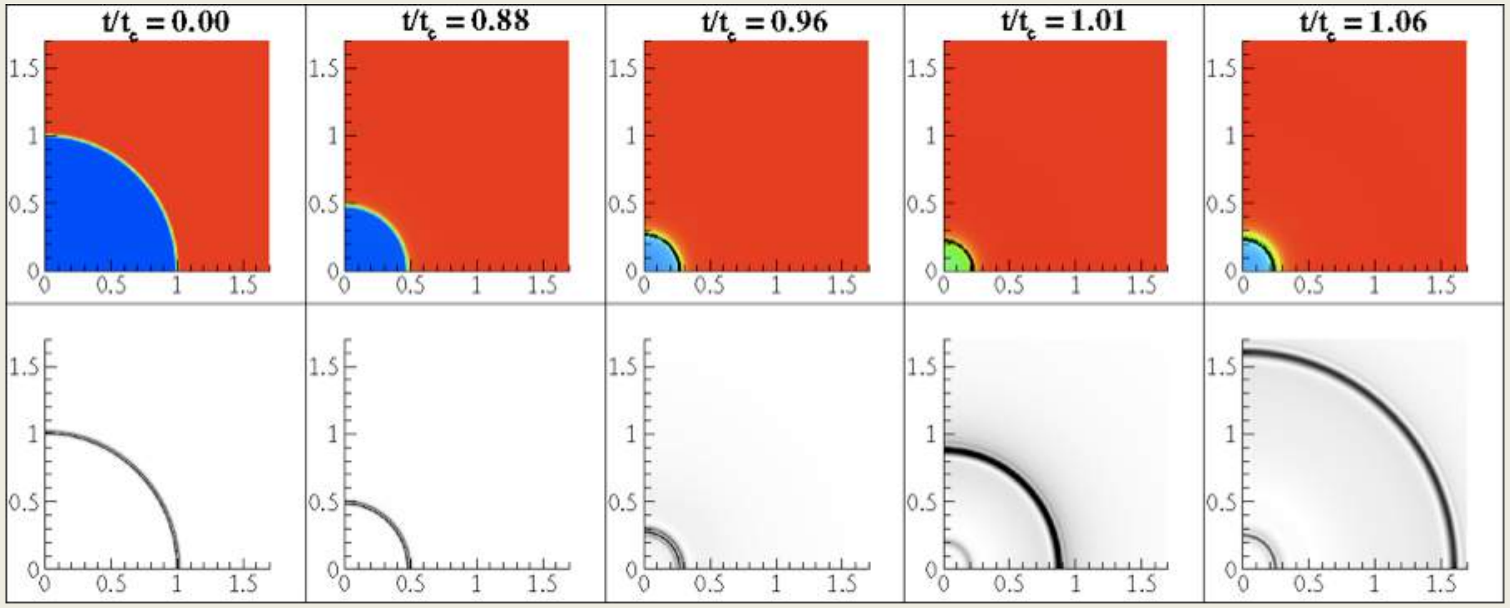
phase transitions

surface tension

$$\boldsymbol{T} = \mu \left(\nabla \mathbf{u} + \nabla \mathbf{u}^T \right) + \eta \nabla \cdot \mathbf{u} \boldsymbol{I} + \\ - \lambda \nabla \rho \otimes \nabla \rho - \left[p_0 + \frac{1}{2} \left(-\lambda + \rho \frac{\partial \lambda}{\partial \rho} \right) |\nabla \rho|^2 - \rho \nabla \cdot (\lambda \nabla \rho) \right] \boldsymbol{I}$$

$$\mathbf{q}_e = -k \nabla \theta + \lambda \rho \nabla \rho \nabla \cdot \mathbf{u}$$

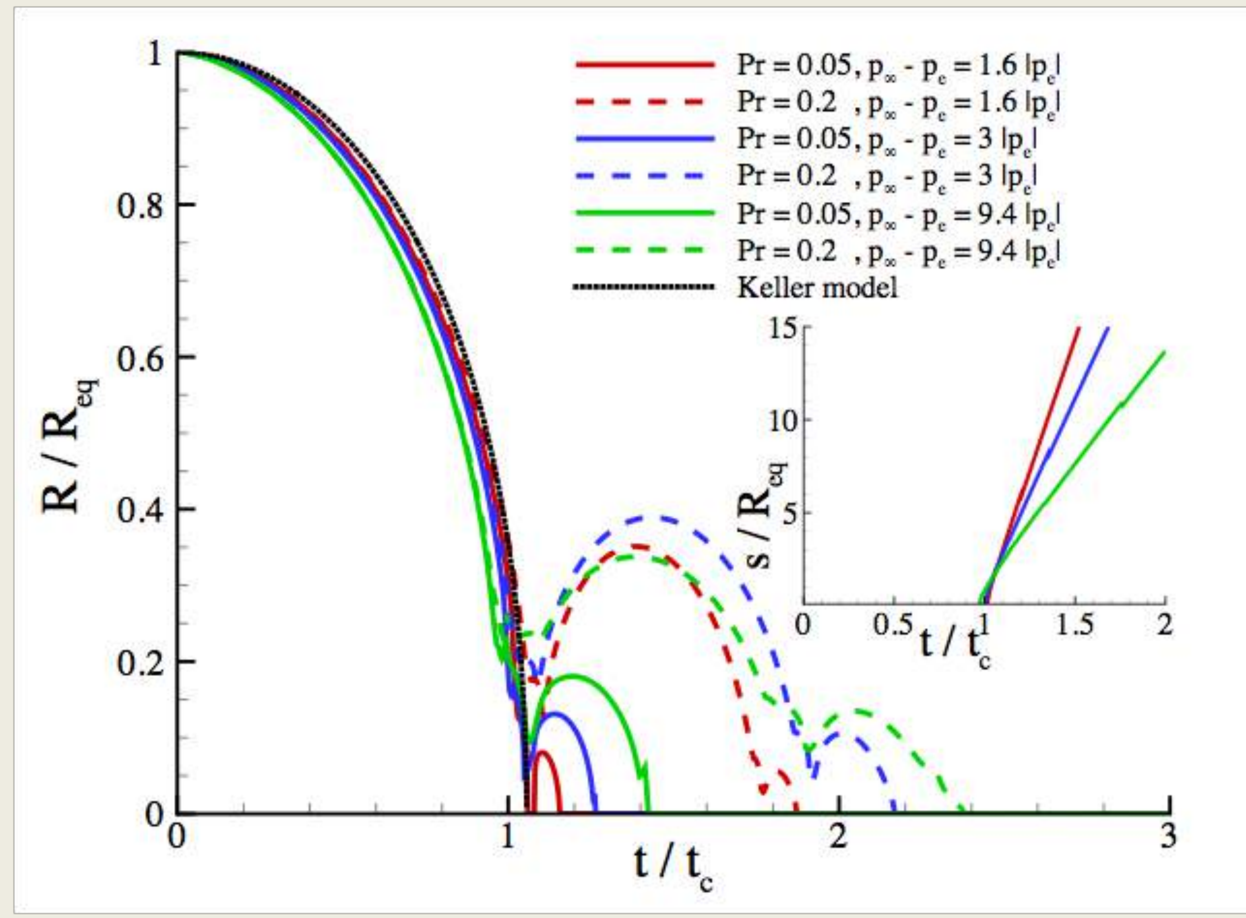
Collapse dynamics in free space



Density field (top)
Pressure gradient (bottom)

(pressure gradient visualizes bubble interface and radiated shock)

- Strong overpressure prevents complete condensation (rebounds)
- A shock wave is emitted at rebound
- Strong thermal effects (sub-micron bubbles)
- Successive rebounds emit weaker and waker shocks



PRL **114,** 064501 (2015) PHYSICAL REVIEW LETTERS week ending 13 FEBRUARY 2015

Shock Wave Formation in the Collapse of a Vapor Nanobubble

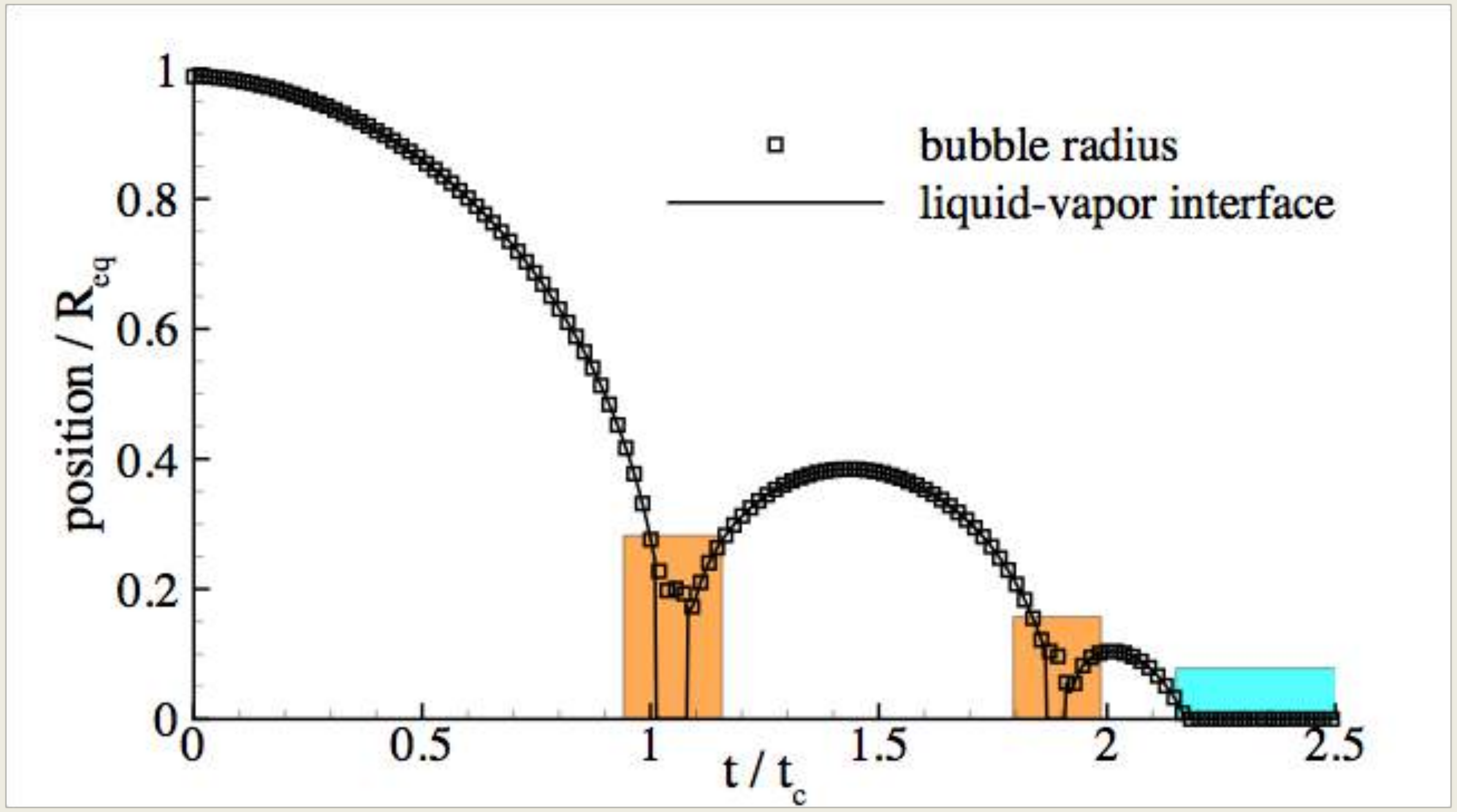
F. Magaletti, L. Marino, and C. M. Casciola*

A cartoon of collapse dynamics

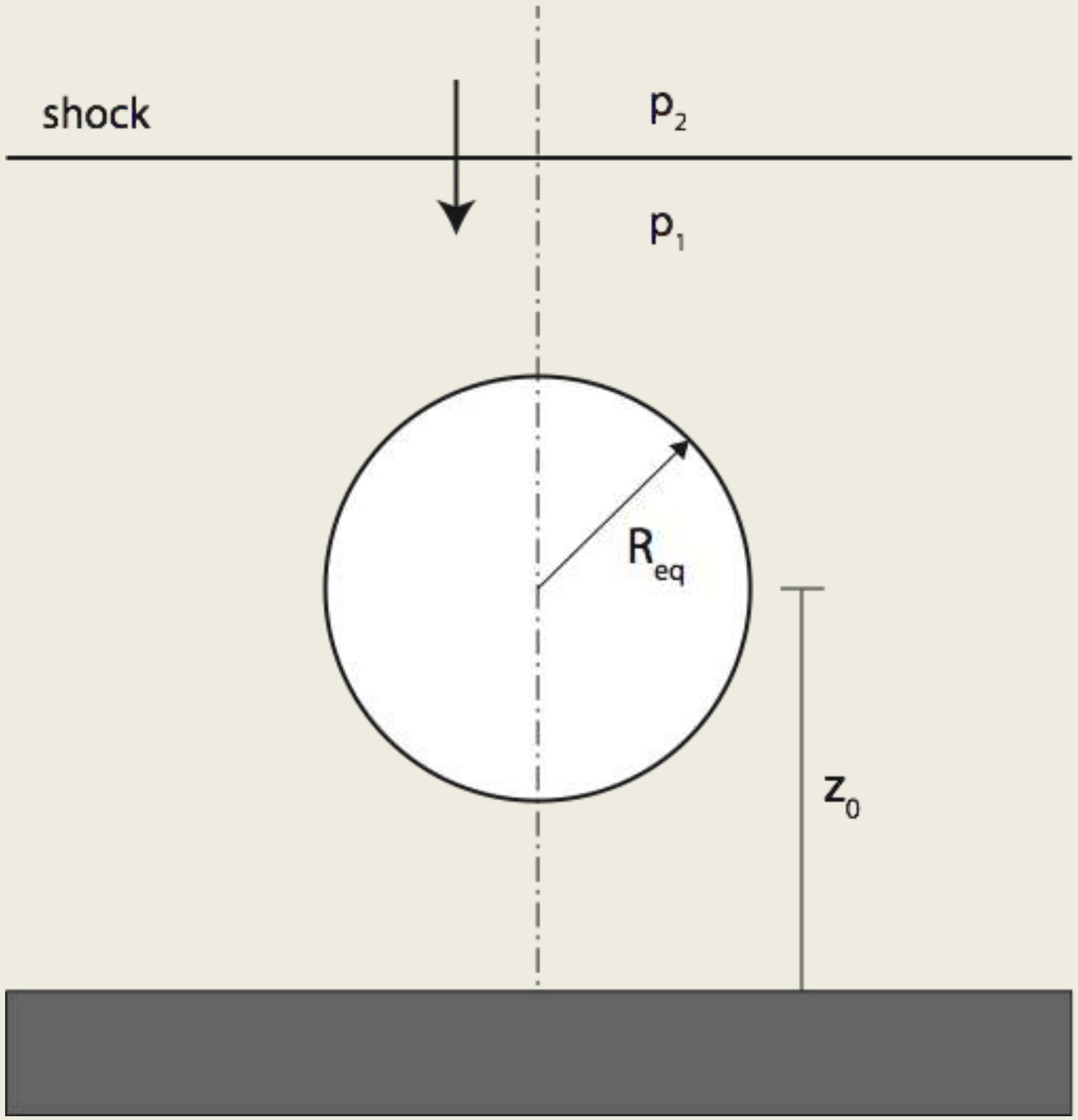
Color legend

- Liquid phase
- Supercritical phase
- Vapour phase

- supercritical fluid (incondensable —> rebound)
- For insufficient compression vapour fully condensates



Bubble Collapse Near a Wall



- Vapor bubble with in equilibrium with liquid (radius R_{eq}, center at z_0
- Impinging shockwave intensity $I = (p_2 - p_1)/p_1$
- Simulations for different z_0 and I

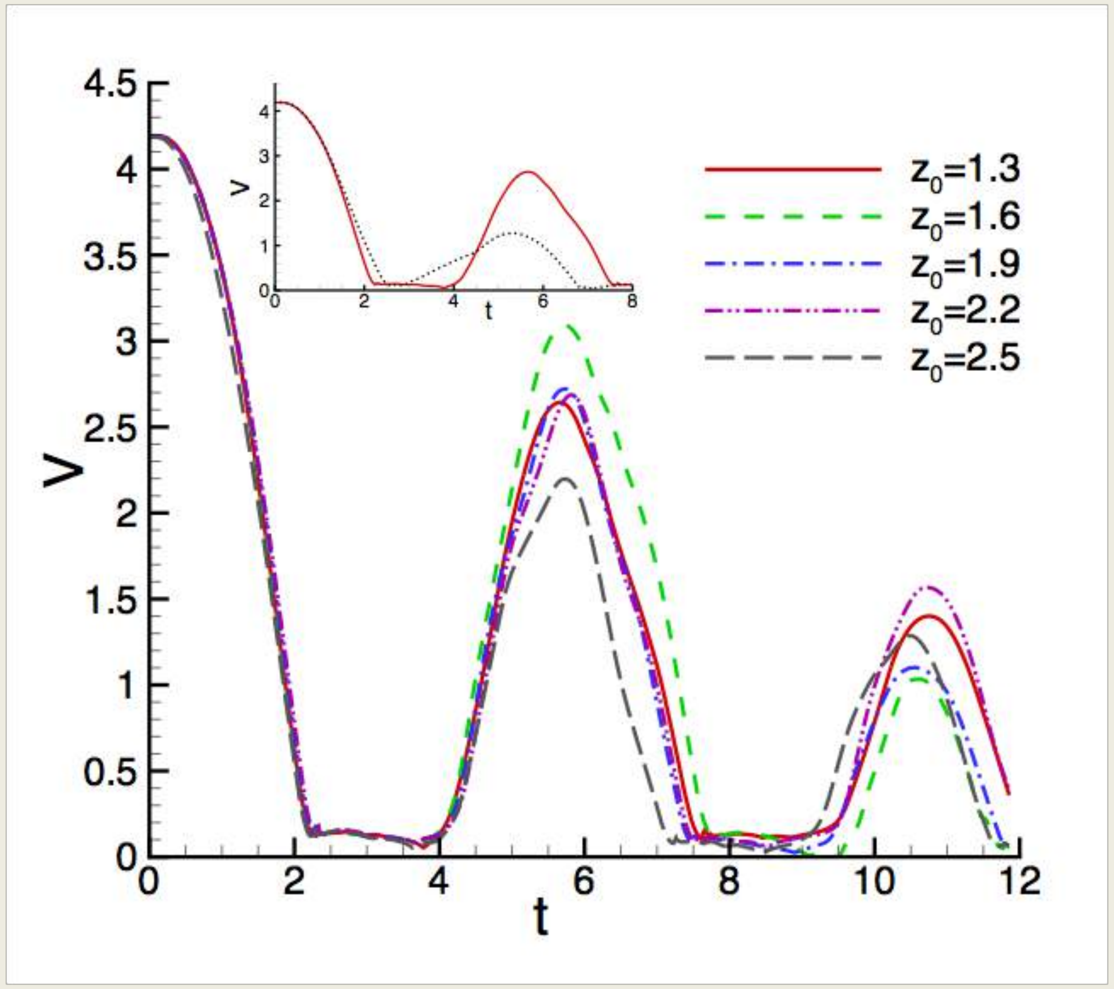
PERGAMON

International Journal of Multiphase Flow

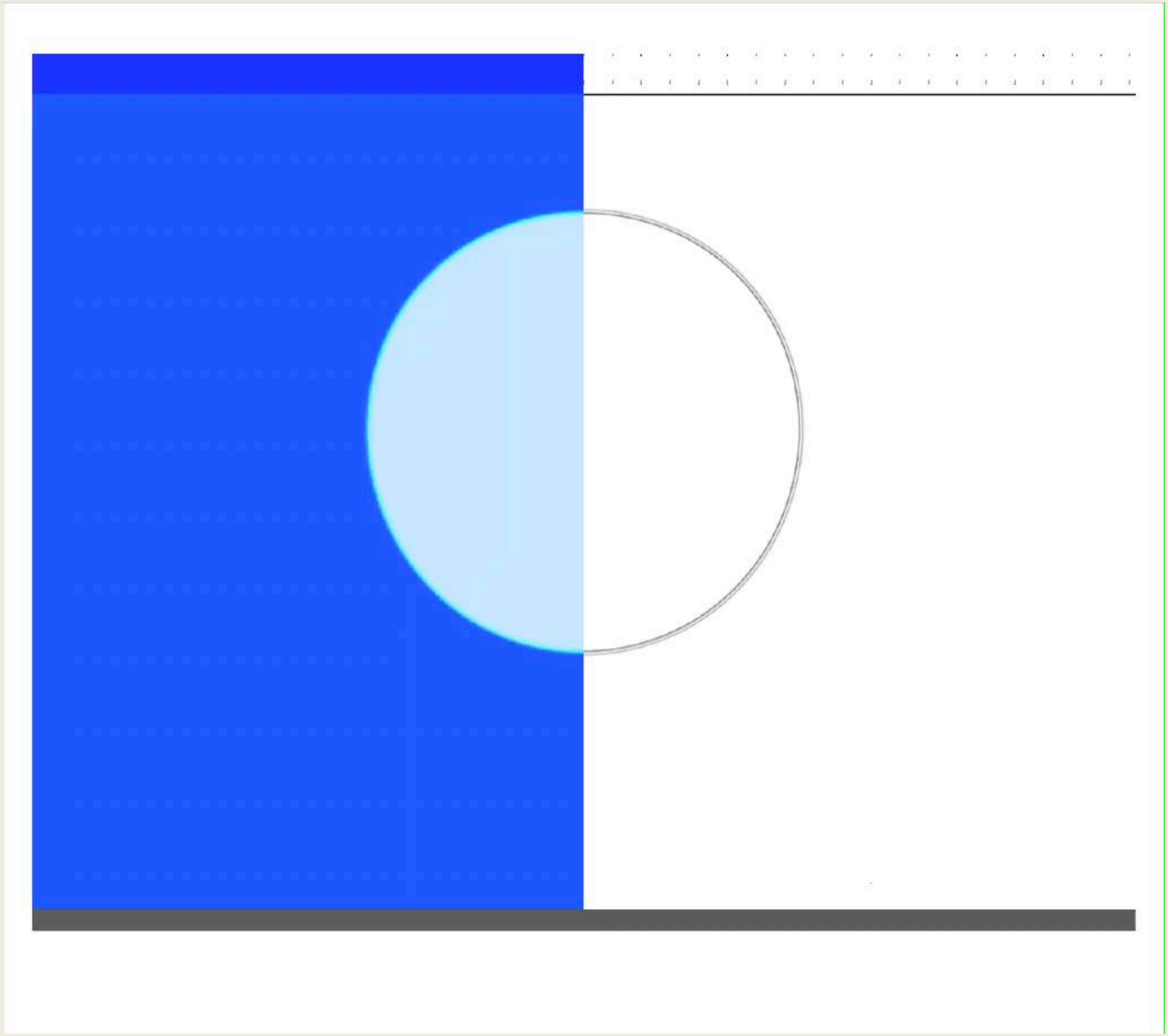
International Journal of Multiphase Flow

Shock-induced collapse of a vapor nanobubble near solid boundaries

Francesco Magaletti[a], Mirko Gallo[a], Luca Marino[a], Carlo Massimo Casciola[a,*]

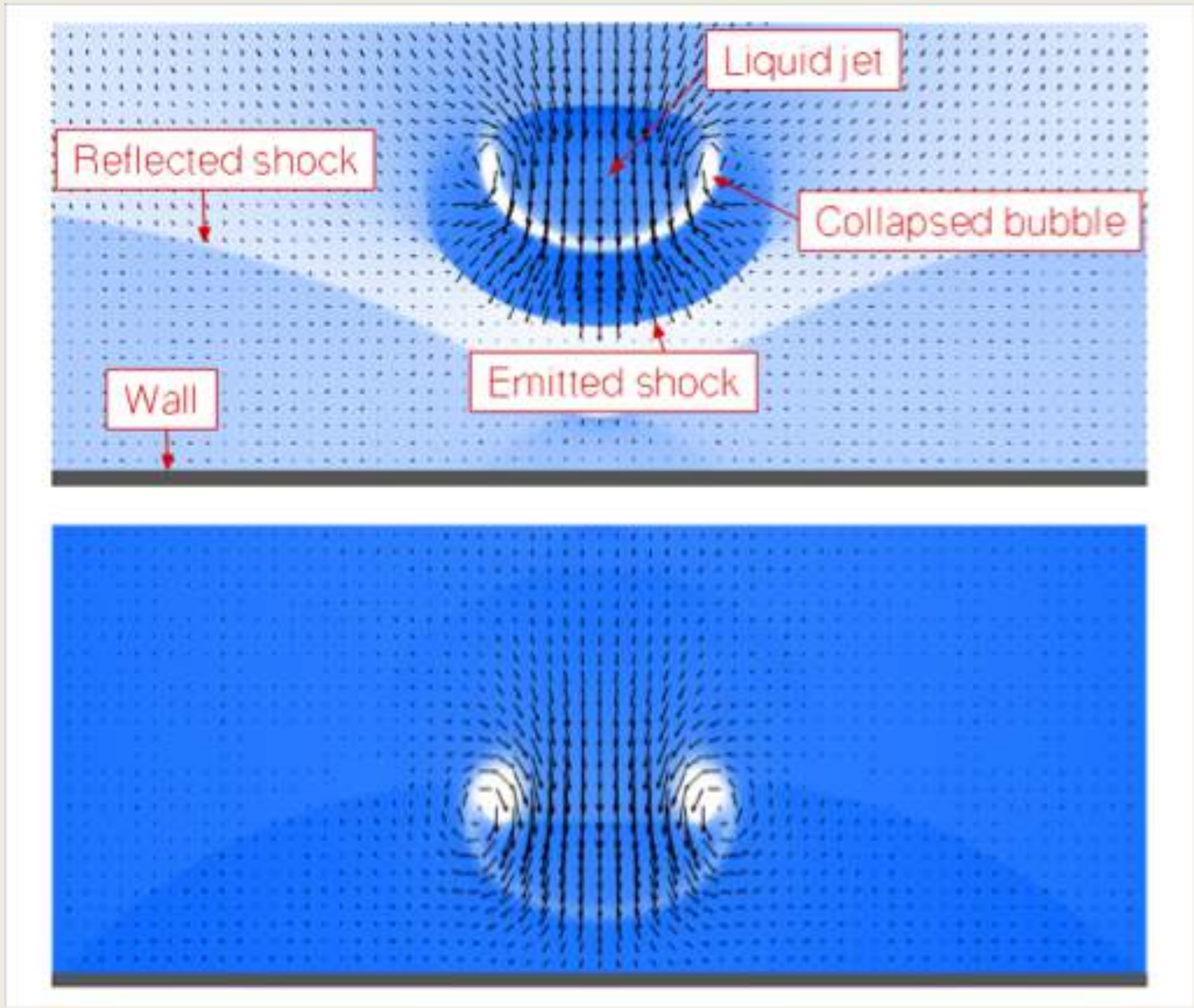


Bubble Collapse Near a Wall

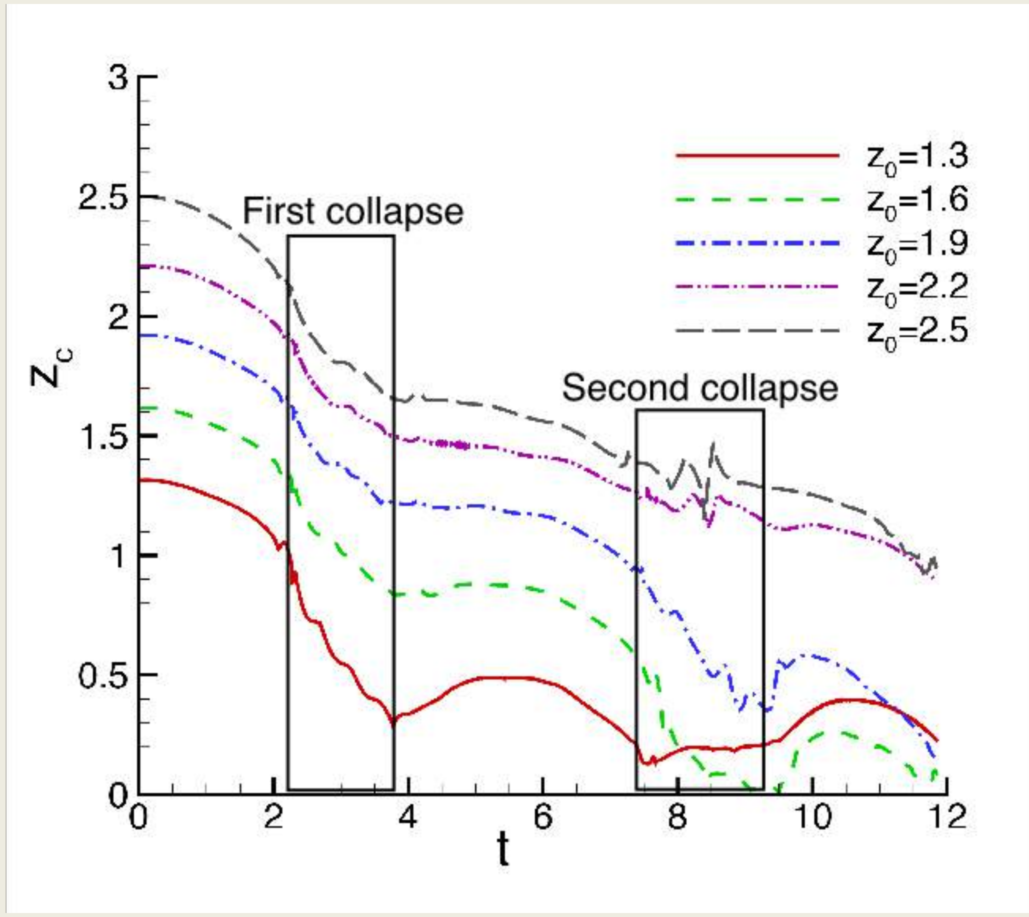


Bubble Collapse Near a Wall

$$I = 400,\ z_0/R_{eq} = 2.2$$



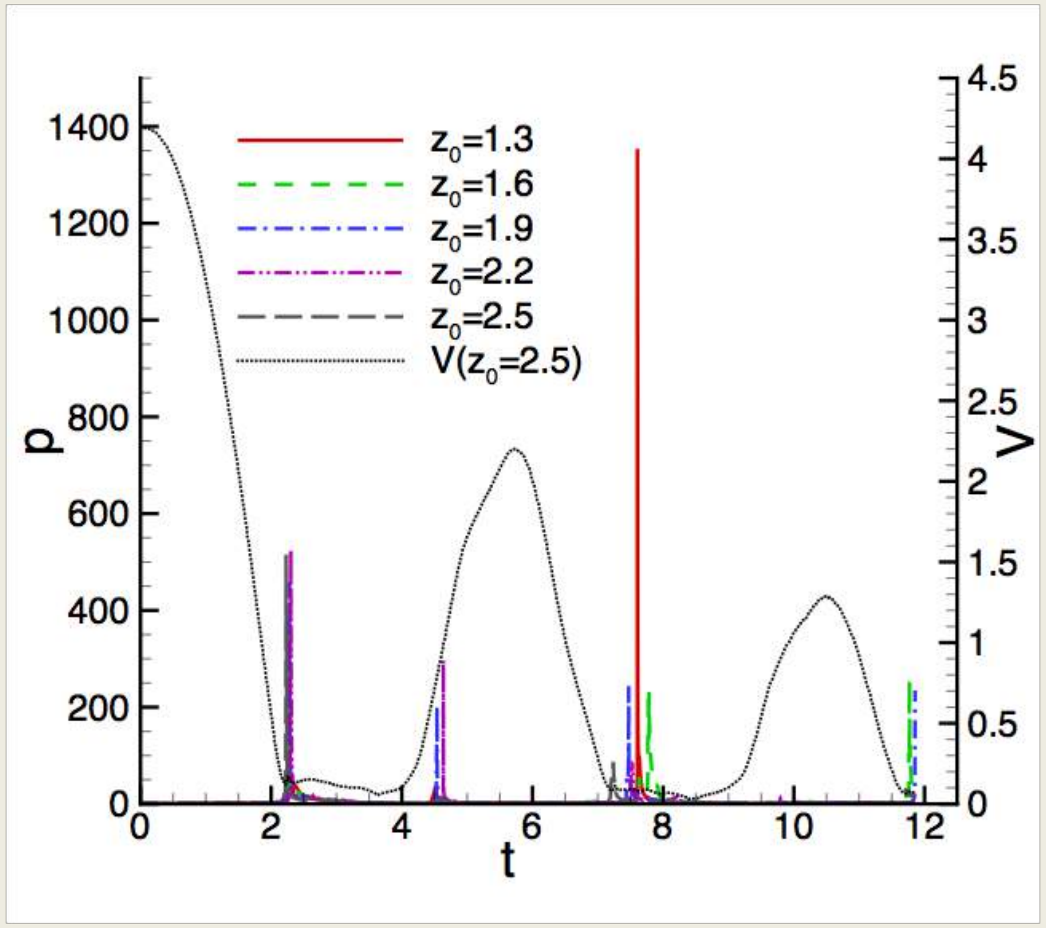
Bubble center of mass



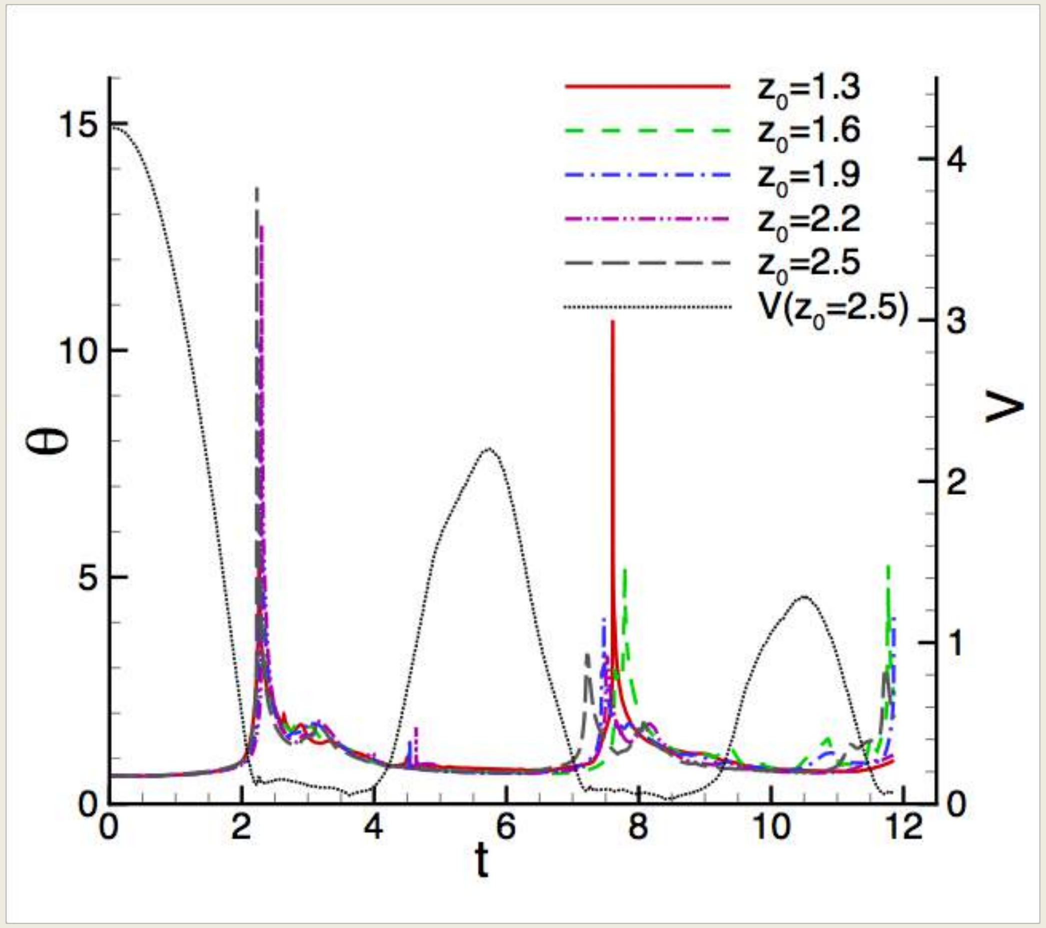
The axial flow after bubble collapse convects the re-expanding bu

Bubble Collapse Near a Wall

Pressure



Temperature



- Pressure and temperature peaks at minimum bubble volume
- Pressure peak at the wall

- Huge wall pressure peak when the bubble gets close to the wall (second collapse)

Fluctuating Hydrodynamics & Cavitation

Fluctuating Hydrodynamics
(Lifshitz, Landau, Uhlembeck, Onsager)

- Entropy Functional and Fluctuations

$$\Delta S = S - S_0 = \Delta S\left[\delta\rho, \delta\mathbf{v}, \delta\theta\right] = \int_V s\left(\mathbf{x}, t\right) - s_0\, dV$$

$$P_{eq}\left[\Delta\right] = \frac{1}{Z} e^{\frac{\Delta S}{k_B}} \simeq \frac{1}{Z_0} e^{-\frac{1}{2k_B}\int_V \Delta^T \mathbf{H}\, \Delta\, dV} \qquad \boldsymbol{\Delta} = \left(\delta\rho, \delta\mathbf{v}, \delta\theta\right)$$

- Functional Langevin Equation

$$\partial_t \Delta = \mathbf{M} \cdot \frac{\delta \Delta S_0}{\delta \Delta} + \mathbf{f} \qquad \mathbf{f} = \mathbf{K} W$$

$$\frac{\delta \Delta S_0}{\delta \Delta} = -\mathbf{H} \cdot \boldsymbol{\Delta} \qquad \mathbf{M} = \mathbf{L}\mathbf{H}^{-1}$$

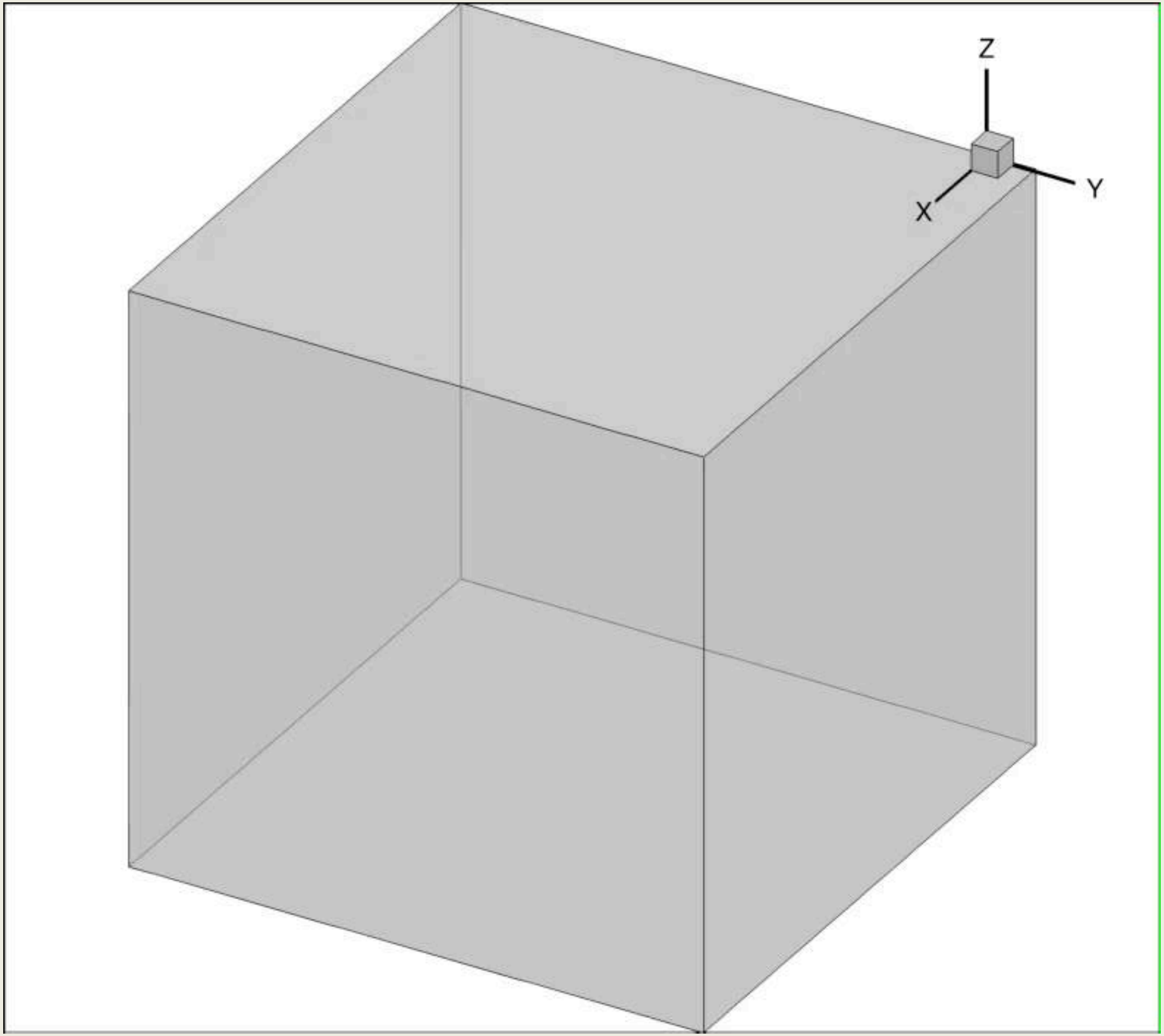
$$\mathbf{L} = \begin{pmatrix} 0 & -\rho\partial_x & 0 \\ -\frac{c_T^2}{\rho_0}\partial_x & \frac{\mu}{\rho_0}\partial_{xx} & -\frac{1}{\rho_0}\partial_\theta p \partial_x \\ 0 & -\frac{\theta_0}{\rho_0 c_v}\partial_\theta p \partial_x & \frac{k}{\rho_0 c_v}\partial_{xx} \end{pmatrix} \qquad \mathbf{K} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & \frac{\sigma_v}{\rho_0} & 0 \\ 0 & 0 & -\frac{\sigma_\theta}{\rho_0 c_v} \end{pmatrix}$$

- Fluctuation Dissipation

$$\sigma_v = \sqrt{2\mu\theta_0}\partial_x$$

$$\mathbf{Q} = k_B\left(\mathbf{M} + \mathbf{M}^\dagger\right)\delta\left(\hat{x} - \tilde{x}\right) \qquad \sigma_\theta = \sqrt{2k_0{\theta_0}^2}\partial_x$$

Vapour Nucleation & Fluctuating Hydrodynamics



Bubble Dynamics & Turbulent Transport

Micro-Macro-Micro

J. Fluid Mech. (2015), *vol.* 773, *pp.* 520–561. © Cambridge University Press 2015 520
doi:10.1017/jfm.2015.258

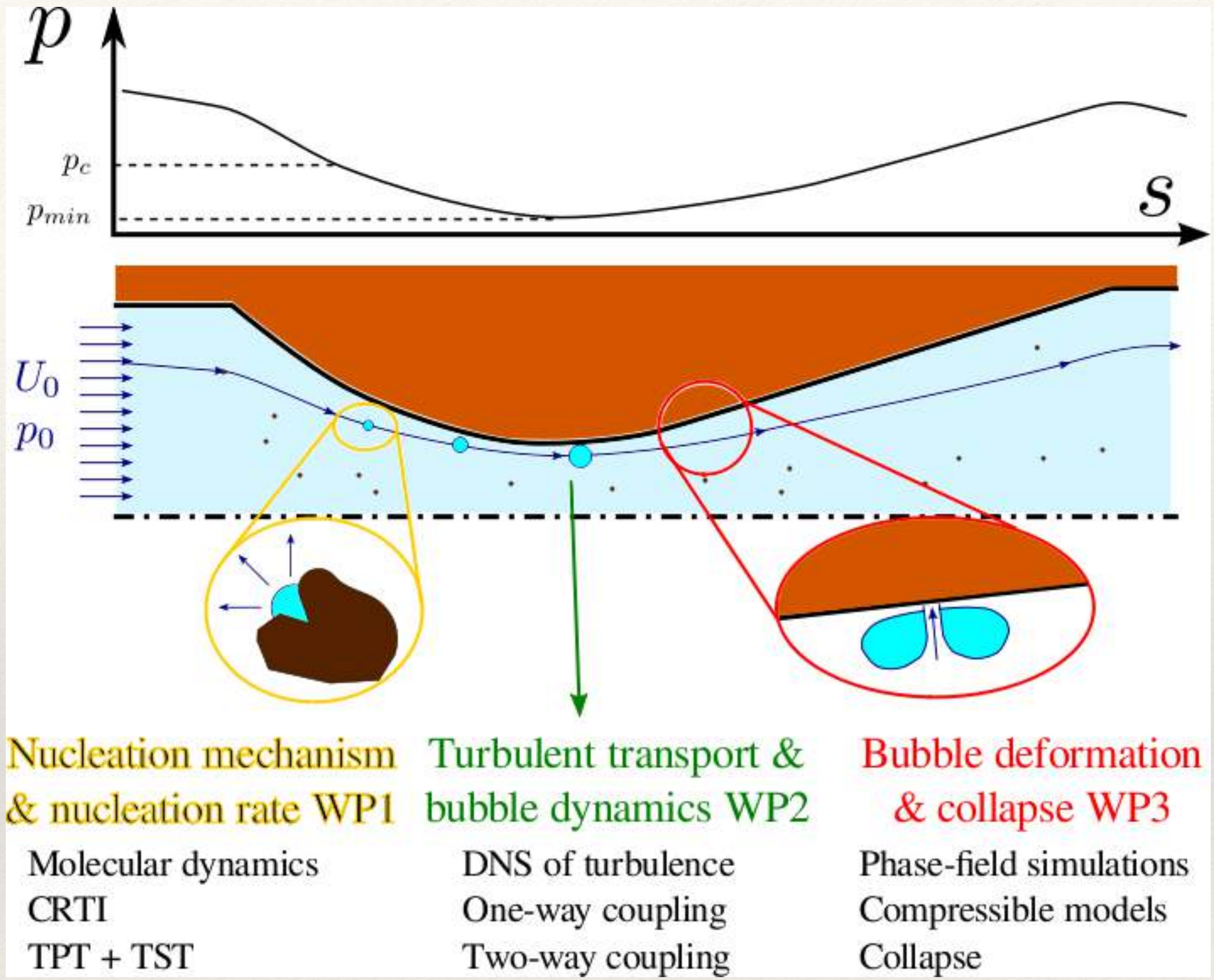
Exact regularized point particle method for multiphase flows in the two-way coupling regime

P. Gualtieri[1,†], F. Picano[2], G. Sardina[3] and C. M. Casciola[1]

PHYSICAL REVIEW FLUIDS (to appear)

Turbulence modulation by a suspended phase

Gualtieri P., Battista F., and Casciola C.M.



- Microscopic inception: MD
- Macroscopic transport: turbulence
  - micro-bubbles radius dynamics (Rayleigh-Plesset)
  - turbulence modulation (ERPP)
  - large bubbles (VoF)
- Microscopic collapse: PF

Micro-bubble dynamics

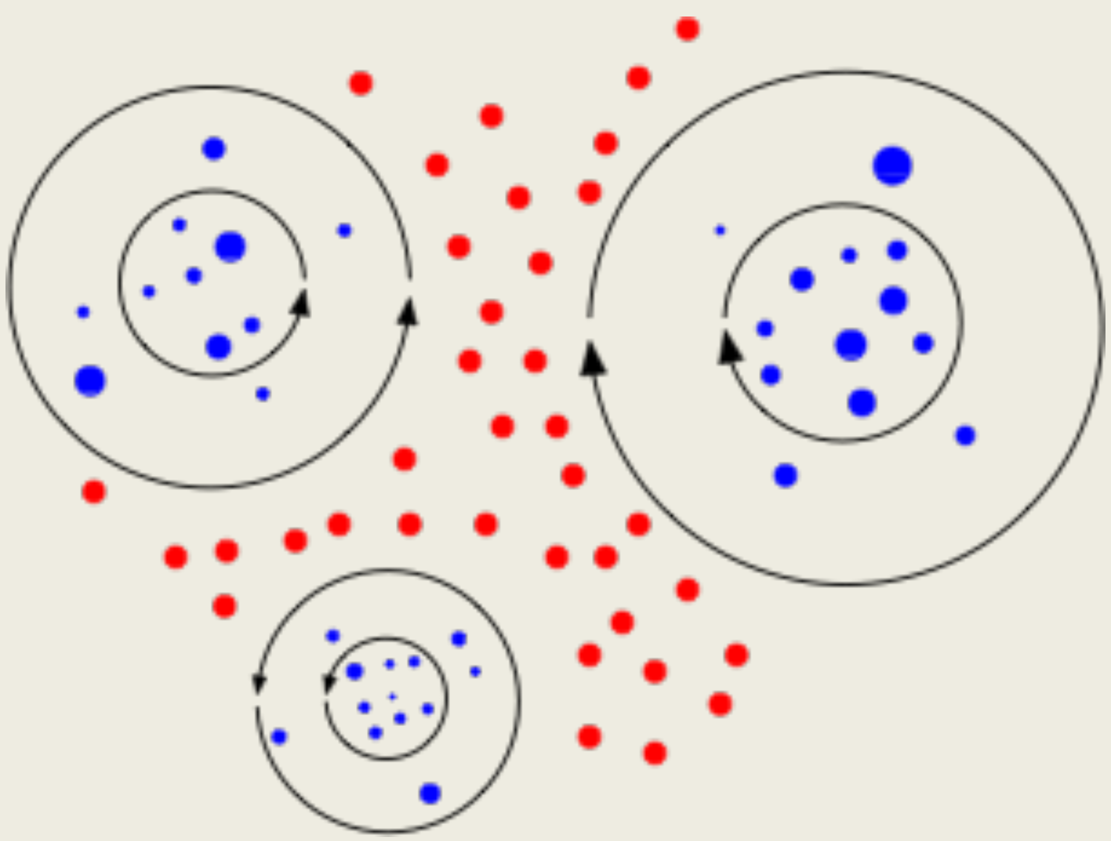
Newtons' law

$$\frac{d\mathbf{v}_p}{dt} = \underbrace{\frac{1}{\tau_p}\left(\mathbf{u}\big|_p + \frac{a_p^2}{6}\nabla^2\mathbf{u}\big|_p - \mathbf{v}_p\right)}_{\text{Stokes Drag}} + \underbrace{\beta\frac{D\mathbf{u}}{Dt}\Big|_p}_{\text{Added mass}} + \underbrace{\frac{\beta}{3}\left(\mathbf{u}\big|_p - \mathbf{v}_p\right)\times\boldsymbol{\zeta}\big|_p}_{\text{Lift}}$$

Stokes Number

$$\tau_p = \left(\frac{\rho_p}{\rho_f} + \frac{1}{2}\right)\frac{d_p^2}{18\nu} \Rightarrow St_\eta = \frac{\tau_p}{\tau_\eta}$$

$$\beta = \frac{3}{2\left(\frac{\rho_p}{\rho_f} + \frac{1}{2}\right)}$$



clustering

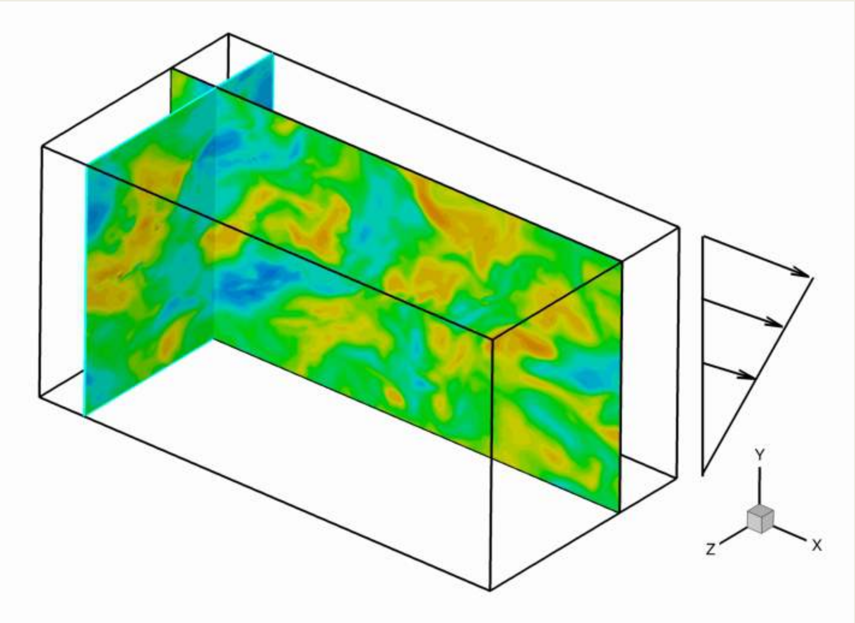
$$\nabla\cdot\mathbf{v} = \tau_p(\beta - 1)\left(S^2 - \Omega^2\right) < 0$$

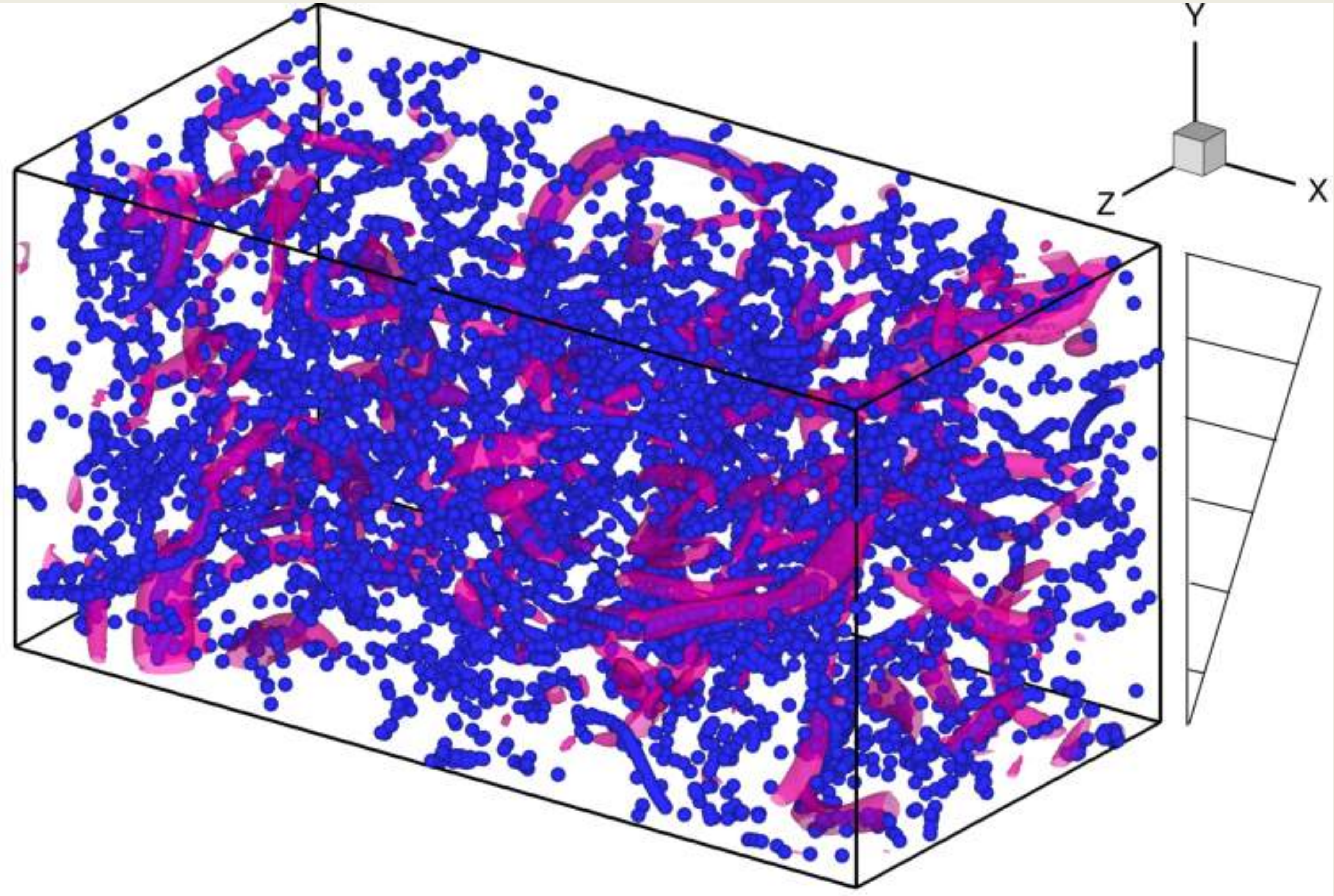
- bubbles $\beta = 3 \Rightarrow \Omega > S$
- particles $\beta = 0 \Rightarrow \Omega < S$

S =strain rate; Ω =rotation rate

Bubbles in the Box

DNS of Homogeneous shear turbulence





Clustering inside vortices

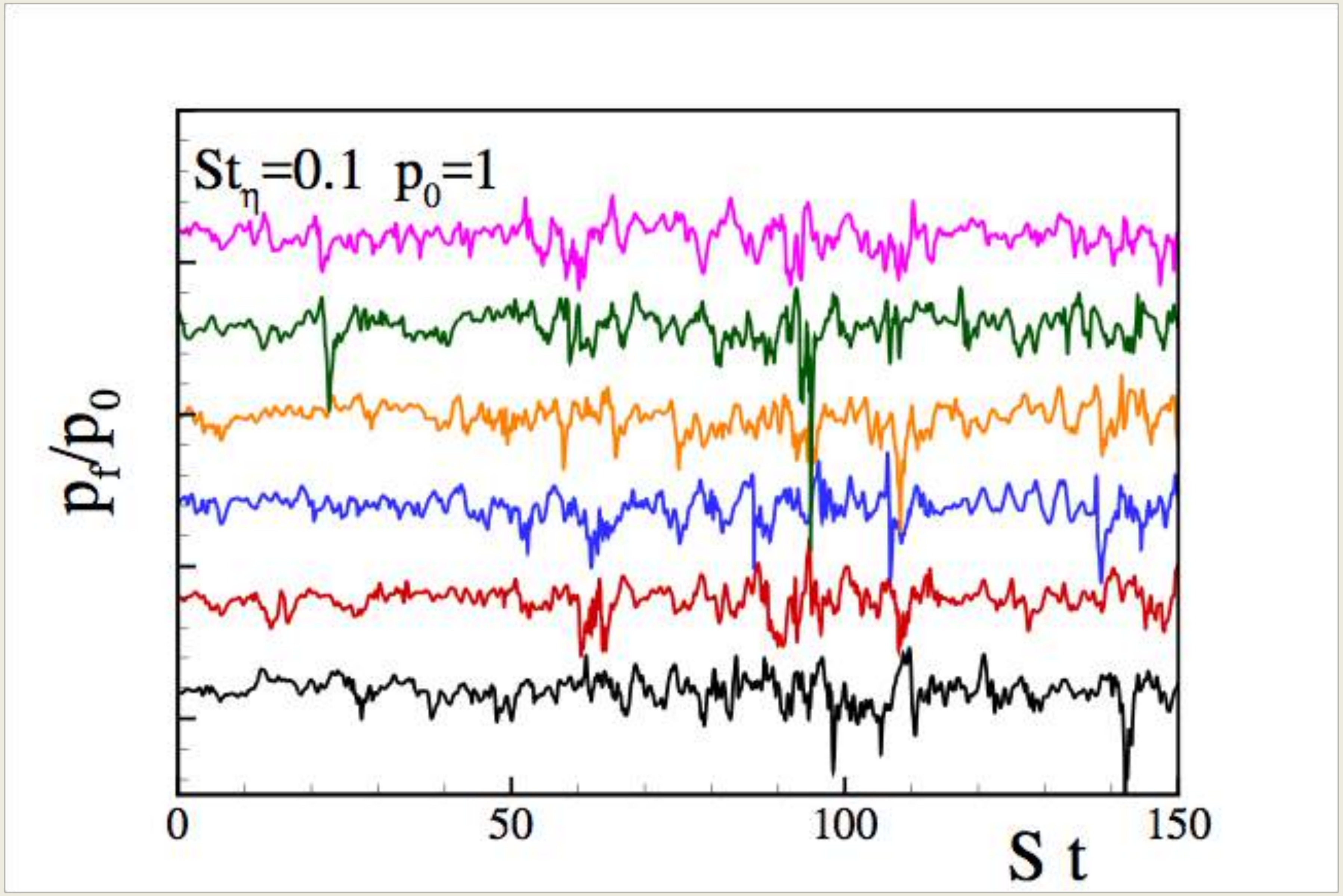
Iso-surfaces of the "D" invariant: coherent vortical structures & instantaneous bubble position

Bubble radius dynamics: Rayleigh-Plesset

$$R\frac{d^2R}{dt^2}+\frac{3}{2}\left(\frac{dR}{dt}\right)^2+\frac{4}{Re}\frac{1}{R}\frac{dR}{dt}+\frac{2}{We}\frac{1}{R}=p_b(t)-p_f[\mathbf{x}_b(t)]$$

Gas bubble: Isentropic $p_b(t)V_b^{\gamma}(t)=p_{b,0}V_{b,0}^{\gamma}$

Turbulent pressure signal $p_f[\mathbf{x}_b(t)]=p_0+p'[\mathbf{x}_b(t)]$ $We=\frac{\text{inertia}}{\text{surface tension}}$

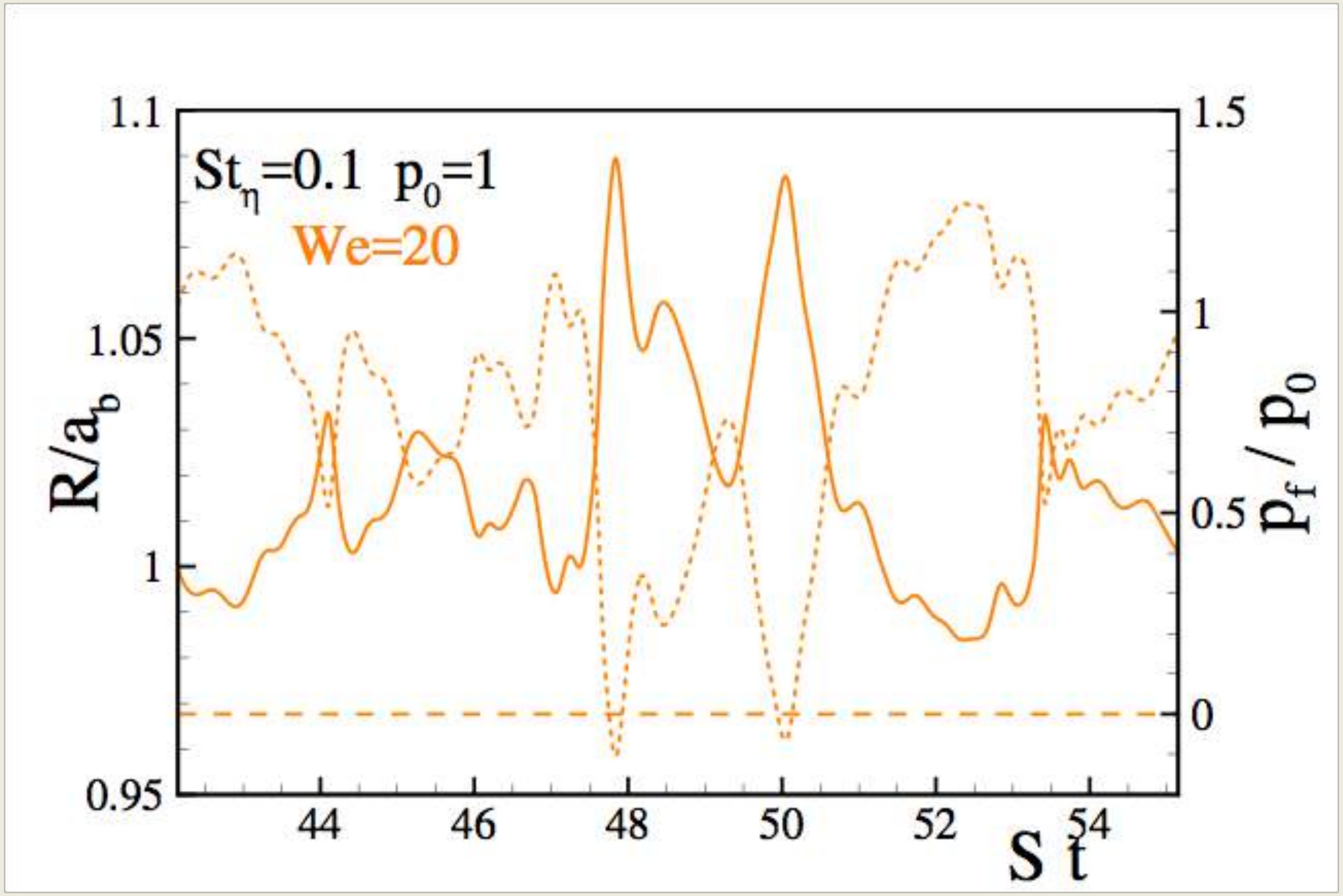


Bubble radius dynamics: Rayleigh-Plesset

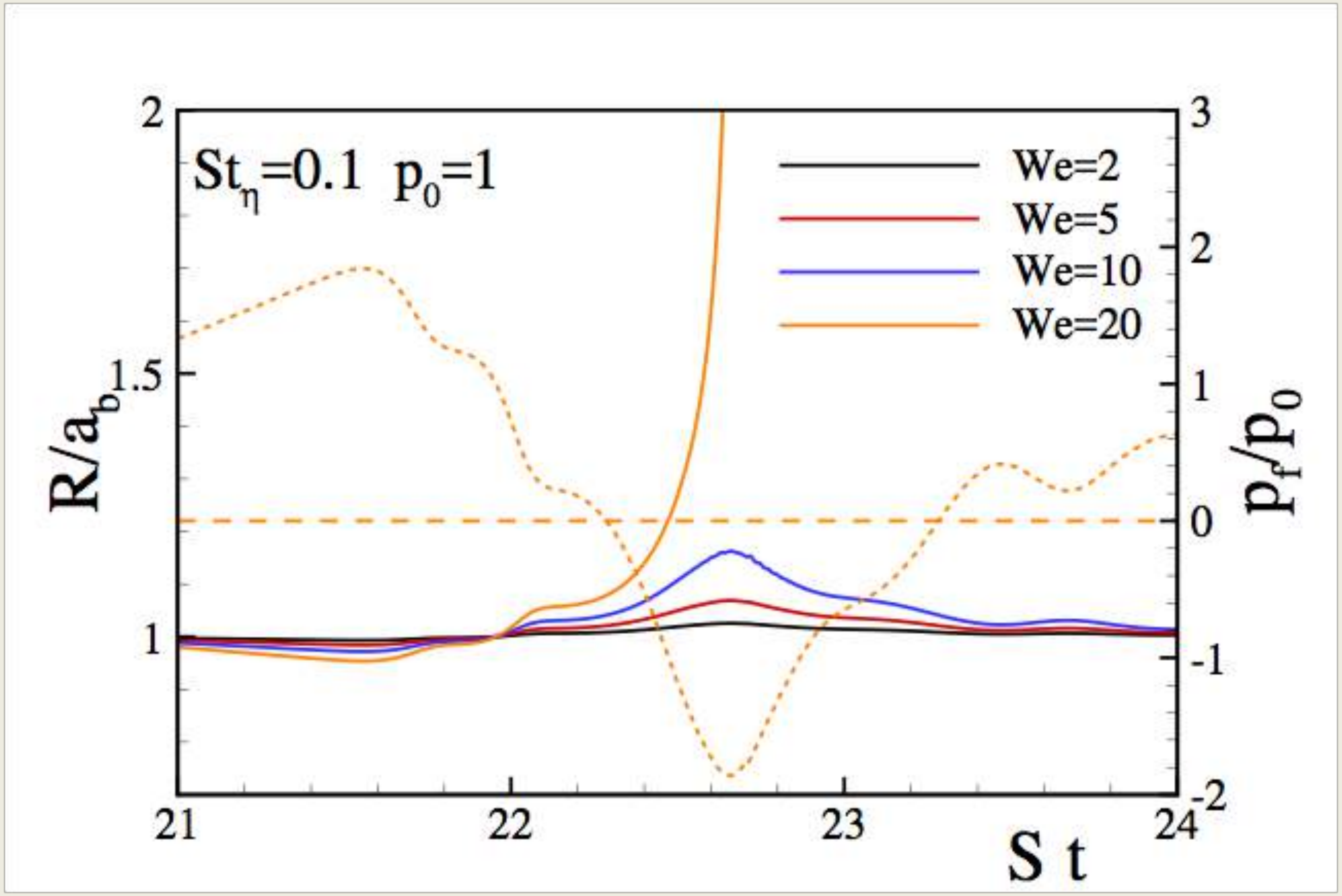
$$R\frac{d^2R}{dt^2} + \frac{3}{2}\left(\frac{dR}{dt}\right)^2 + \frac{4}{Re}\frac{1}{R}\frac{dR}{dt} + \frac{2}{We}\frac{1}{R} = p_b(t) - p_f[\mathbf{x}_b(t)]$$

Gas bubble: Isentropic $p_b(t)V_b^{\gamma}(t) = p_{b,0}V_{b,0}^{\gamma}$

Turbulent pressure signal $p_f[\mathbf{x}_b(t)] = p_0 + p'[\mathbf{x}_b(t)]$ $We = \dfrac{\text{inertia}}{\text{surface tension}}$

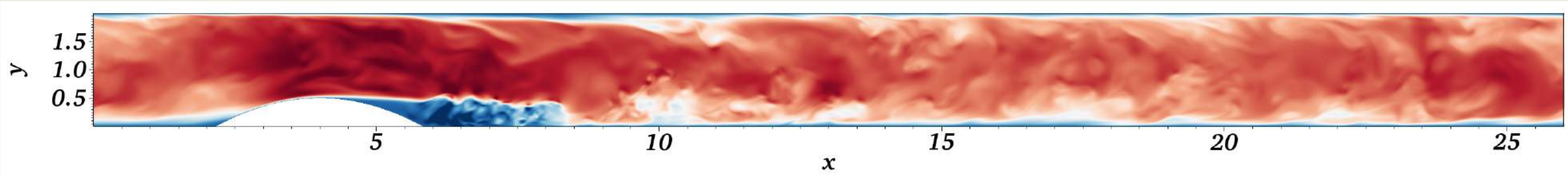


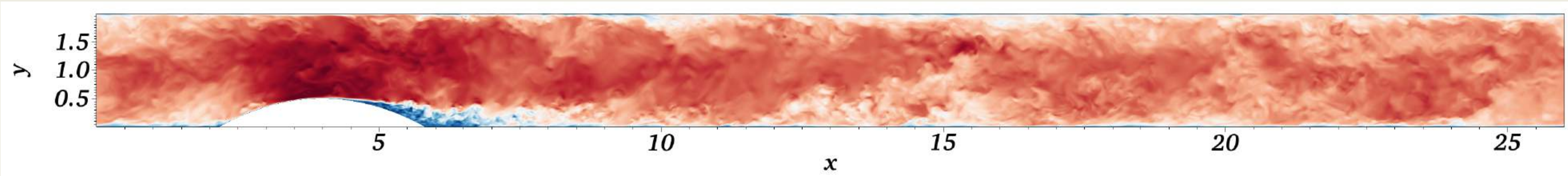
Can a bubble blow-up?

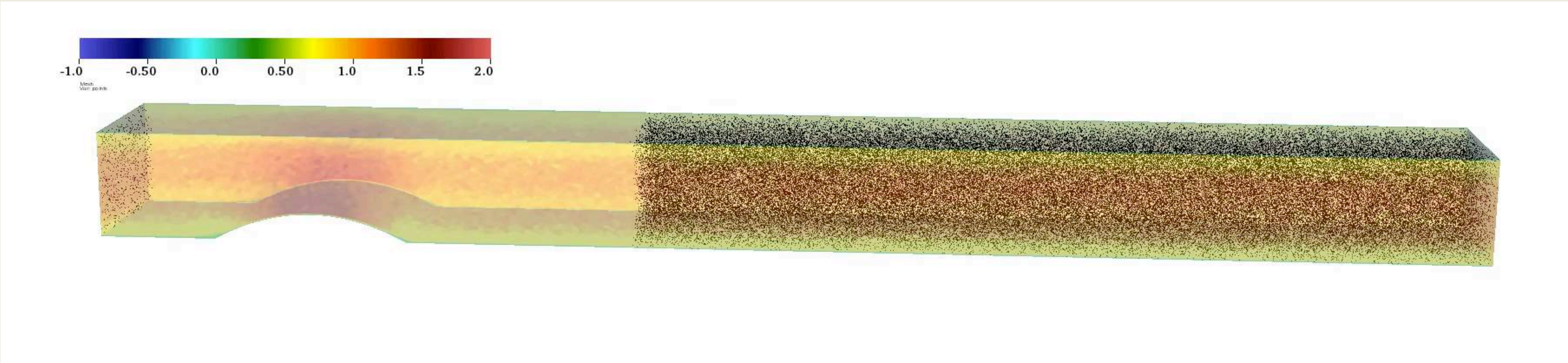


- Intermittent pressure bursts
- Intrinsic RP time-scale to be correlated with
  - pressure correlation time-scale
  - time spent in negative pressure regions

Micro-Bubble Transport in Turbulence



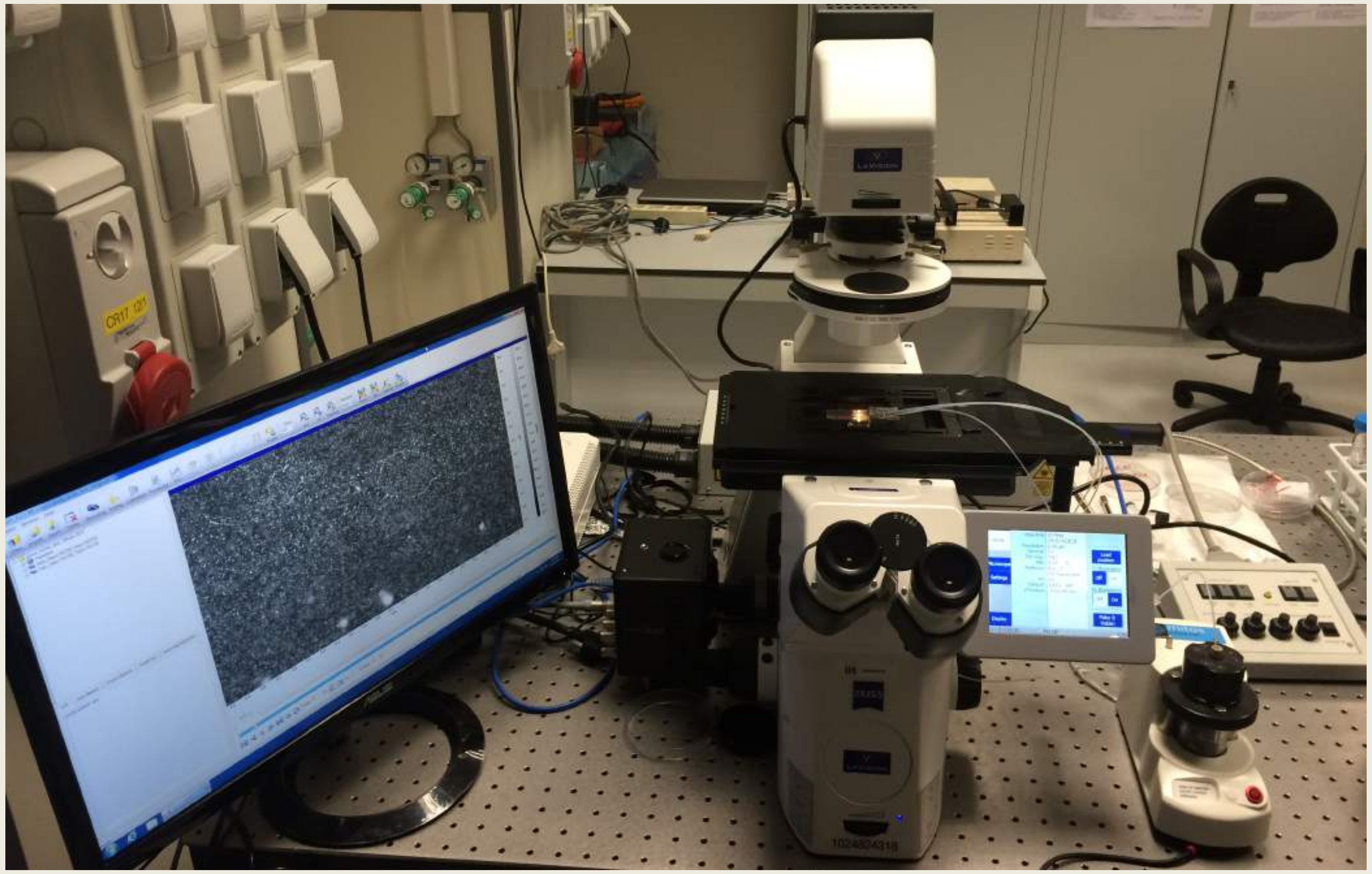


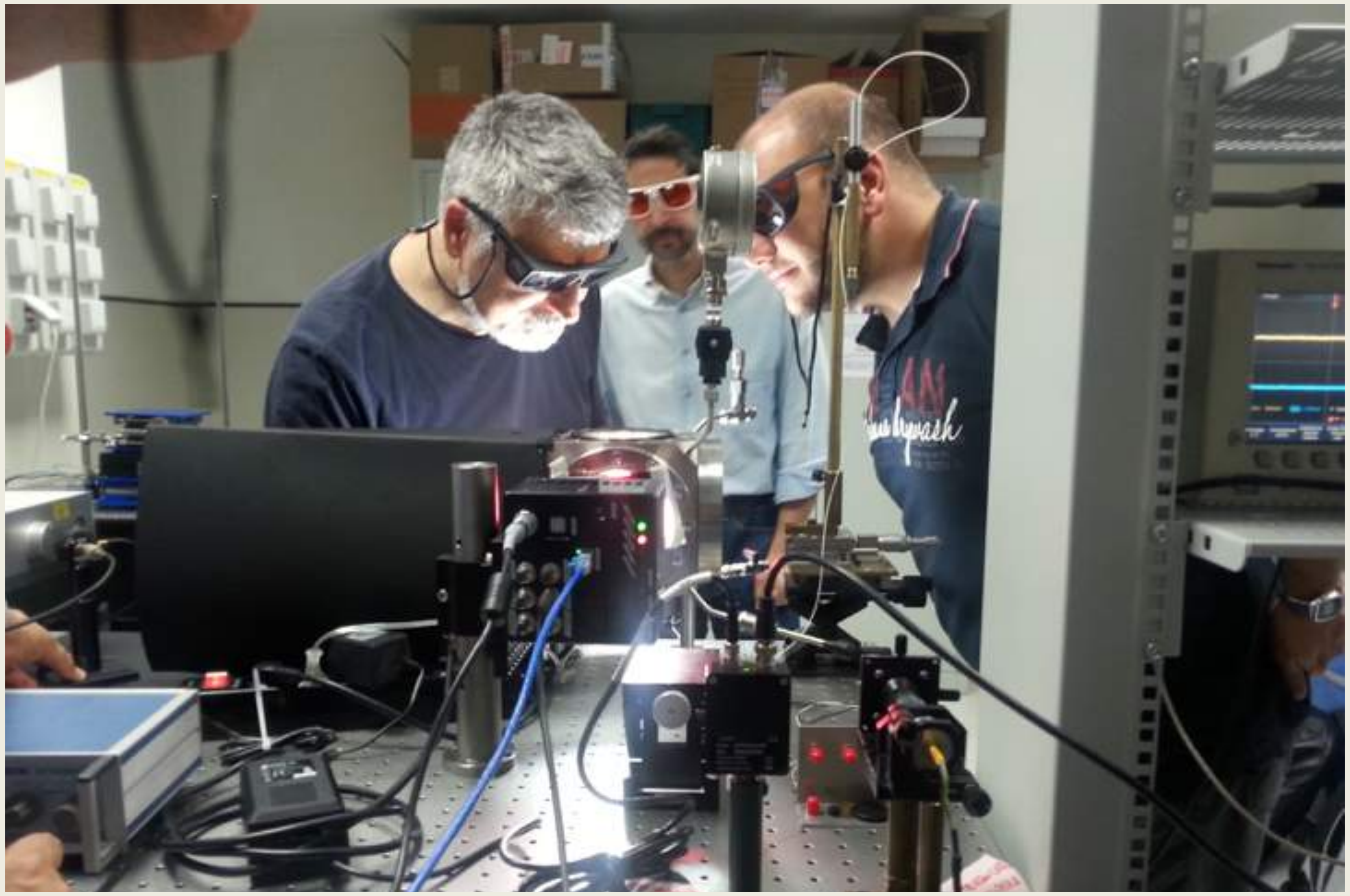


Microfluidic Lab

MicroFlu Lab

- Micro-PIV
- Fluorescence Confocal Microscopy
- High Speed Imaging
- Fiber Optic Hydrophone
- Micro-fabrication
- Cell-culture





MicroFlu Lab

- **Micro-PIV**
- Fluorescence Confocal Microscopy
- High Speed Imaging
- Fiber Optic Hydrophone
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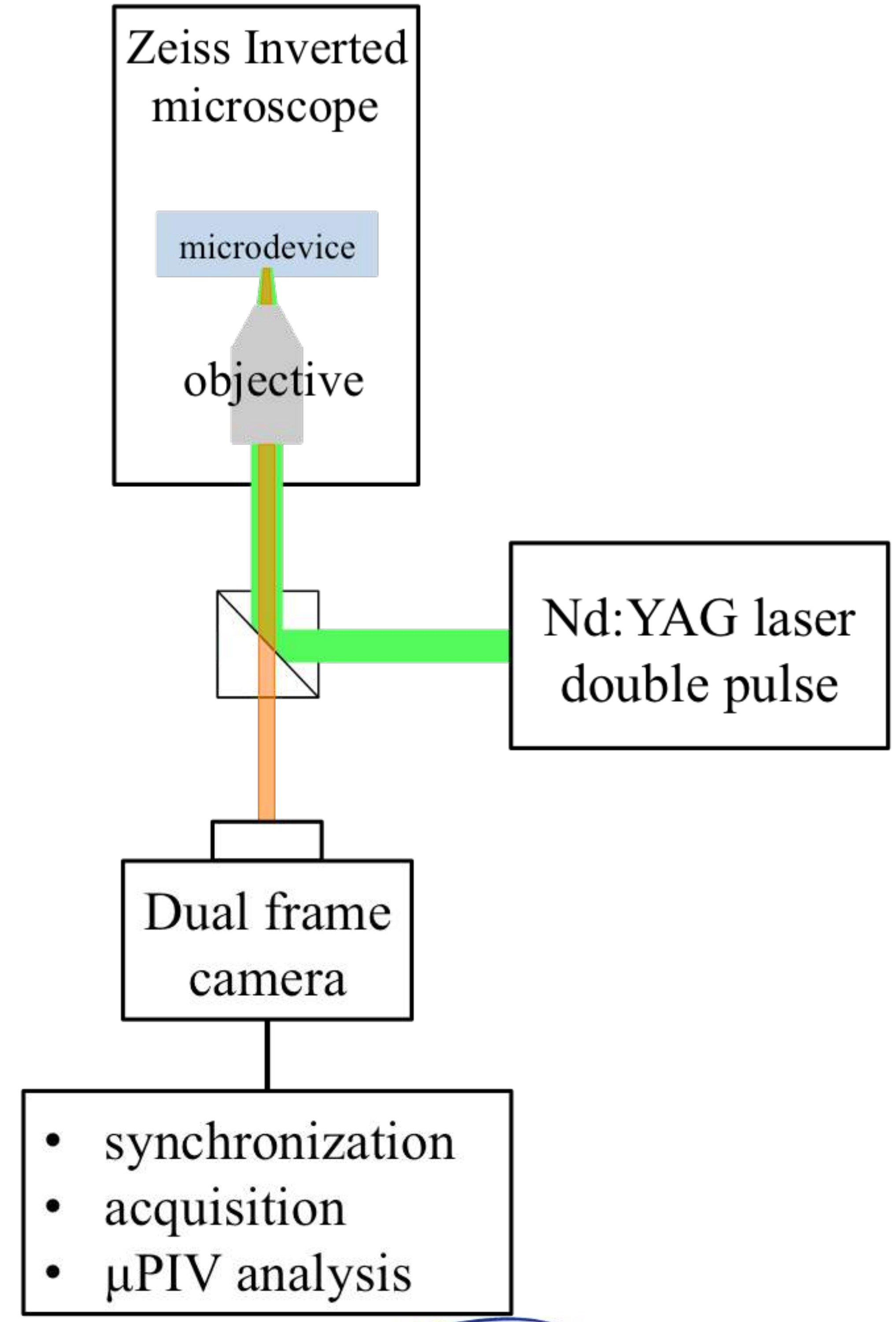
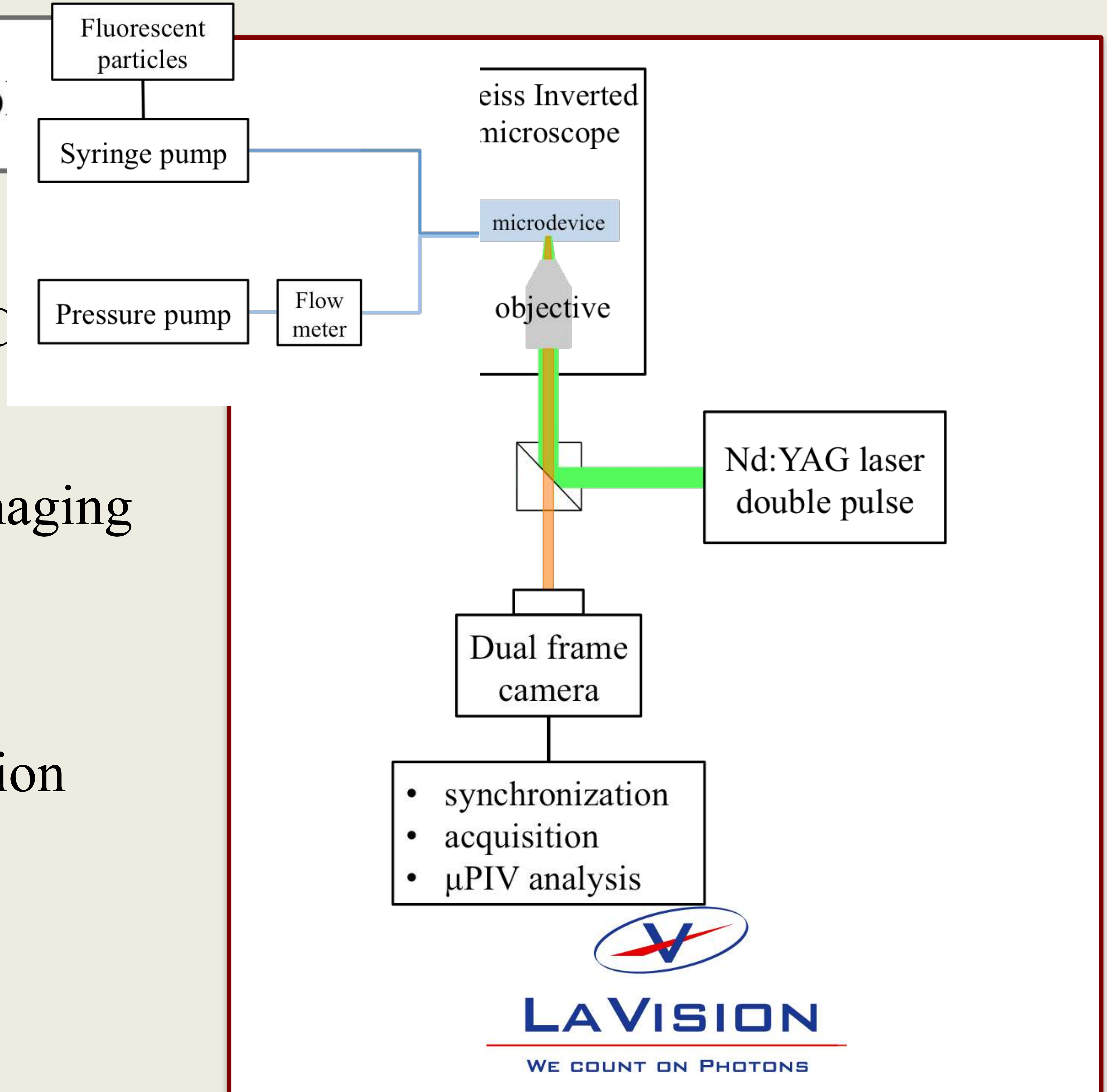


LaVision
We count on Photons

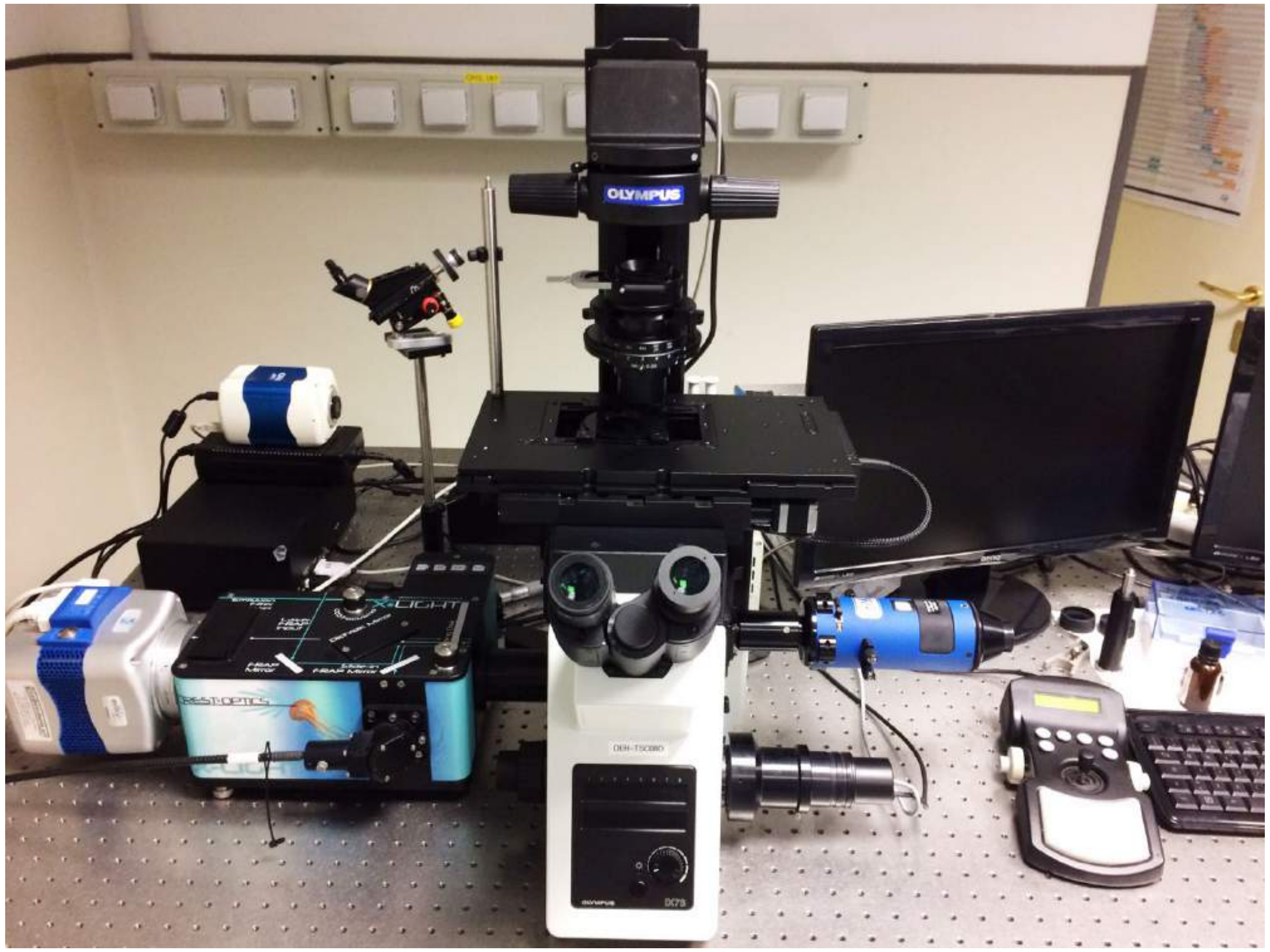
Micro

- **Micro-PIV**
- Fluorescence C
  Microscopy
- High Speed Imaging
- Fiber Optic
  Hydrophone
- Micro-fabrication
- Cell-culture



MicroFlu Lab

- Micro-PIV
- **Fluorescence Confocal Microscope**
- High Speed Imaging
- Fiber Optic Hydrophone
- Micro-fabrication
- Cell-culture



Confocal microscope (Olympus iX73 FluoView1220) operated in epi-fluorescence

Evolve 512 Delta EMCCD camera

OLYMPUS

MicroFlu Lab

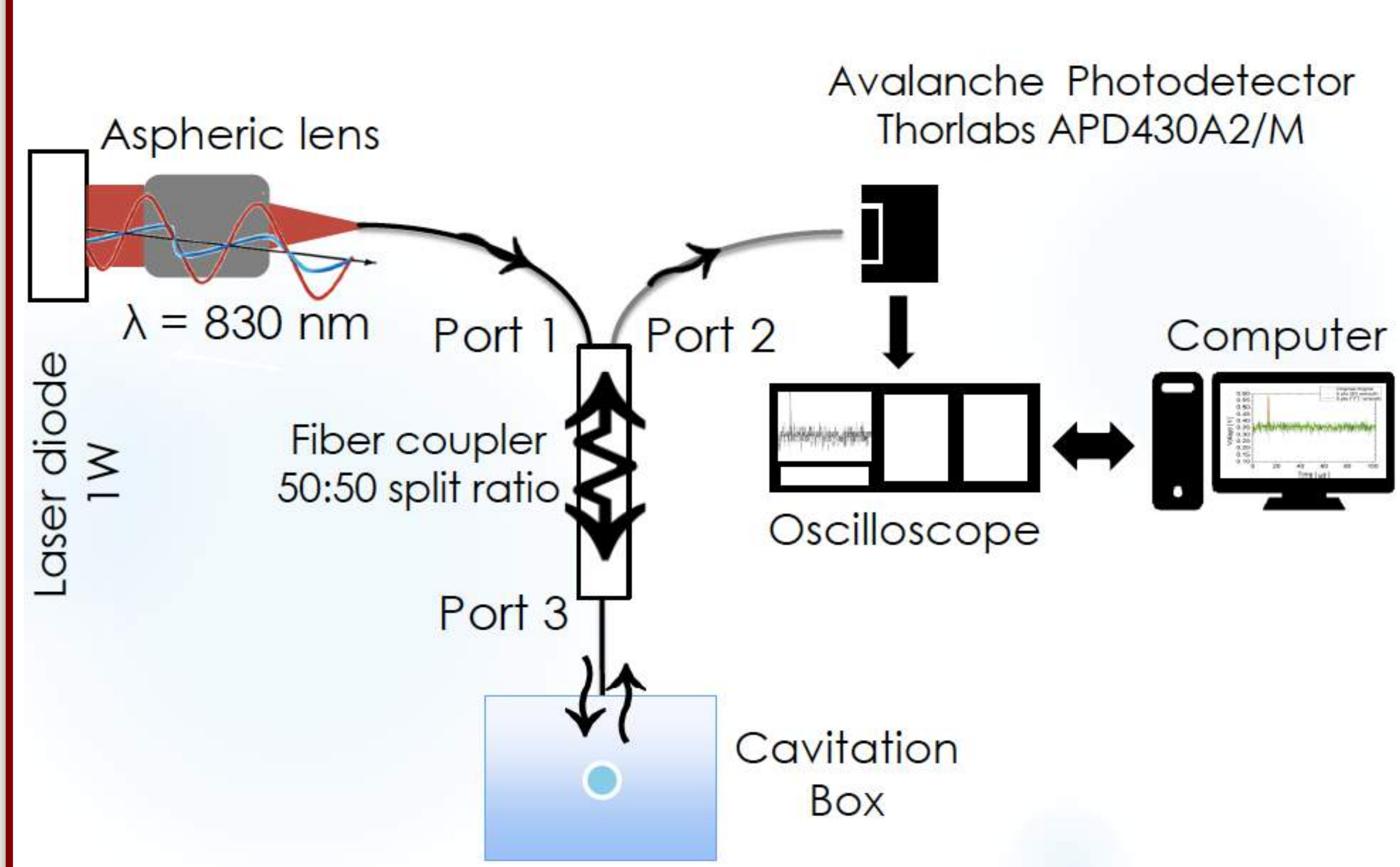
- Micro-PIV
- Fluorescence Confocal Microscopy
- **High Speed Imaging**
- Fiber Optic Hydrophone
- Micro-fabrication
- Cell-culture

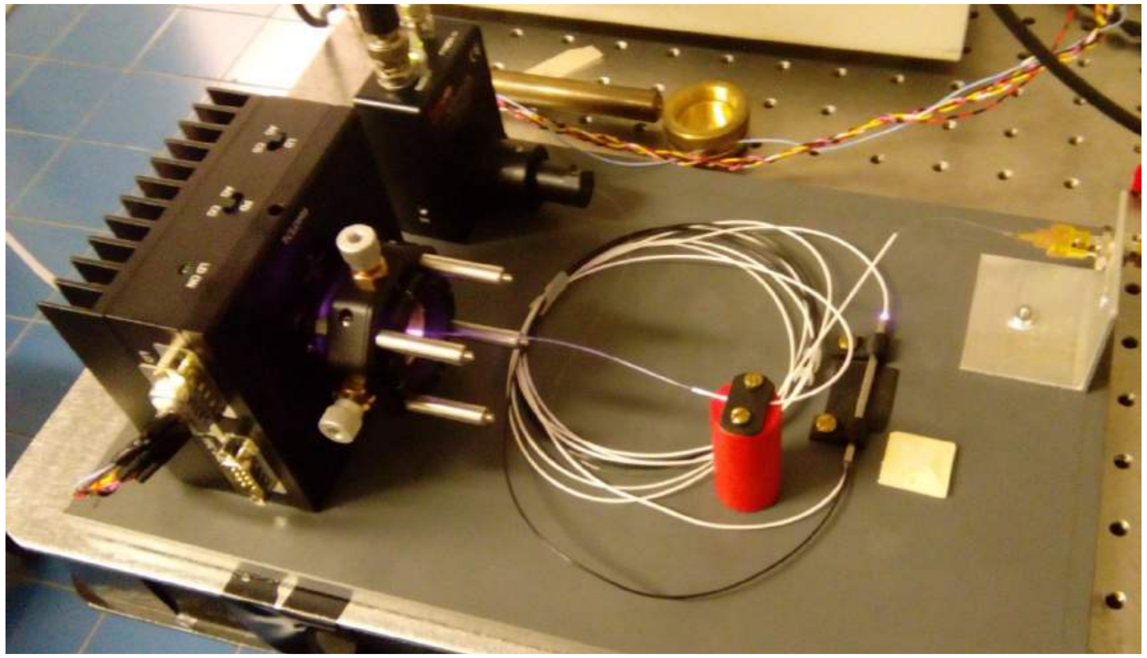
Photron Mini UX1000

- CMOS sensor
- 10 µm x 10 µm pixel size
- Resolution 1280 x 1024
- 4000 *fps* @ full frame
- 800.000 *fps* @ 1D

MicroFlu Lab

- Micro-PIV
- Fluorescence Confocal Microscopy
- High Speed Imaging
- **Fiber Optic Hydrophone**
- Micro-fabrication
- Cell-culture



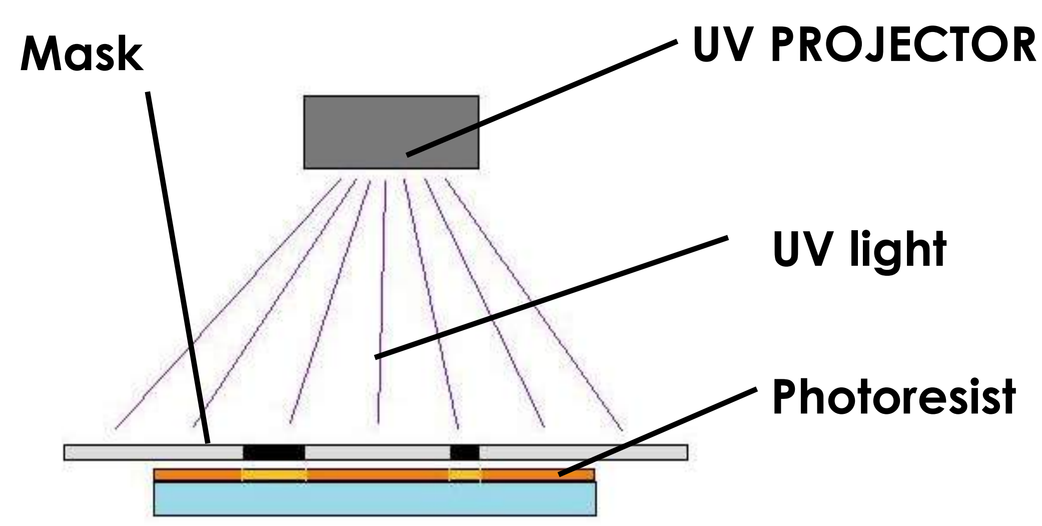


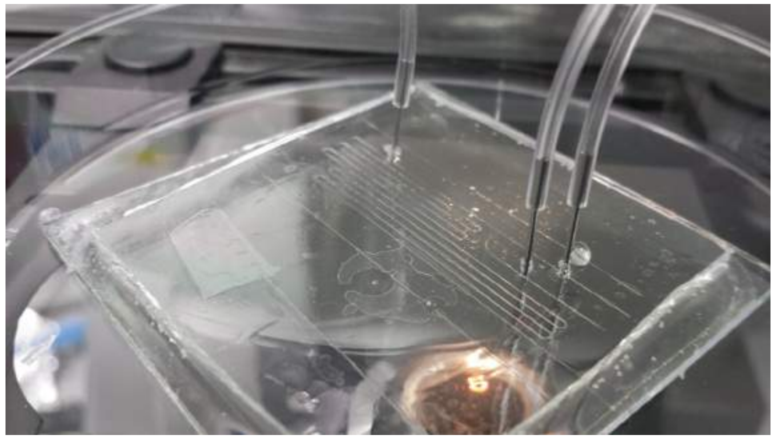
SBAI – La Sapienza

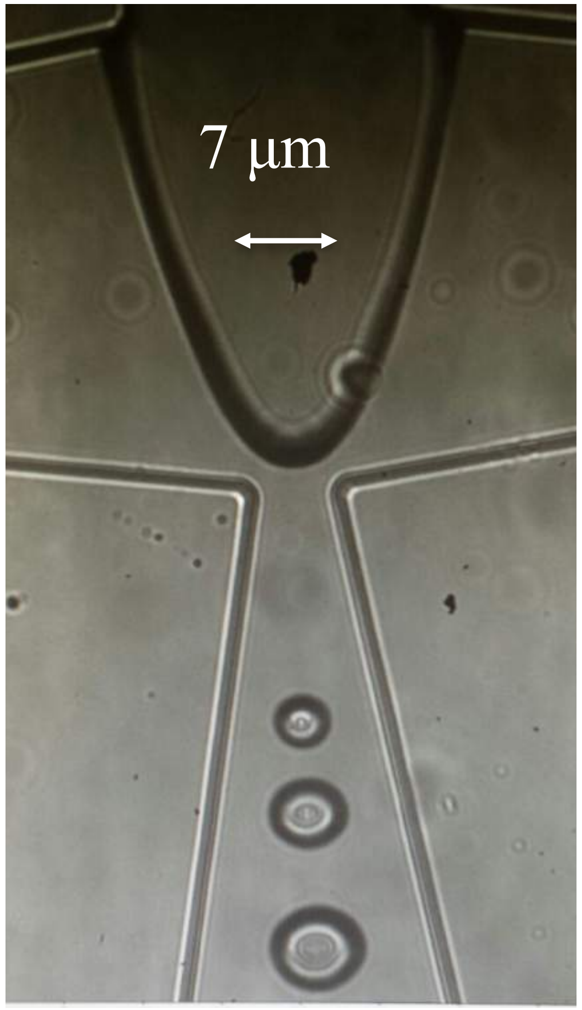
MicroFlu Lab

- Micro-PIV
- Fluorescence Confocal Microscopy
- High Speed Imaging
- Fiber Optic Hydrophone
- **Micro-fabrication**
- Cell-culture

Lithography



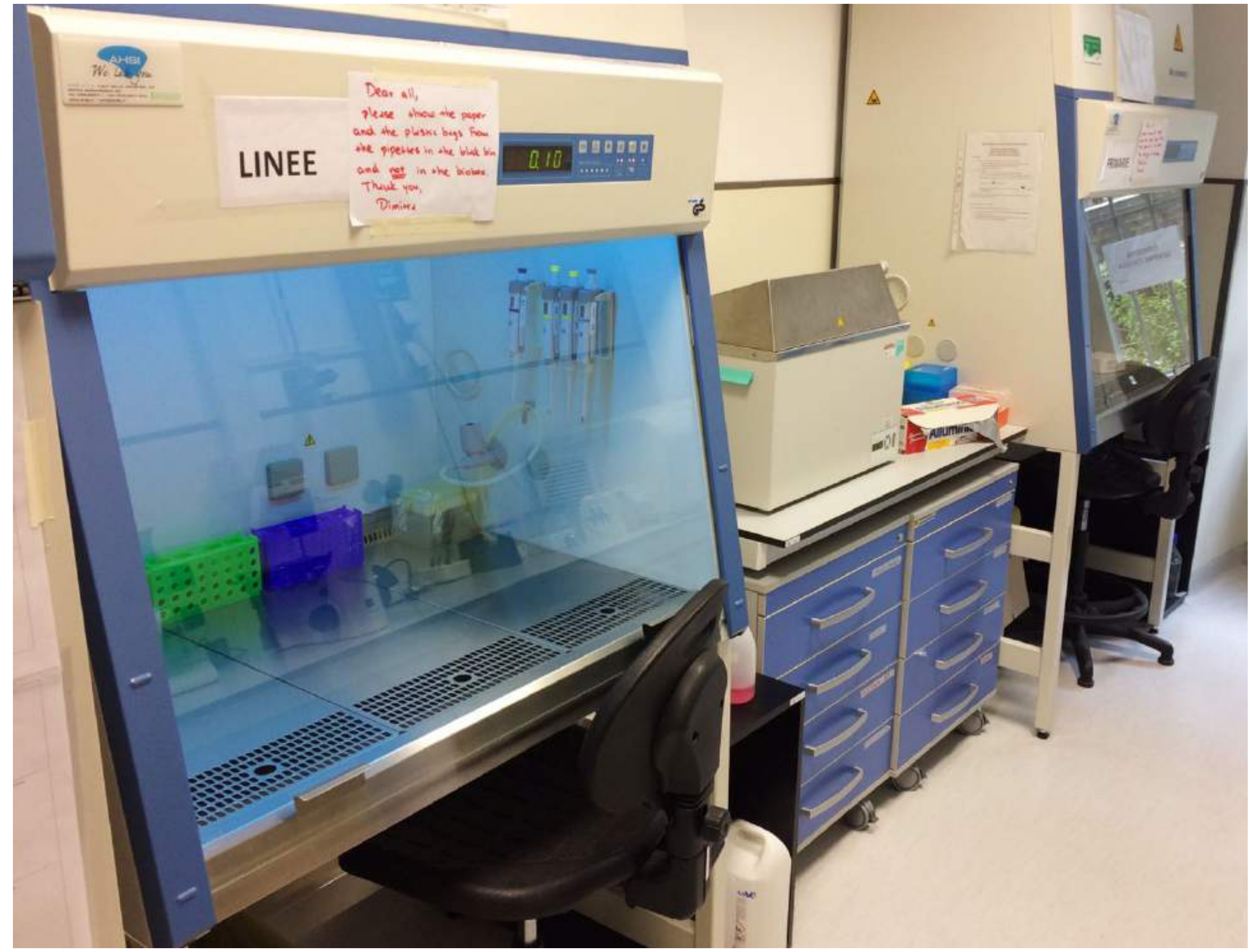


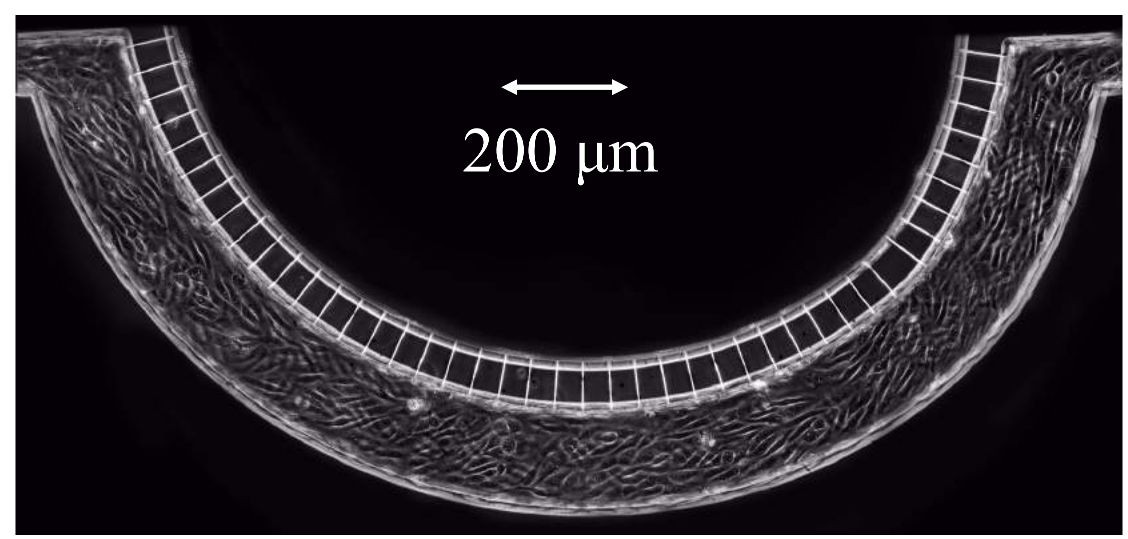


DIET – La Sapienza

MicroFlu Lab

- Micro-PIV
- Fluorescence Confocal Microscopy
- High Speed Imaging
- Fiber Optic Hydrophone
- Micro-fabrication
- **Cell-culture**





Cavitation in Biochips

Department of Mechanical and Aerospace Engineering

Cavitation enhanced drug delivery

Giulia Silvani (DIMA - IIT)

Chiara Scognamiglio (DIMA - LPMC)

Davide Caprini (DIMA)

Giorgia Sinibaldi (DIMA)

Luca Marino (DIMA)

Mauro Chinappi (Torvergata)

Giovanna Peruzzi

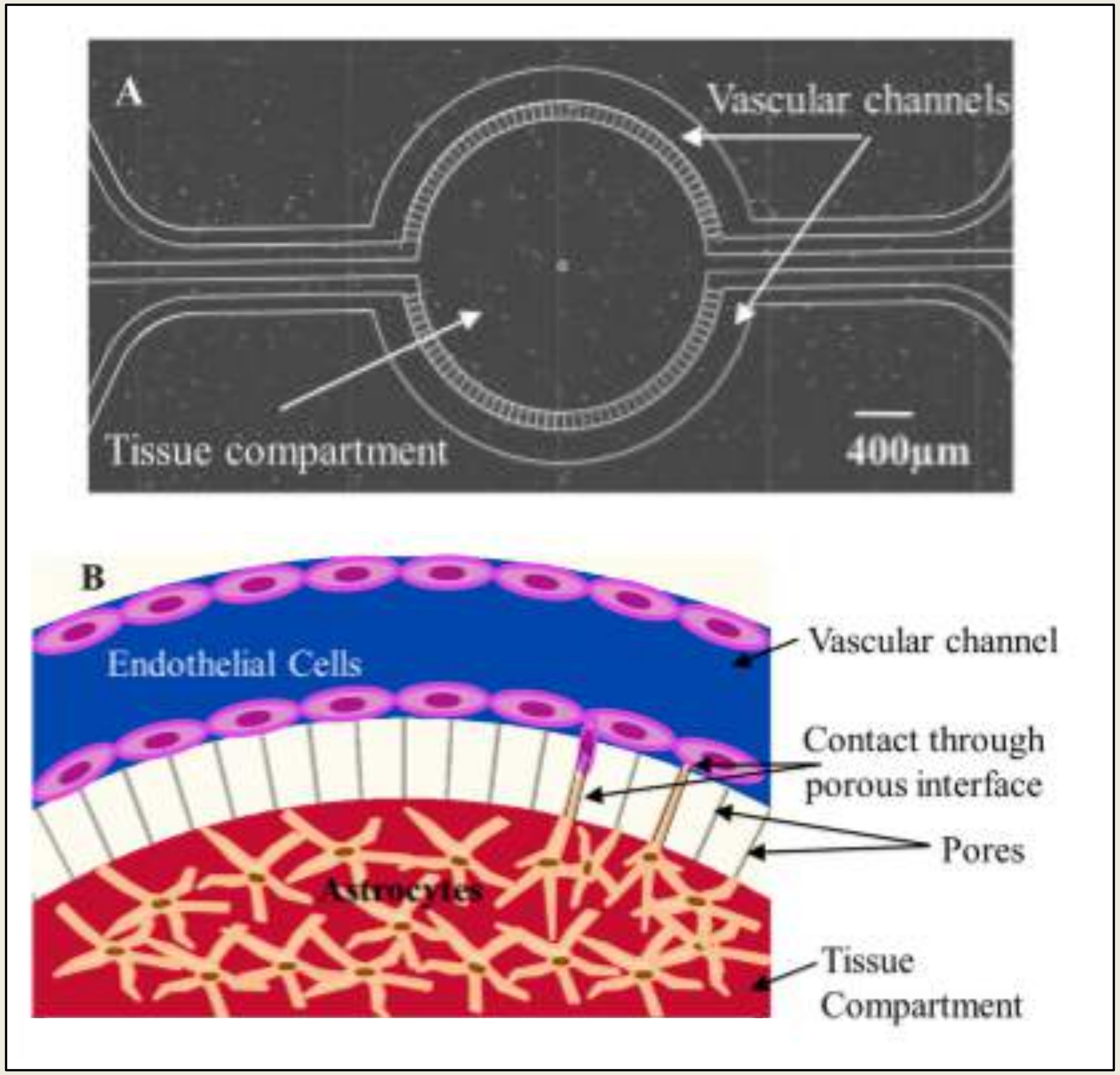
G. Durando

MicroFlu Lab

Prof. M. Kiani

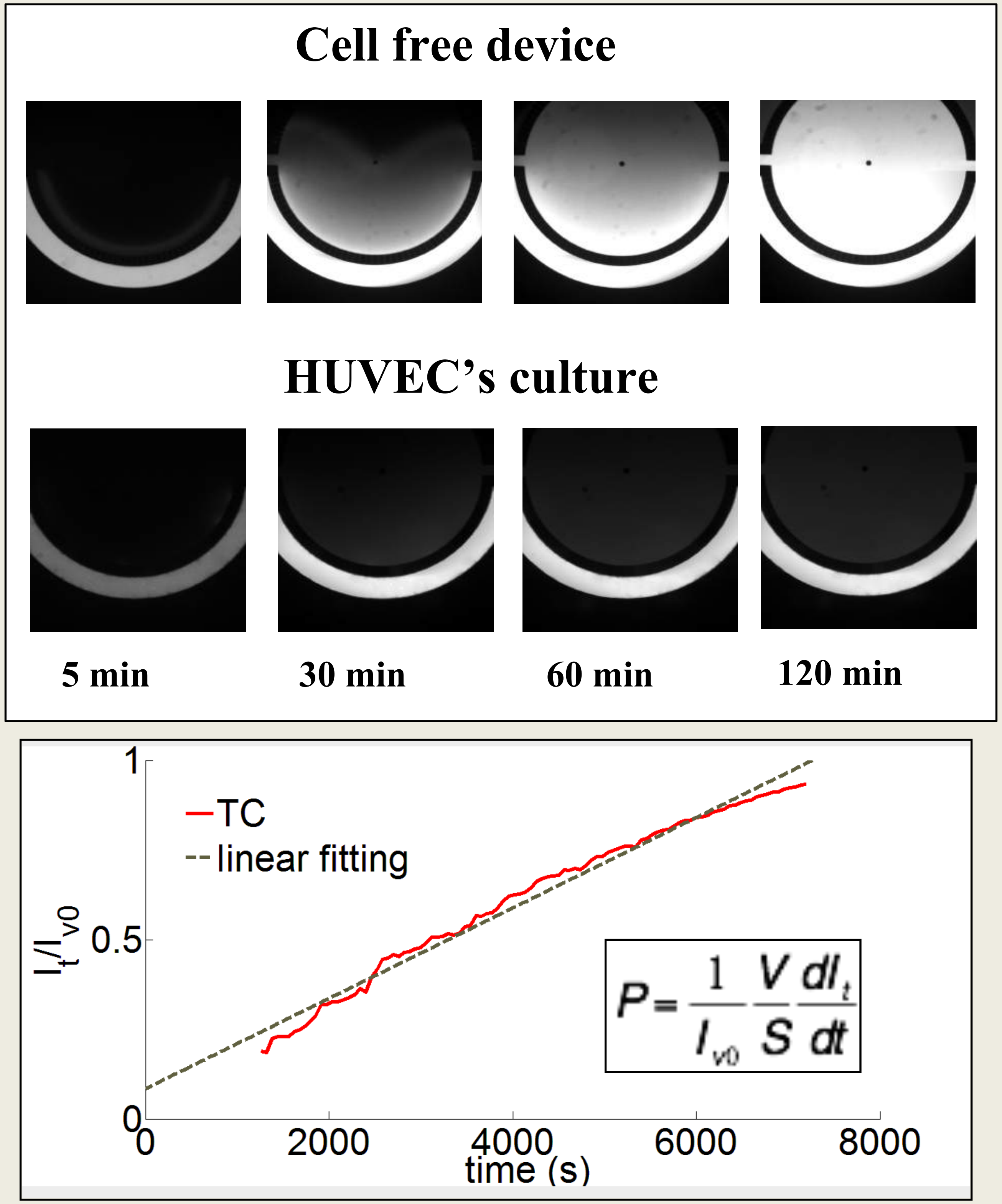
Cavitation enhanced drug delivery

Blood vessel on a chip



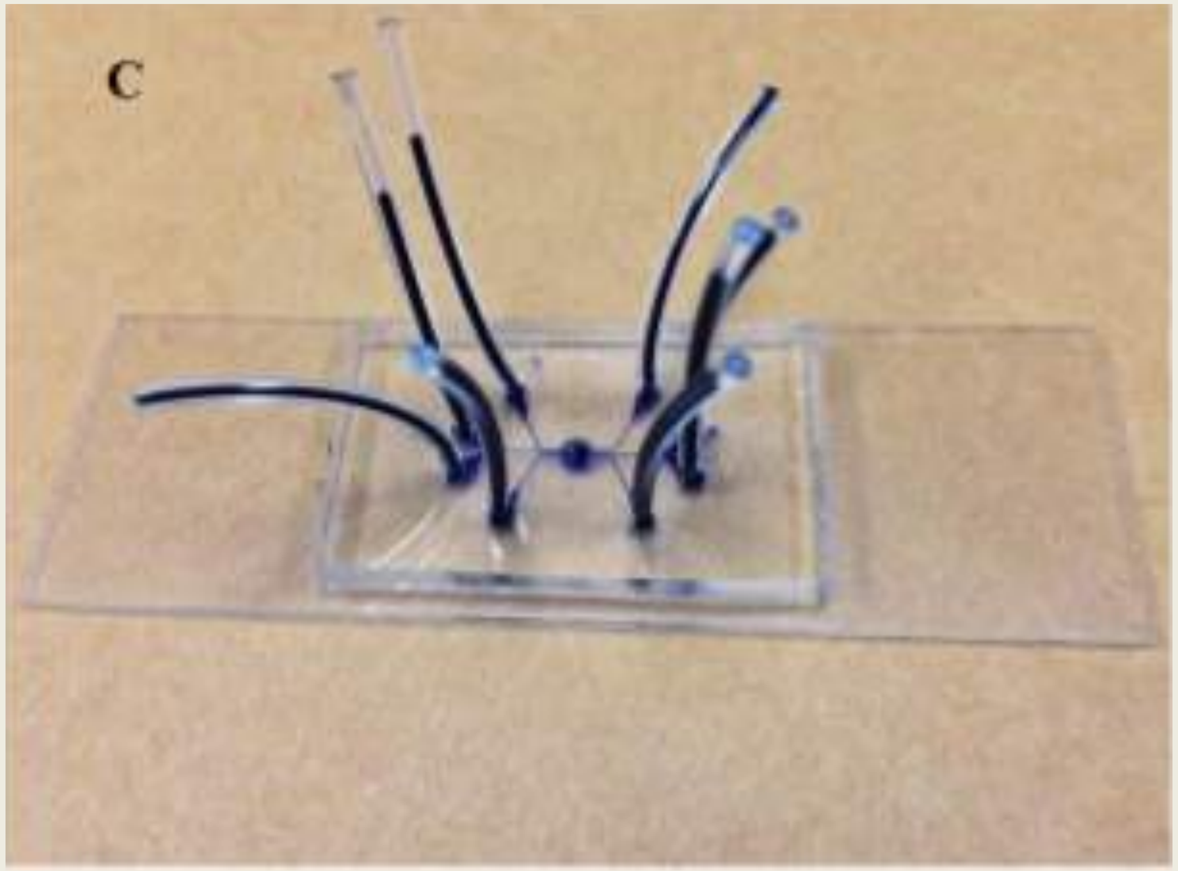
Deosarkar et al., PLOS ONE 2015

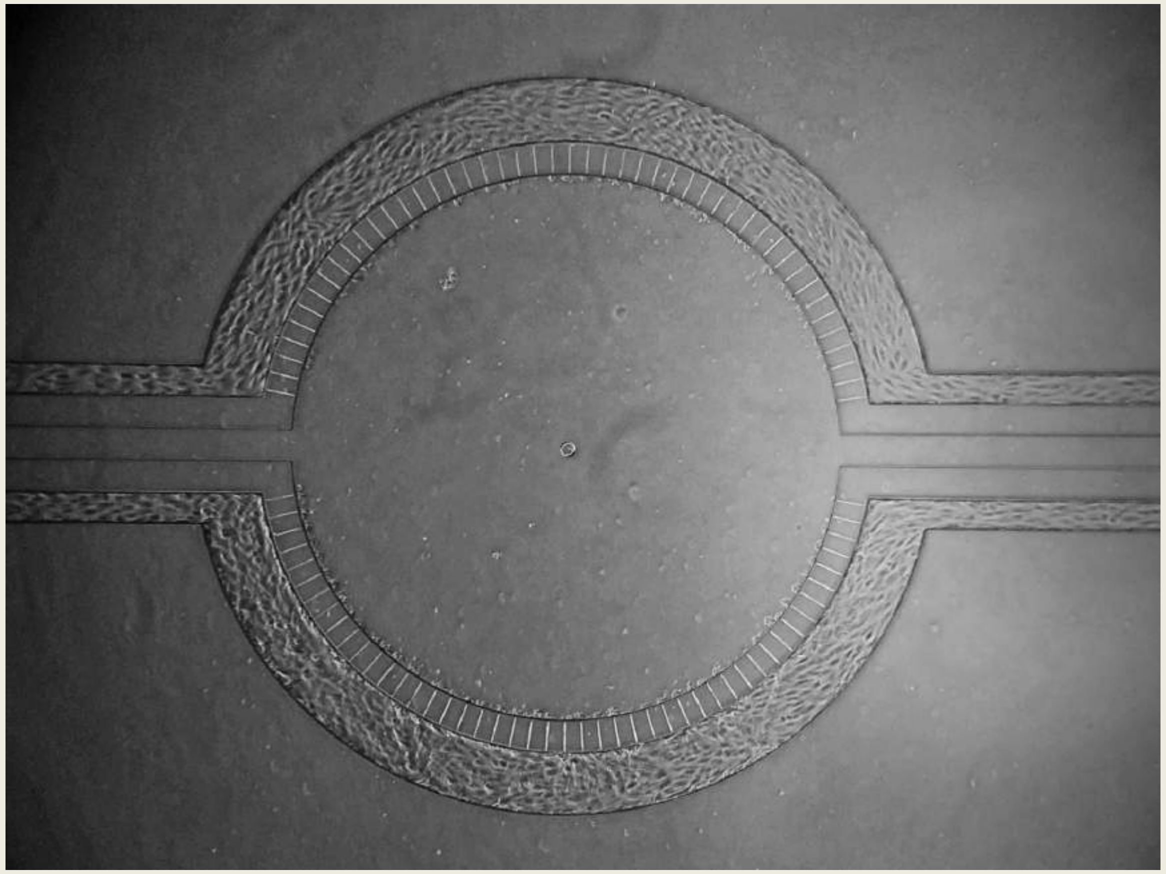
Permeability measurements



Cavitation enhanced drug delivery

Unique features of the device

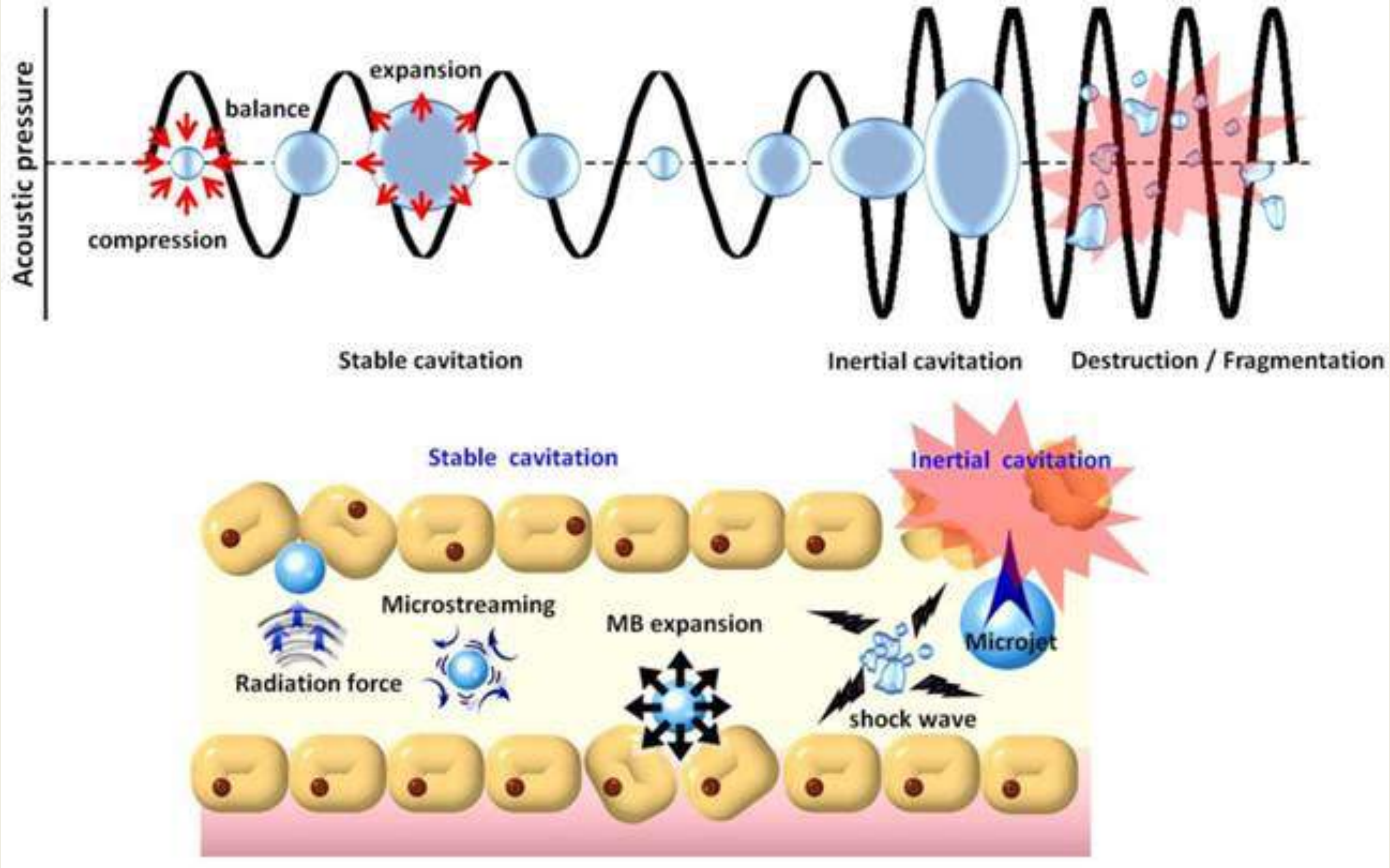




- Realistic sizes
- Correct perfusion rate
- Correct physiological shear stress intensity
- Ability to reproduce the biochemical interactions between tumor and endothelium

Cavitation enhanced drug delivery

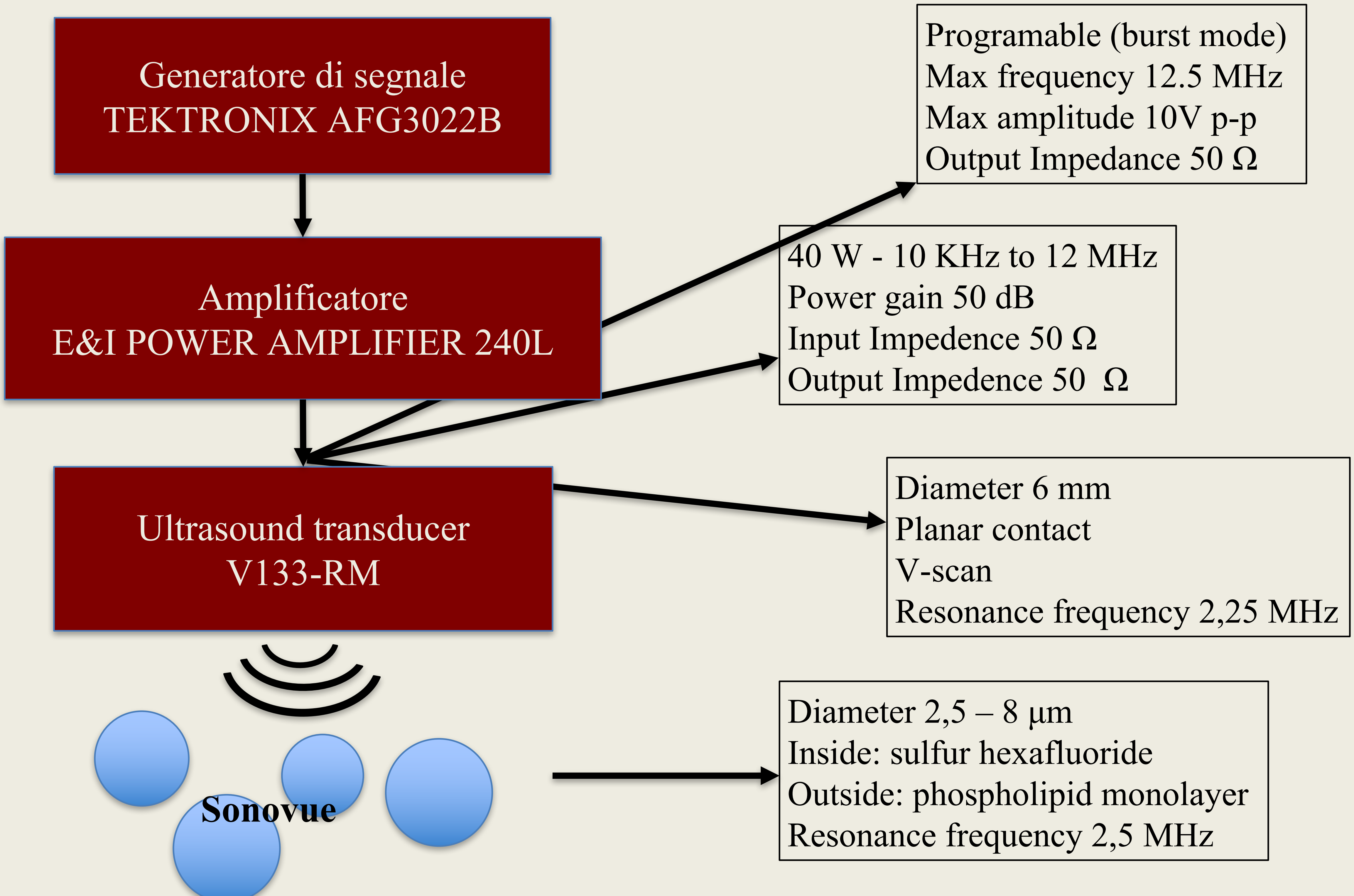
Micro-bubbles and **ultrasounds** for drug delivery to solid tumours



Hao-Li Liu et al., Theranostics 2014

Cavitation enhanced drug delivery

Ultrasounds chain



Experimental Microfluidics

Department of Mechanical and Aerospace Engineering

Experimental Microfluidics

Davide Caprini (DIMA)
Chiara Scognamiglio (DIMA - LPMC)
Giorgia Sinibaldi (DIMA)
Luca Marino (DIMA)
Mauro Chinappi (Torvergata)

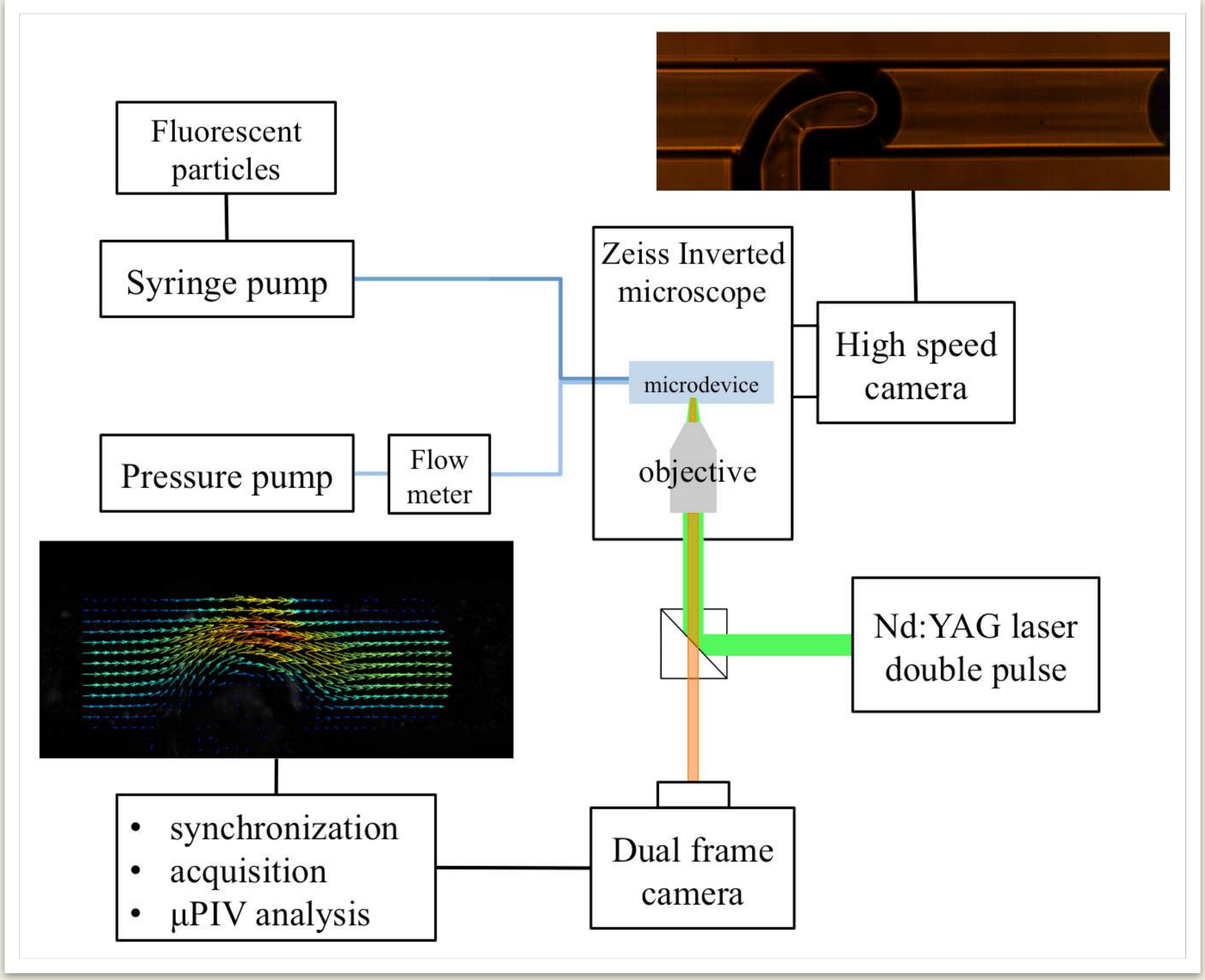
DIET - Dipartimento di Ingegneria Elettrica e Telecomunicazioni
Prof. A. Nascetti

MicroFlu Lab

Université Nice Sophia Antipolis
LPMC
Xavier Noblin

Bubbles in micro-devices

MicroPIV + high speed imaging



Micro-bubbles generator

Bubble generation

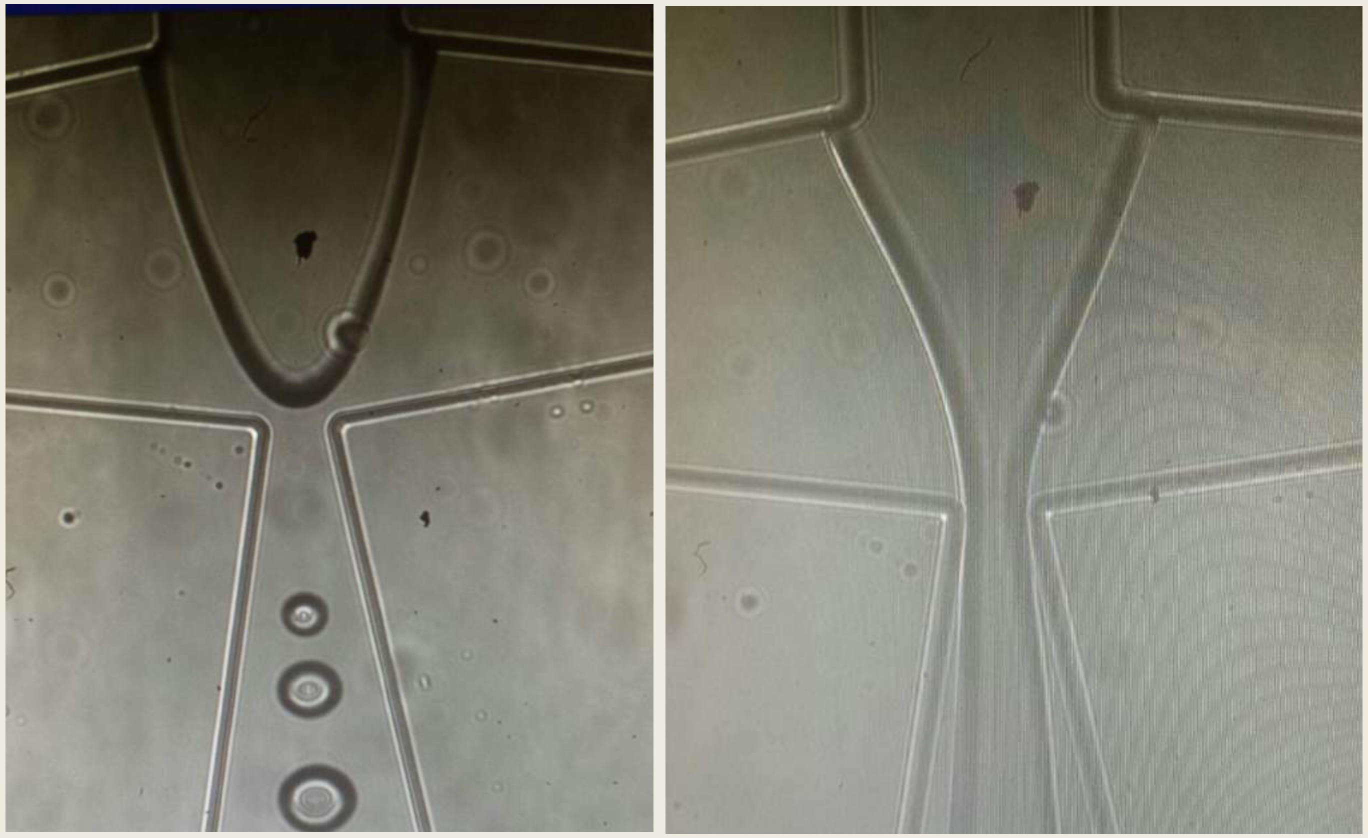
- ◇ Gas insufflation
- ◇ Electric spark
- ◇ Focused laser
- ◇ Cavitation

Position control and excitation

- ◇ Electrowetting (EWOD)
- ◇ Ultrasounds

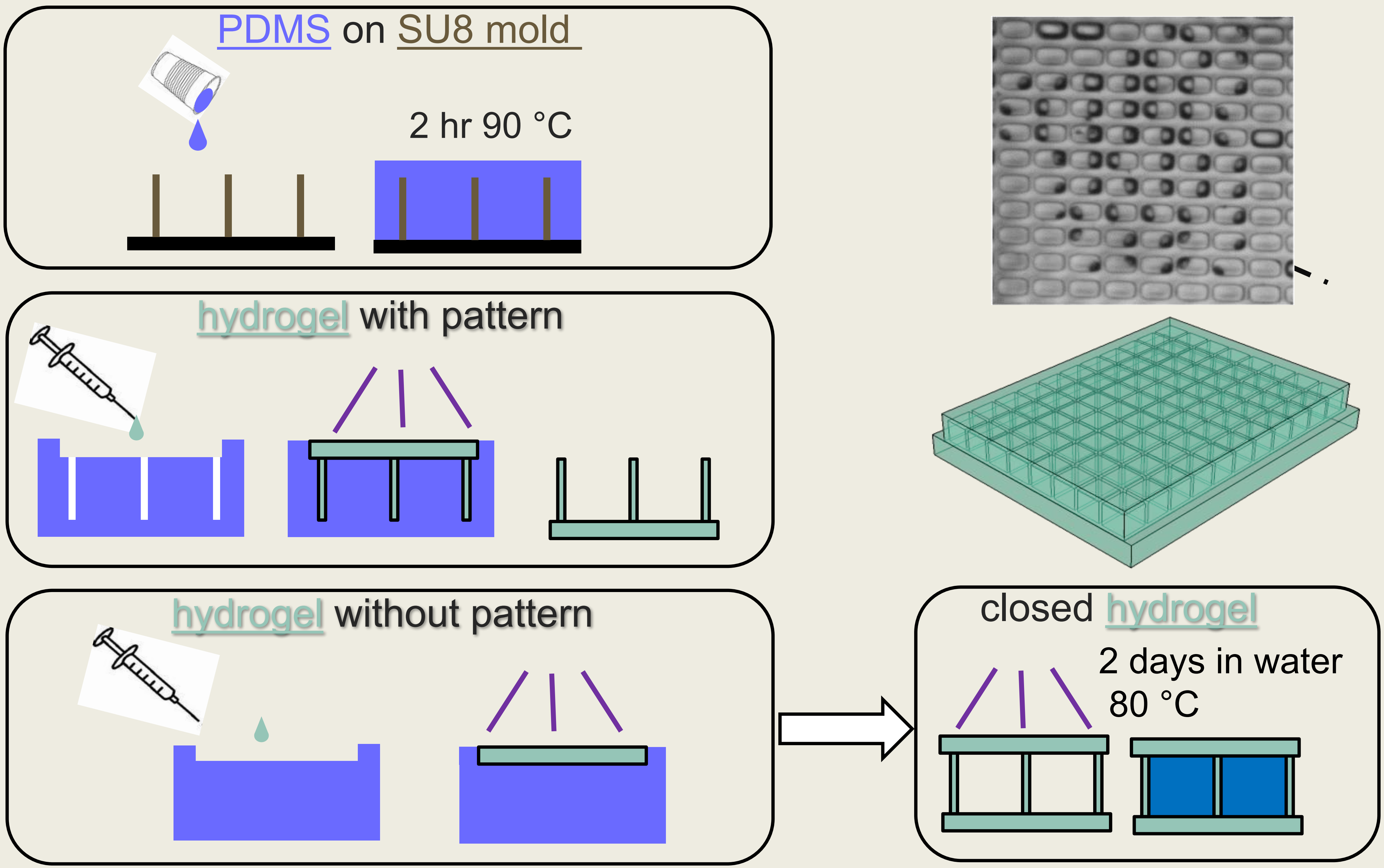
Fluid dynamic characterization

- ◇ Micro-PIV
- ◇ High speed imaging
- ◇ Hydrophone
- ◇ Shadowgraph



Cavitation confined in Micro-system

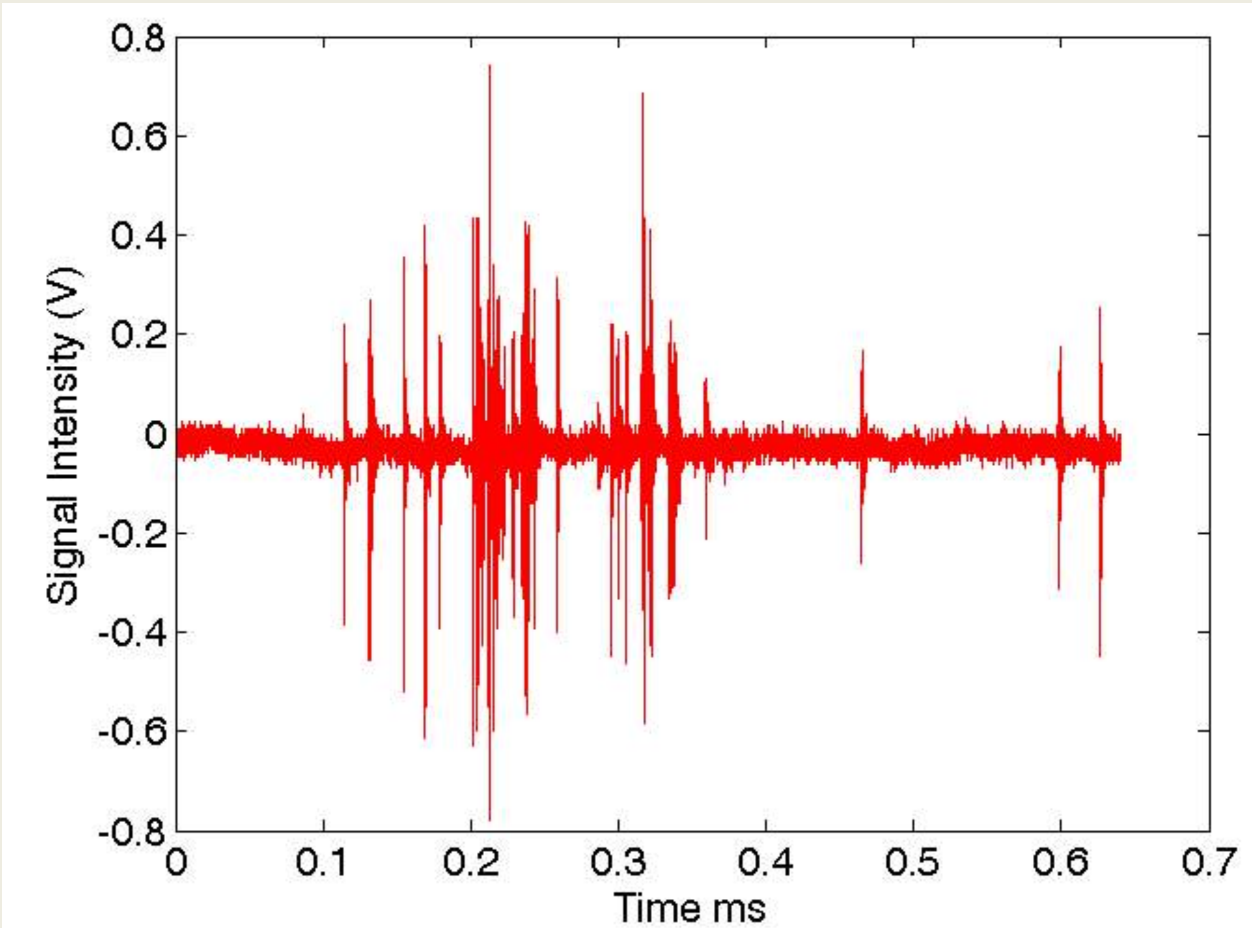
Biomimetic device fabrication

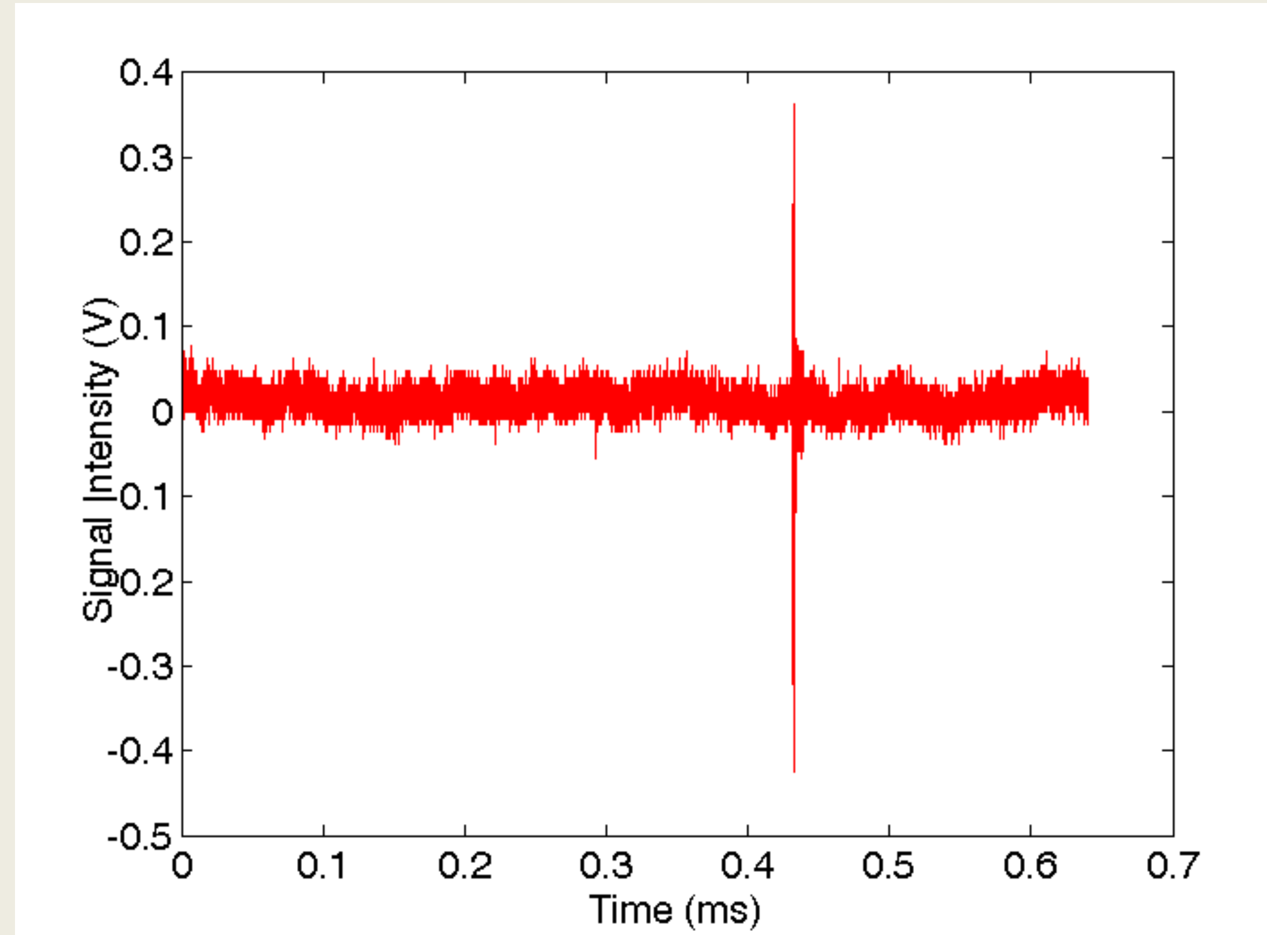


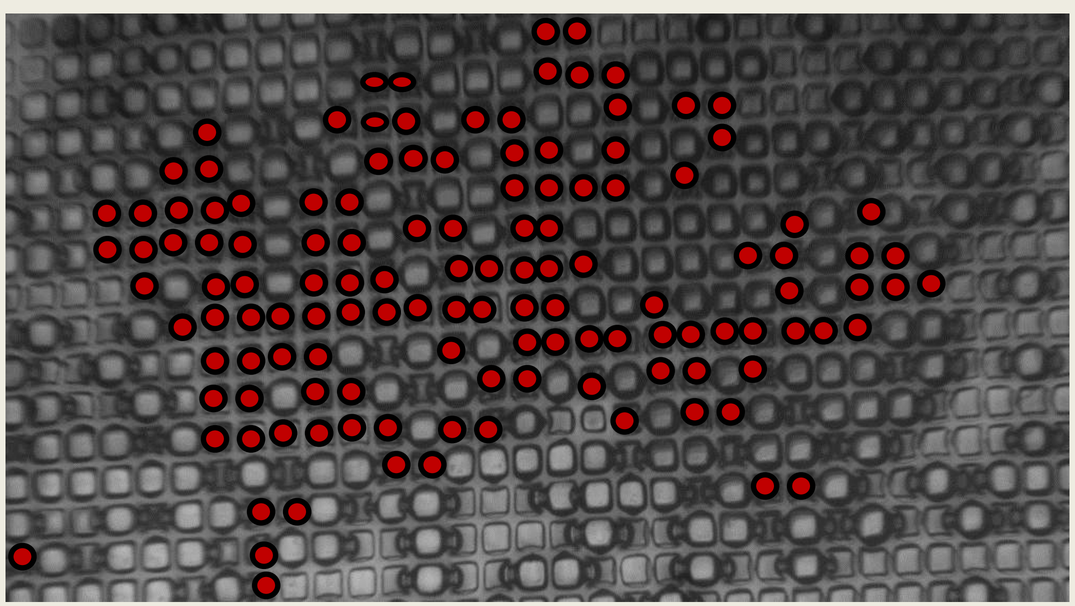
Bubbles acoustic signature

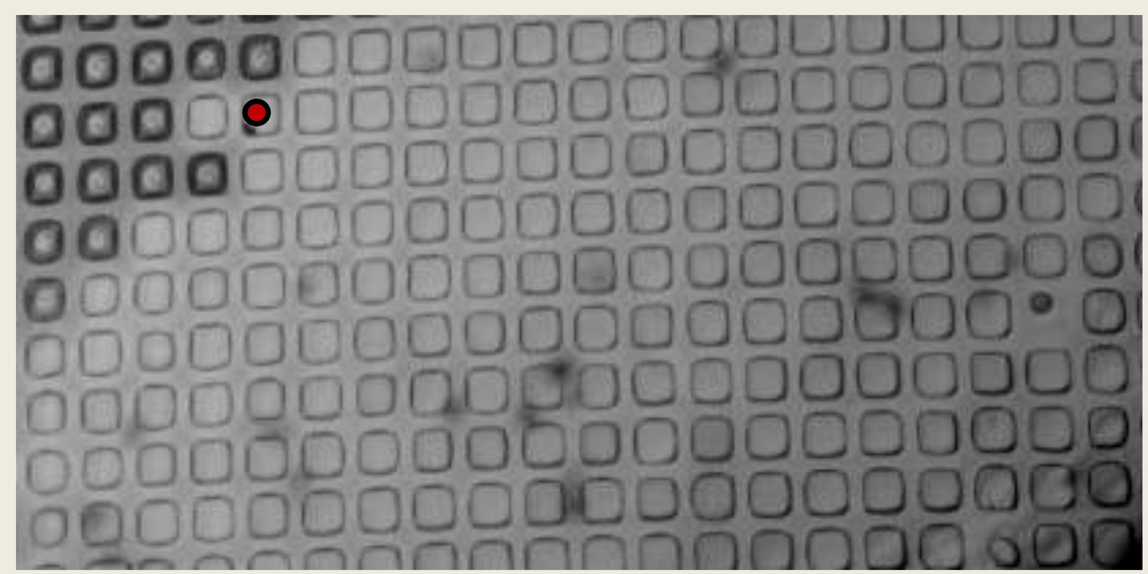
10 µm walls

20 µm walls









Laser Induced Cavitation

SAPIENZA UNIVERSITÀ DI ROMA

Department of Mechanical and Aerospace Engineering

Laser Induced Cavitation Bubble

Giorgia Sinibaldi (DIMA)

Davide Caprini (DIMA)

Agostino Occhicone (DIMA –SBAI)

Luca Marino (DIMA)

Mauro Chinappi (Torvergata)

The Italian Ship Model Basin INSEAN

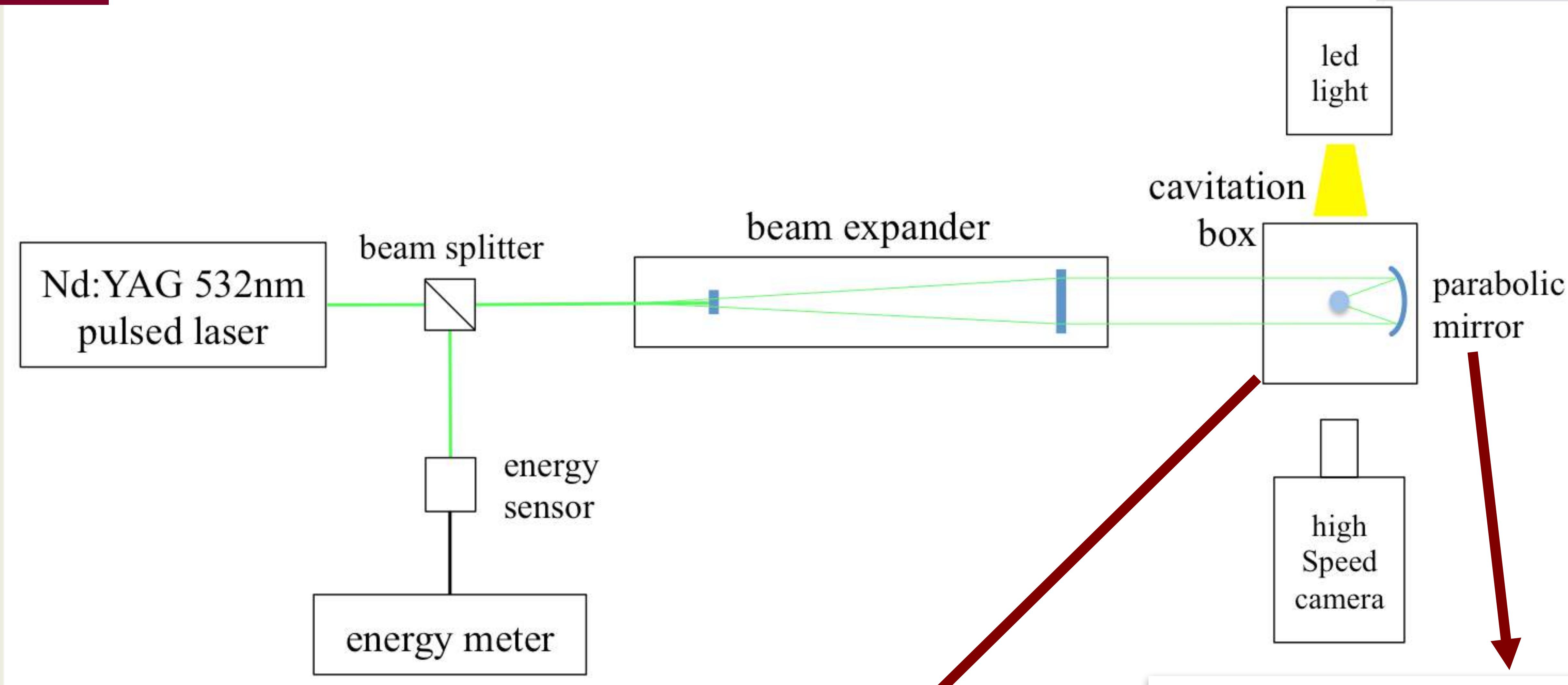
Francisco Pereira

SBAI - Dipartimento di Scienze di Base Applicate all'Ingegneria

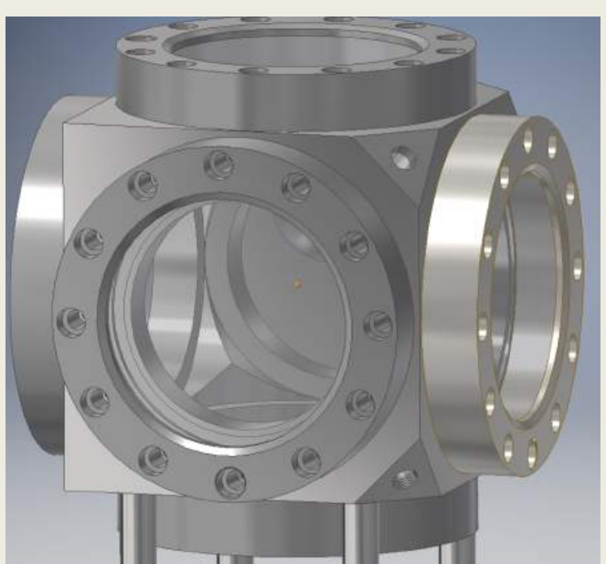
Prof. F. Michelotti

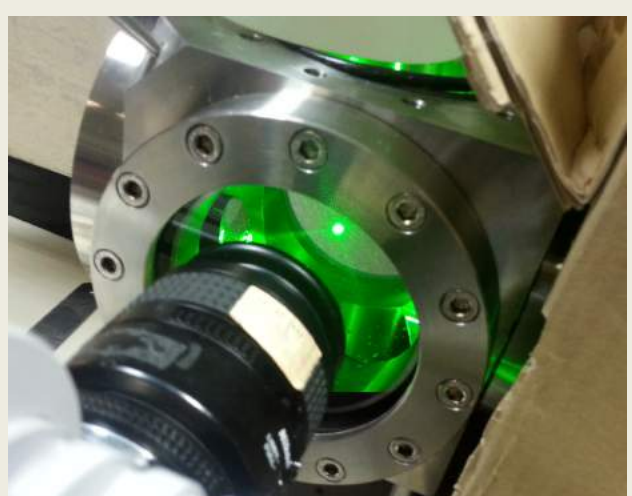
MicroFlu Lab

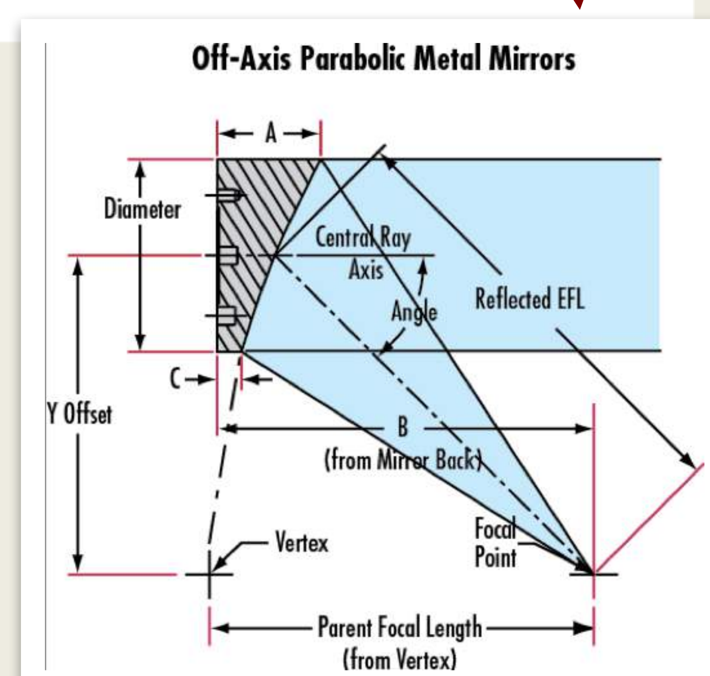
Set up



led
light
cavitation
box
beam expander
beam splitter
Nd:YAG 532nm
pulsed laser
parabolic
mirror
energy
sensor
energy meter
high
Speed
camera

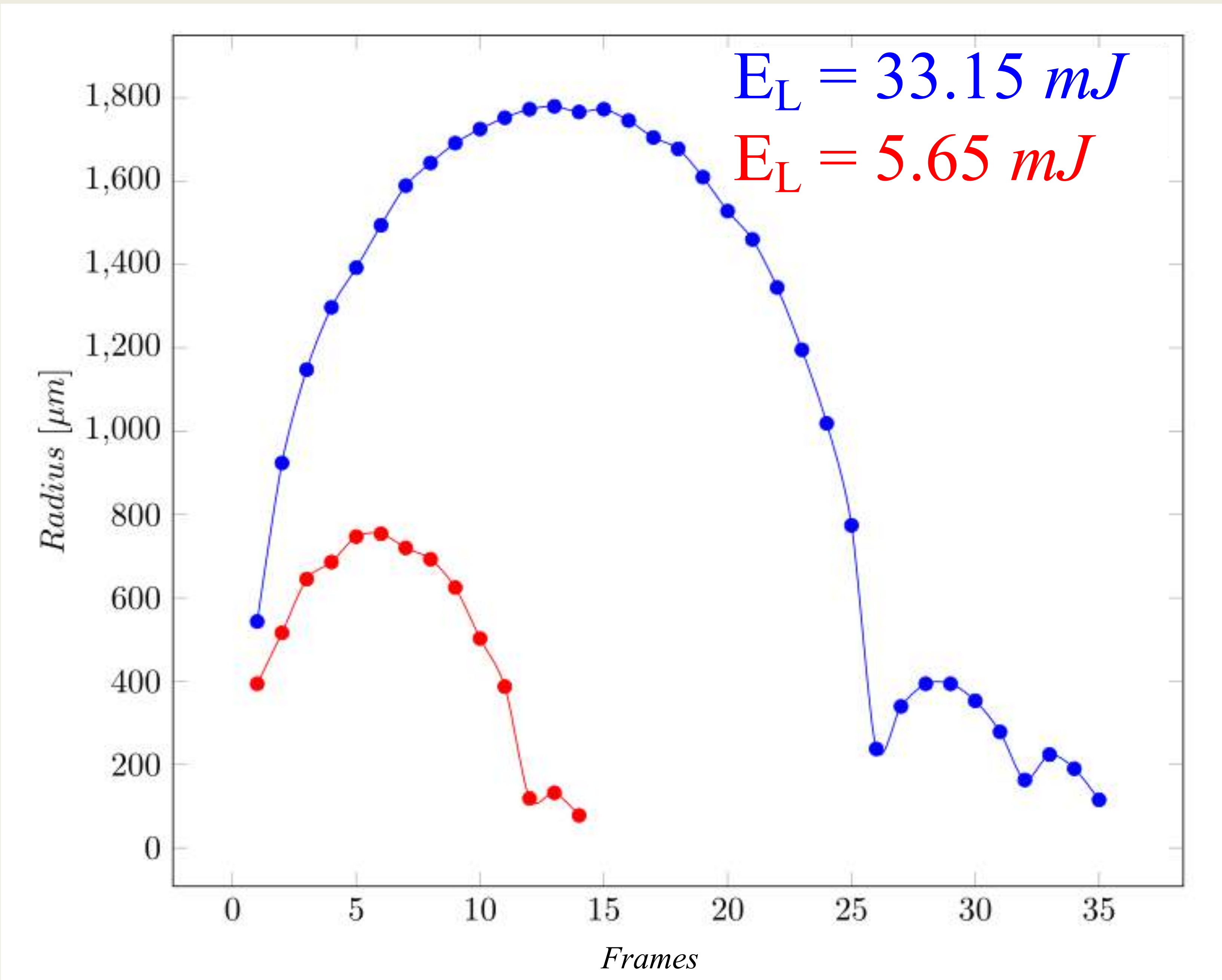






Off-Axis Parabolic Metal Mirrors
A
Diameter
Central Ray
Axis
Angle
Reflected EFL
C
Y Offset
B
(from Mirror Back)
Vertex
Focal
Point
Parent Focal Length
(from Vertex)

Bubble dynamics



80.000 *fps*

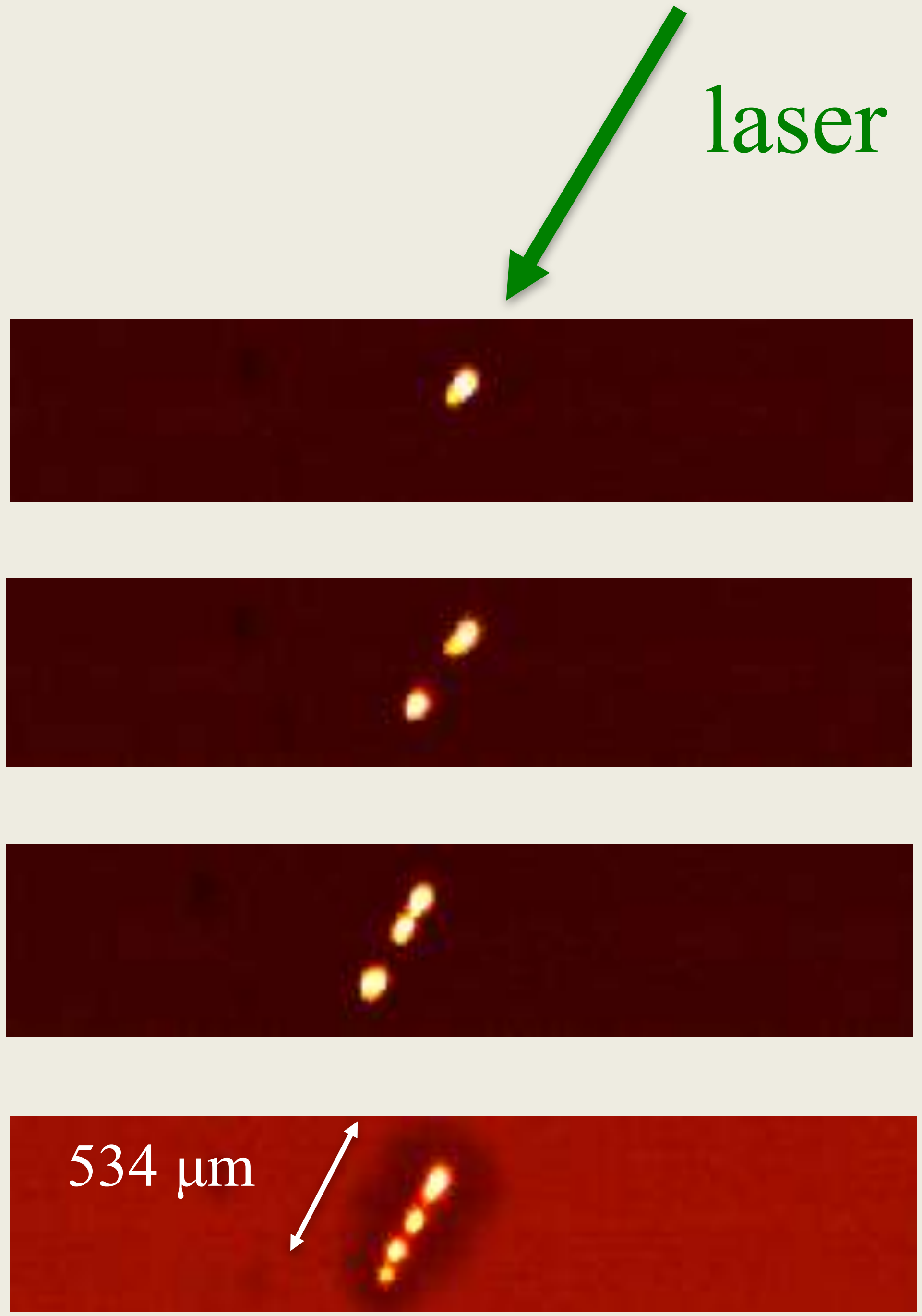
(Interframing time 12,5 μs)

“Spherical” rebound

Plasma Analysis

Multiple plasma

laser



(same laser energy)

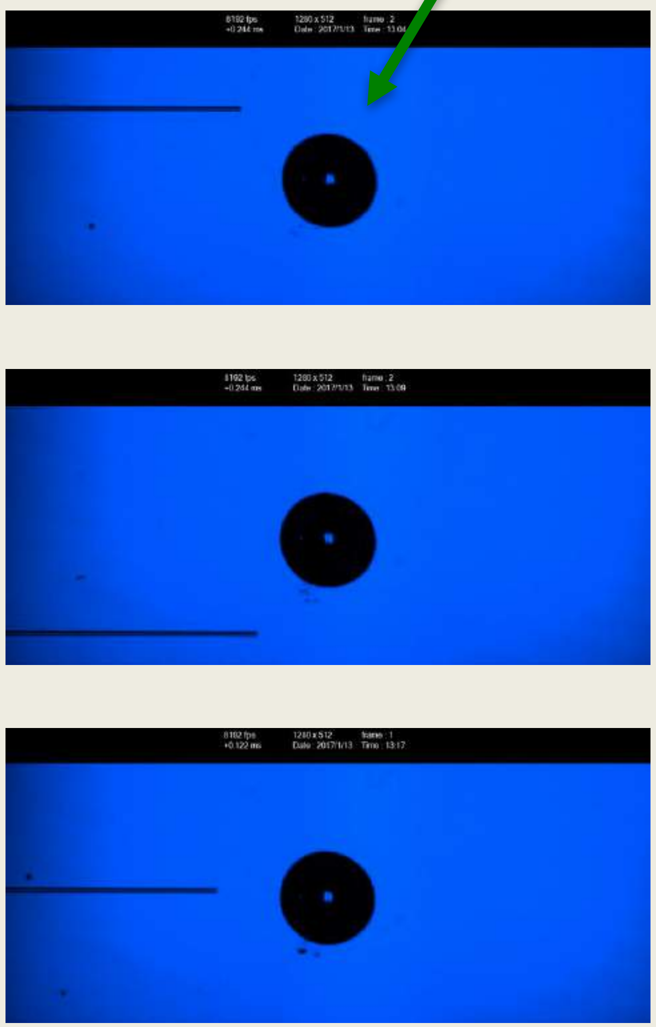
Three plasmas - one bubble

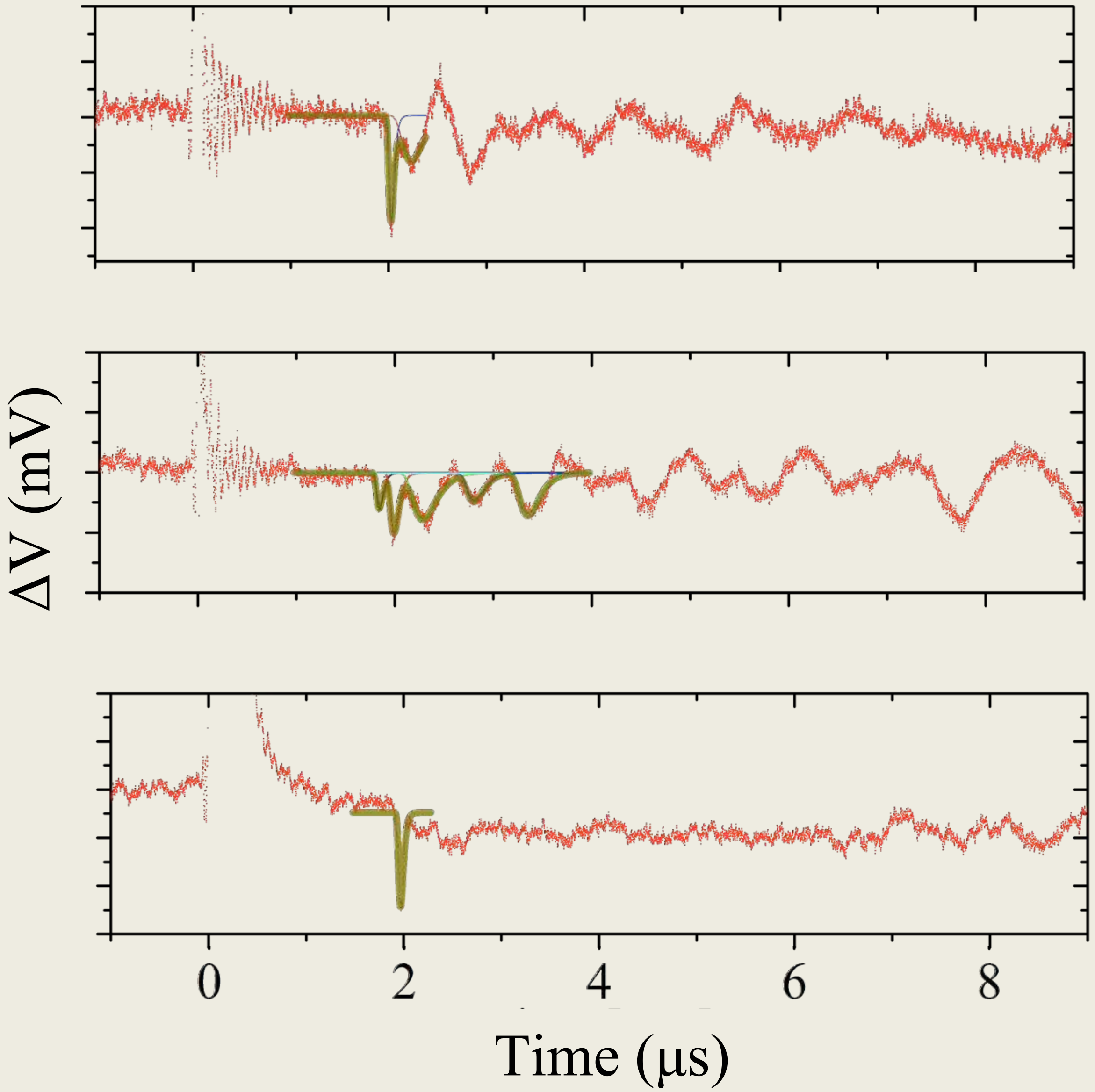
Three plasmas - three bubbles

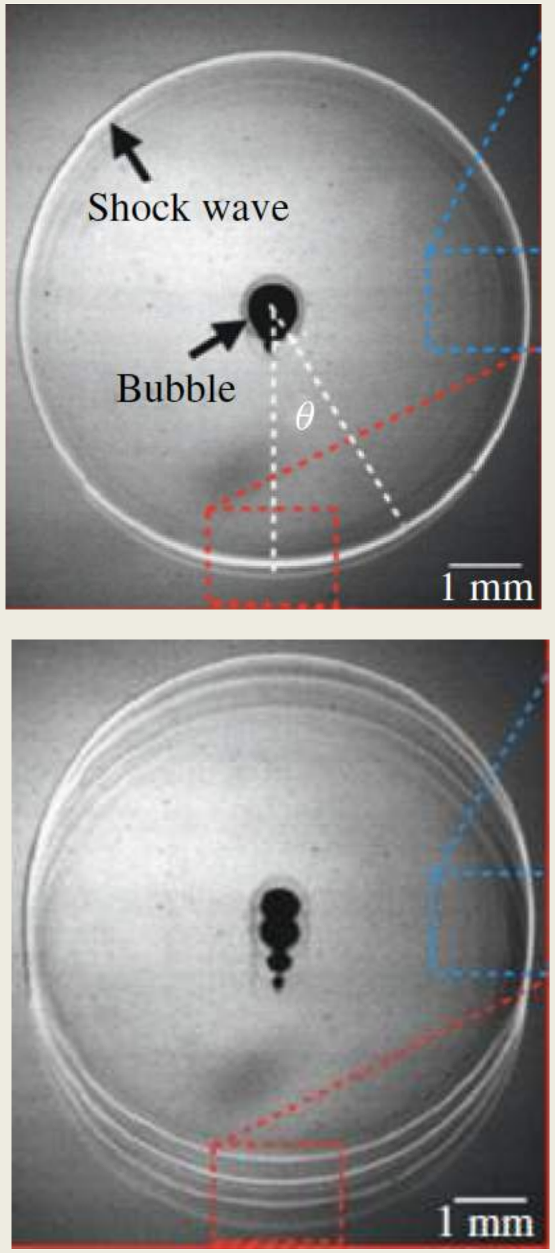
Hydrophone

Breakdown shock wave emission

laser





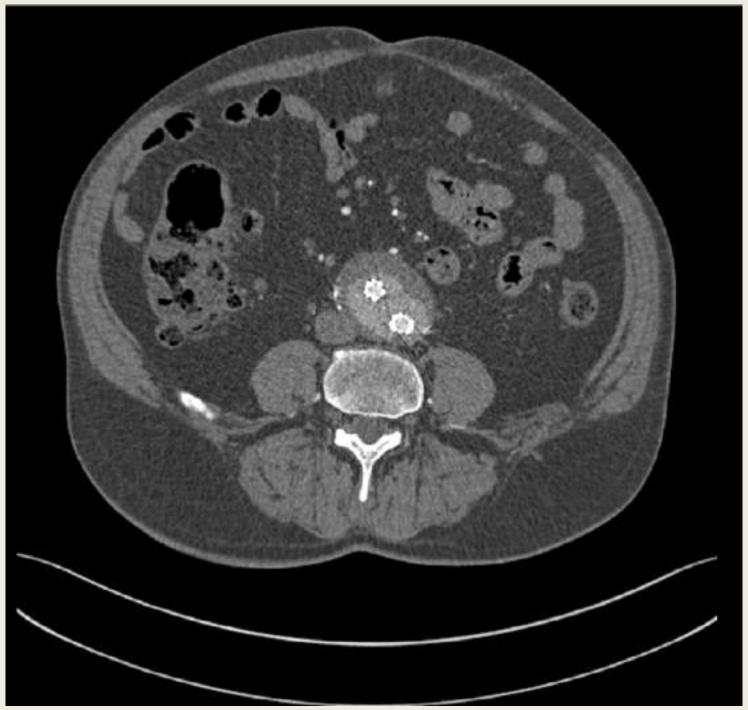


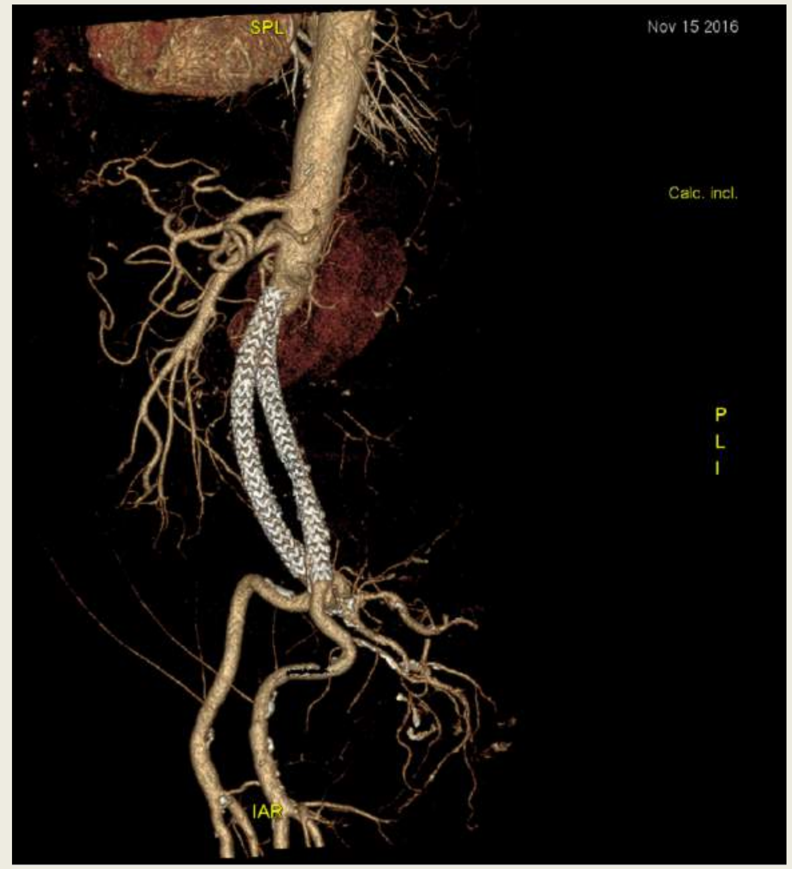
Tagawa et al 2016

After Implant Hemodynamics

After Implant Hemodynamics

Endologix





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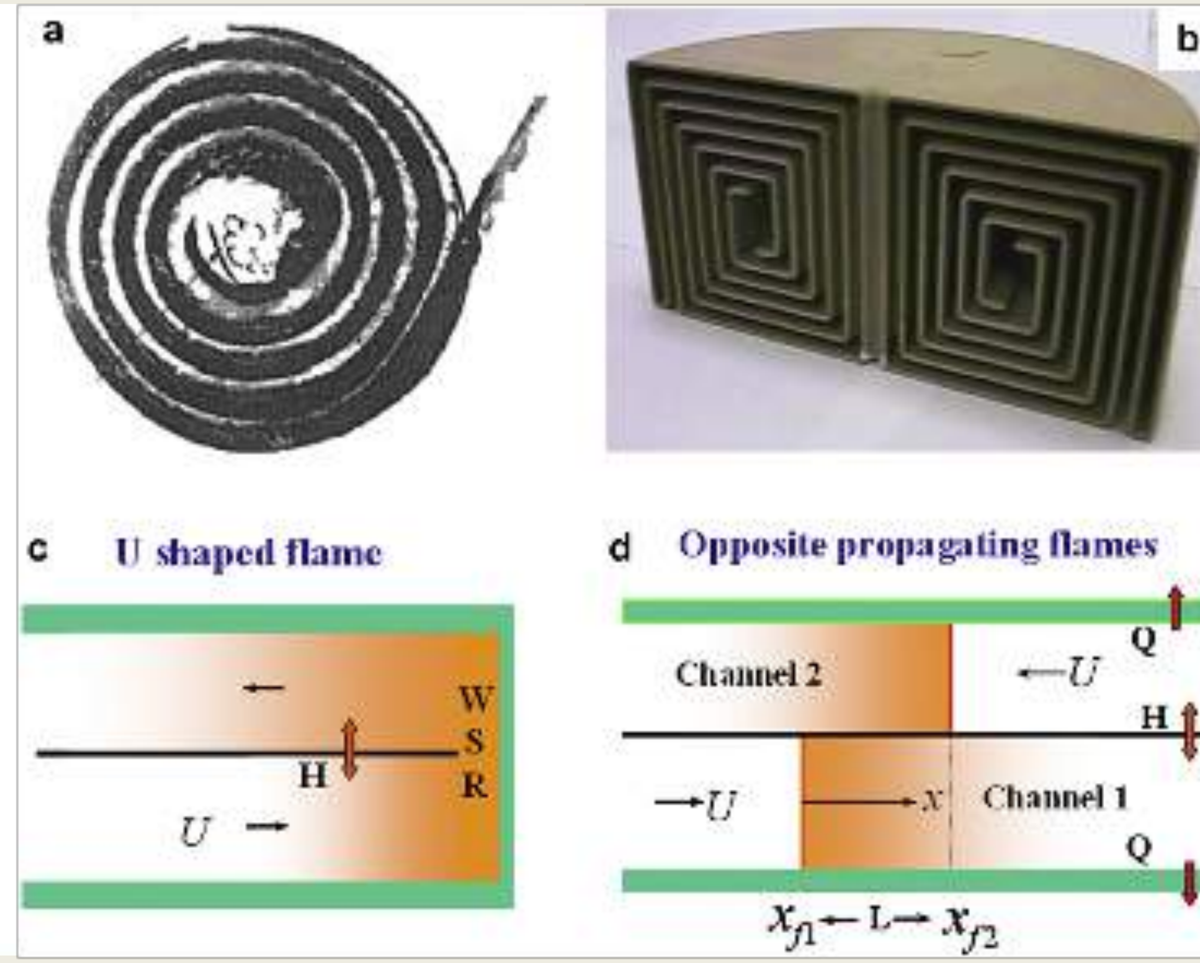
Paolo Gualtieri (DIMA)

DMCM - Dipartimento di Medicina Clinica e Molecolare

M. Taurino

Microcombustors

Microcombustors



Francesco Battista (DIMA)

Gianmatteo Carapellotti (MS DIMA)

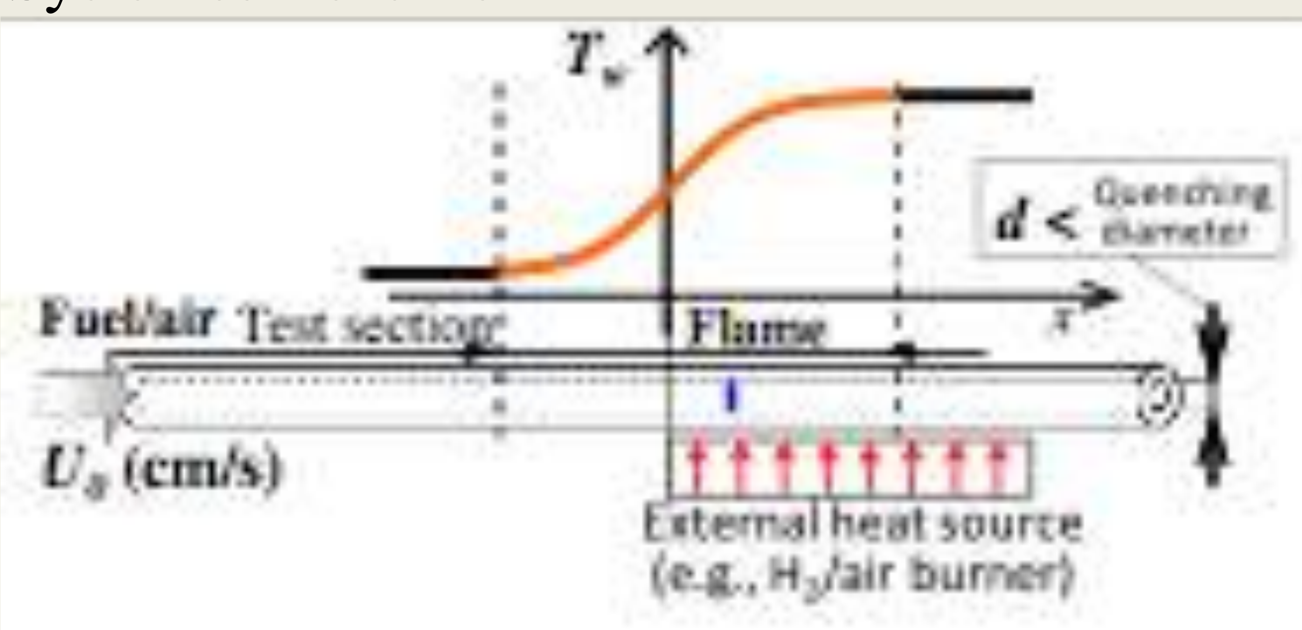
Matteo Hakimi (MS DIMA/UPMS)

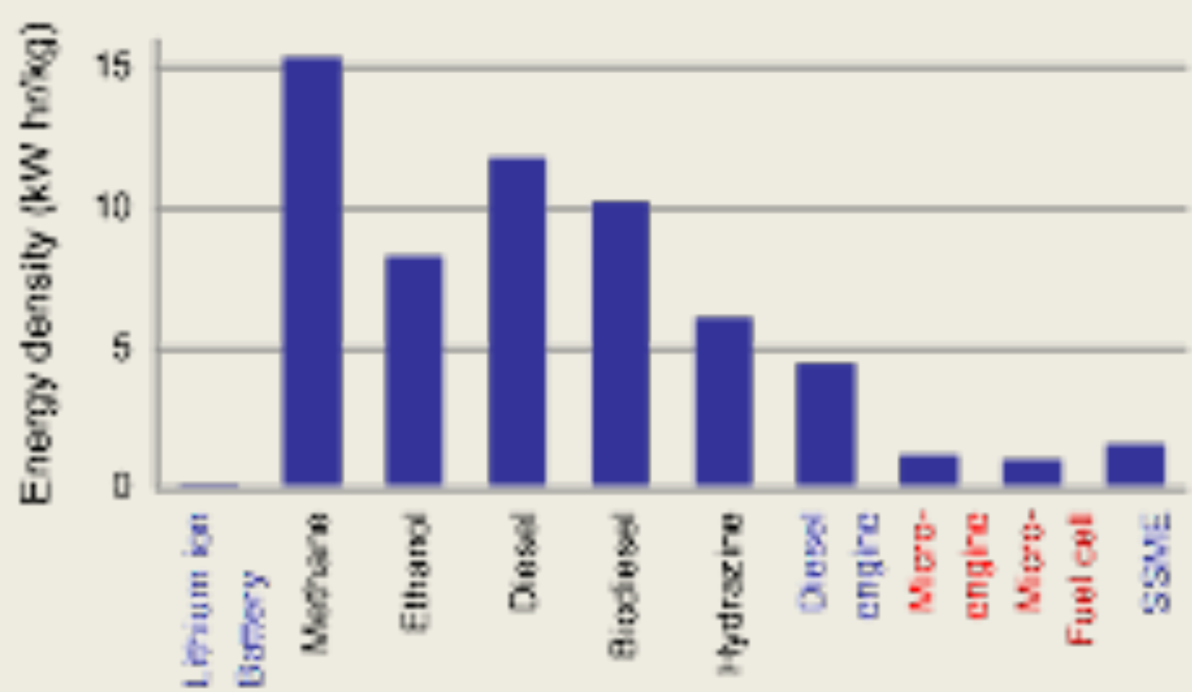
UPMC SORBONNE UNIVERSITÉS

S. Chibbaro

CNRS - Laboratoire de Combustion et Systemes Reactifs

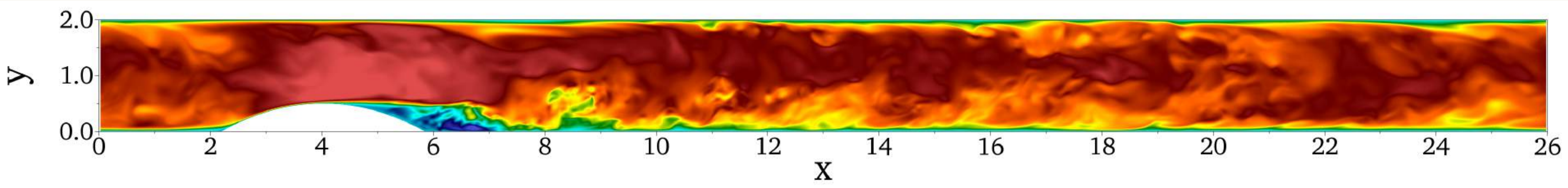
- Lithium ion batteries E = 0.2 kWh/kg
- micro combustors E=10 kWh/kg

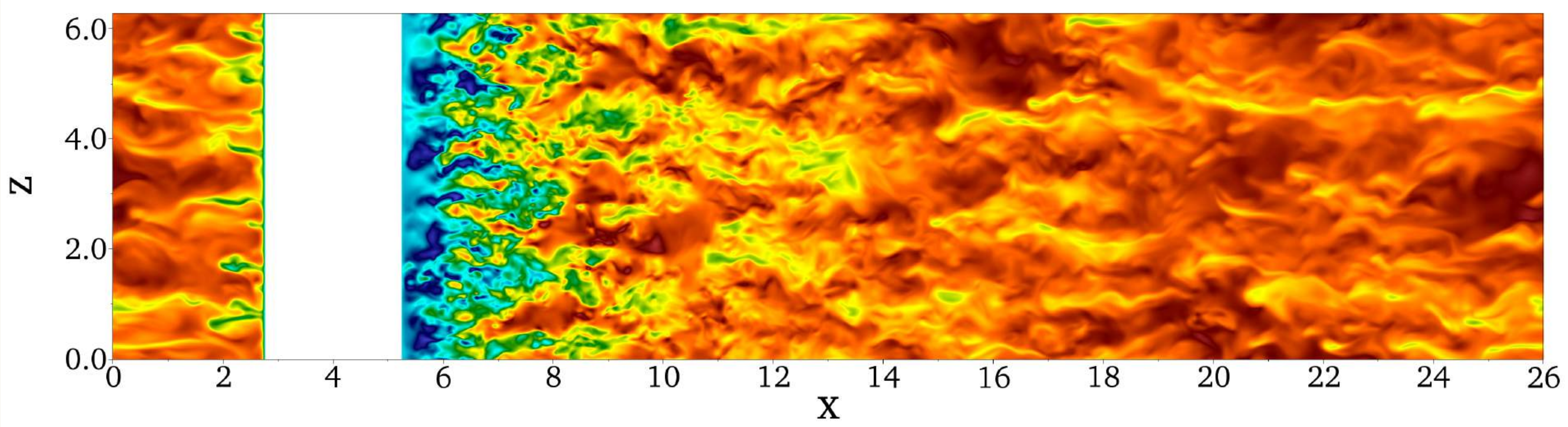




Fundamental Turbulence

Fundamental Turbulence





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E. Longmire, X. Jimenez