

## Scientific Report

ESF Exploratory Workshop on

# Physics of micro- and nano-flows

Leiden, (The Netherlands), 8-12 June 2008

Convened by:

**Lydéric Bocquet <sup>①</sup>, Detlef Lohse <sup>②</sup>, Federico Toschi <sup>③</sup> and  
Patrick Tabeling <sup>④</sup>**

<sup>①</sup> Condensed Matter Laboratory, University of Lyon, France

<sup>②</sup> Faculty of Science and Technology, University of Twente, Netherlands

<sup>③</sup> Istituto per le Applicazioni del Calcolo, Consiglio Nazionale delle Ricerche, Roma, Italy

<sup>④</sup> LMM, Ecole Supérieure de Physique et de Chimie Industrielles, Paris, France

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# **“Physics of micro- and nano- flows”**

**Leiden June 9-12 2008**

## **Organizers :**

Lydéric Bocquet, Prof., University of Lyon  
Federico Toschi, Prof., University of Eindhoven  
Detlef Lohse, Prof., University of Twente  
Patrick Tabeling, Dr., ESPCI, Paris

## **1. Executive summary**

- The workshop took place in the building of the Lorentz Center, Leiden University. The Lorentz Center provides remarkably convenient facilities, with – in addition to the conference room -- the help of a local secretary, offices for all participants, WIFI with access to most scientific journal, and a very large discussion room. The scientific discussions strongly benefited from this facilities.
- A dinner has been organized, which has been appreciated by the participants and helped participant in getting acquainted.
- The workshop gathered ~30 researchers
- From the opinion of participants, the workshop provided an excellent opportunity to discuss the state-of-the-art of this developing field, and explore new directions and the future of this emerging domain.

As discussed below, there is an opportunity to develop an international network on these topics.

## **2. Scientific content of the event**

During recent years, the pursuit of scale reduction inherent to nanotechnologies has been extended to the fluidic domain, with the very active development of micro-fluidics and now nano-fluidics. Such microscale “lab on a chip” devices are already widely used in biotechnological applications for target screening, for drug design, and for the analysis of small probes of biological material. However, increasing the density of fluidic operations on a chip even further, i.e. miniaturising fluidic devices more, leads to new questions and challenges, both from a fundamental and an application point of view. A key point is that future devices working at nano-scales cannot be thought on a basis of further scale reduction of existing devices working at larger scales: New solutions have to be found, taking the peculiarities of the small scales into account. This requires fundamental breakthroughs in their intrinsic operation and functionalities.

In this context, the aim of the workshop was to give an important contribution in the comprehension of flows at micro- and nano- scales and their potential couplings to the largest scales. We have gathered a community of experimentalists, theoreticians, computer scientists and technologists, working with different perspectives on fluid dynamics in very small systems and at interfaces. During the talks and accompanying discussions, we have explored the fundamental aspects of the physics of fluids at these scales, their modeling, and the new experimental tools and techniques, which have been specifically developed to assess the dynamics at the smallest scales.

During the workshop, talks and discussions have been organized around three themes:

- Micro- and Nano- flows
- New challenges in experimental fluid dynamics at small scales
- Modelling of fluids in small volumes

Round tables took place with the aim to controversially discuss some important subjects: slippage effects, their origin and implication in future nanofluidic devices; nanobubbles, the existence and control and fundamental understandings.

From the various talks and discussions among the participants, several scientific points have emerged:

- The microfluidic domain has now reached a level of maturation, where applications beyond "simple plumbers" starts to emerge, and which – as a key point – benefit crucially from the small scales involved (Strook, Weitz, Colin, Bocquet, ...). In other words, microfluidics is obviously not just a microscale downsizing of fluidic plumbers, but a clever use of specificity of phenomena occurring at the microscales has shown a very strong potential for future phenomena and applications. New applications are explored in this context, eg for desalinization, encapsulation, chemistry... It thus becomes clear that new microfluidic potentialities are being continuously invented, preparing for the future of this domain. New routes to develop nanofluidic systems are now being developed with emerging new routes with high potential. The new physical and chemical phenomena which occur at these scales are currently explored (Lemay, Riedo, Stein, Mugele, Tabeling)
- In parallel, there is a strong effort to develop fundamental understanding of fluid dynamics at the smallest scales, and involving complex – eg nanostructured – surfaces (Netz, Lohse, Vinogradova, Bazant, Squires, Bocquet, ...). The role of surface dynamics, surface nanoscale behavior, molecular effects, ... is now actively studied. In particular the recent development of new tools (computational, fundamental) has allowed to re-explore "old" phenomena (eg like electrokinetics), revisiting/reinventing their potential impact for micro and nano devices. This has driven new experiments in this context (Stein, Eijkel, Tabeling, etc.). This domain has therefore driven a strong back-and-forth interaction between experiments and theory.

- A subject which attracted a lot of attention is the possible existence of surface nanobubbles (Attard, Craig, Lohse, Vinogradova). The discussions addressed both new experimental evidences and possible theoretical explanations.
- Quite similarly to experimental microfluidics, simulations techniques have now reached a level allowing to go beyond the methodology level and address the physical questions raised by the specific behavior at nano and micro scales (Yeomans, Pagonabarraga, Sbragaglia, ...). Computational techniques like Lattice-Boltzmann and phase-field models are employed to study questions involving complex multiscale dynamics connecting the behavior at microscales to phenomena occurring at nanoscales.
- In parallel it is interesting to note that quite similar progress has been made for molecular simulations, *e.g.* Molecular Dynamics, which are now able to reach large scales (time and spatial) for ever more detailed and realistic models (Netz, Attard).

### **3. Content Assessment of the results, contribution to the future direction of the field**

At the end of the workshop the organizers took several concrete actions towards shaping the field of fundamental micro- and nanofluidics in Europe:

1. In a plenary discussion we jointly explored the possibility to apply for a research network on the fundamentals of micro- and nanofluidics, in order to systematically keep a closer interaction amongst experts who participated to this ESF exploratory workshop.
2. A smaller group of scientists, namely the organizers of the workshop, met to agree on concrete actions to be taken towards a joint European proposal on the subject. Key groups for such a network were identified. Submission in 2008 was considered to be unrealistic because of lack of time. Submission in 2009 is a realistic option. One of the organizers of the present ESF network will coordinate this effort.
3. The coordinator Prof. Federico Toschi agreed to coordinate a submission of a joint European programme within the COST framework. This proposal (on Lagrangian aspects of particles in flow) has meanwhile been submitted. There is considerable overlap of the groups involved in the COST proposal and the groups present at the ESF meeting.
4. Toschi also agreed to setup a internet database for micro- and nanofluidics, comparable to the database he had already set up for turbulence within the International Collaboration for Turbulence Research, ICTR, see webpage <http://www.ictr.eu/>
5. Immediately after the ESF workshop the Lorentz Center workshop started. Several of the ESF workshop participants extended their stay also to the LC workshop while other joined. During the LC workshop several students also took advantage of the presence of senior researchers to interact.

## 4. Final program

### Sunday 8 June 2008

Afternoon                      *Arrival*

19:30                              *Dinner at Restaurant **Hotel hel Witte Huis Oegstgeest**  
(Wilhelminapark 33, 2342 AE Oegstgeest, Tel: +31 (0)71 515 38 53)*

### Monday 9 June 2008

10.00-10.45                      *Coffee and registration*

10.45-11.10                      **Lorentz Center Welcome by organizers**

**Presentation of the European Science Foundation (ESF)**  
**Michel Mareschal** (Standing Committee for Physical and Engineering Sciences)

**Topic 1:                              New Challenges in experimental fluid dynamics at small scales**

11.10-11.40                      **Serge Lemay** (Delft University of Technology, NL)

11.40-12.10                      **Bruno Andreotti** (Laboratoire Hydrodynamique et Mécanique Physique, ESPCI, Paris, FR)

12.30-14.00                      *Lunch Break*

**Topic 3:                              Micro- and Nano-flows**

14.00-14.30                      **Vincent Craig** (Dept of Applied Mathematics, Australian National University, AU)

14.30-15.00                      **Elisa Riedo** (School of Physics, Georgia Institute of Technology, US)

15.00-15.30                      **Julia Yeomans** (Rudolf Peierls Centre for Theoretical Physics, Oxford, UK)

15.30-16.00                      *Coffee Break*

16.00-16.30                      **Phil Attard** (School of Chemistry, University of Sidney, AU)

16.30-17.00                      **Annie Colin-Exterieur** (CNRS-UMR 5258, Université de Bordeaux, FR)

17.00-17.30                      *Wine and Cheese party*

17.30-18.30                      **Roundtable**

### Tuesday 10 June 2008

**Topic 2:                              Modelling of fluids in small volumes**

09.00-09.40                      **Roland Netz** (Physics Department, Technical University Munich)  
**Driven soft matter in nano-confinement**

09.40-10.10                      **Joel Koplik** (Institute for Physico-Chemical Hydrodynamics, City College of CUNY, New York, US)

10.10-10.30                      *Coffee Break*

10.30-11.00                      **David Weitz** (Department of Physics, Harvard University, US)

11.00-12.30                      **Informal discussions**

12.30-13.30	<i>Lunch Break</i>
13.30-14.00	<b>Roundtable</b>
<b>Topic 2:</b>	<b>Modelling of fluids in small volumes, ctd</b>
14.00-14.30	<b>Mauro Sbragaglia</b> (University of Tor Vergata, Rome, IT) <b>Wetting failure and contact line dynamics in a Couette Flow</b>
14.30-15.00	<b>Martin Bazant</b> (Department of Mathematics, MIT, US)
15.00-15.30	<i>Coffee Break</i>
15.30-17.00	<b>Informal discussions</b>
17.00-18.00	<b>Roundtable</b>

## Wednesday 11 June 2008

<b>Topic 1:</b>	<b>New Challenges in experimental fluid dynamics at small scales</b>
09.00-09.40	<b>Olga Vinogradova</b> (Max-Planck-Institute für Polymerforschung, Mainz, DE)
09.40-10.10	<b>Lydéric Bocquet</b> (LPMCN, Université de Lyon, FR)
10.10-10.30	<i>Coffee Break</i>
10.30-11.00	<b>Patrick Tabeling</b> (LMM, ESPCI, Paris, FR)
11.00-11.30	<b>Derek Stein</b> (Brown University, Atlanta, US)
11.30-12.00	<b>Detlef Lohse</b> (Twente University, Enschede, NL)
11.30-12.30	<b>Informal discussions</b>
12.30-13.30	<i>Lunch Break</i>
13.30-14.00	<b>Roundtable</b>
<b>Topic 3:</b>	<b>Micro- and Nano-flows</b>
14.00-14.30	<b>Marc Fermigier</b> (Laboratoire PMMH, ESPCI, Paris, FR)
14.30-15.00	<b>Christophe Clanet</b> (LadHyX, Ecole Polytechnique, Palaiseau, FR)
15.00-15.30	<i>Coffee Break</i>
15.30-16.00	<b>Frieder Muegele</b> (Faculty of Applied Physics, University of Twente, NL)
16.00-17.00	<b>Roundtable</b> (ctd)
17.00-21.00	<i>Boat trip</i>

## Thursday 12 June 2008

<b>Topic 2:</b>	<b>Modelling of fluids in small volumes</b>
09.30-10.00	<b>Ignacio Pagonabarraga</b> (Facultat de Física, University of Barcelona, ES)
10.00-10.30	<b>Abraham Stroock</b> (Cornell University, Ithaca, US)
10.30-11.00	<i>Coffee Break</i>
11.00-11.20	<b>ShangJiong Yang</b> (University of Twente, NL)

11.20-12.30	<b>Informal discussions</b>
12.30-13.30	<i>Lunch Break</i>
13.30-14.00	<b>Roundtable</b>
<b>Topic 3:</b>	<b>Micro- and Nano-flows</b>
14.00-14.30	<b>Jan Eijkel</b> (University of Twente, NL)
14.30-15.00	<b>Todd Squires</b> (University of California, Santa Barbara, US)
15.00-17.00	<b>Roundtable to discuss follow-up activities in particular concerning possible joint research activities and funding opportunities</b>
17.00	<i>End of ESF Workshop</i>

## 5. Statistical information on participants (age structure, gender repartition, countries of origin, etc.)

We are not aware of the precise age of most participants. We can however state that a good balance between senior scientists (Attard, Weitz, Netz, Tabeling, Lohse, ...) and more 'junior' scientists (Andreotti, Bazant, Colin, ...) has been reached.

Gender repartition : Female : 5 / Male : 23

Countries of origin :

Australia : 2

France : 6

Germany : 1

Holland : 7

Italy : 2

Russia : 1

Spain : 1

UK : 1

US : 7

## 6. Final List of Participants

### Convenor:

1. **Lyderic BOCQUET**  
Condensed Matter Laboratory  
University of Lyon  
Villeurbanne  
69622 Lyon  
France  
Lyderic.Bocquet@ipm.cn.univ-lyon1.fr

4. **Federico TOSCHI**  
IAC  
CNR  
Viale del Policlinico 137  
00161 Roma  
Italy  
toschi@iac.cnr.it

### Co-Convenors:

2. **Detlef LOHSE**  
Faculty of Science and Technology -  
University of Twente  
Physics of Fluids  
Building MEANDER (27)  
P.O. Box 217  
7500 AE Enschede  
Netherlands  
d.lohse@utwente.nl

3. **Patrick TABELING**  
LMM  
ESPCI  
10 rue Vauquelin  
75005 Paris  
France  
patrick.tabeling@espci.fr

### ESF Representative:

5. **Michel MARESCHAL**  
Département de Physique  
Faculté des Sciences  
Université Libre de Bruxelles  
Bld du Triomphe  
CP 223  
1050 Bruxelles  
Belgium  
mmaresch@ulb.ac.be

### Participants:

6. **Bruno ANDREOTTI**  
Laboratoire Hydrodynamique et  
Mécanique Physique (HMP) de l'ESPCI  
10 rue Vauquelin  
75005 Paris  
France  
andreotti @pmmh.espci.fr



7. **Phil ATTARD**  
School of Chemistry, Building F11,  
The University of Sydney, NSW 2006,  
Australia  
NSW 2006 Sidney  
Australia  
phil.attard@chem.usyd.edu.au
8. **Martin BAZANT**  
MIT  
Department of Mathematics, 2-363B  
Cambridge MA 02139-4307  
United States  
bazant@math.mit.edu
9. **Bram BORKENT**  
Physics of Fluids, Faculty of Science and  
Technology - University of Twente  
Building MEANDER (27), P.O. Box 217  
7500 AE Enschede  
Netherlands  
b.m.borkent@tnw.utwente.nl
10. **Christophe CLANET**  
Ecole Polytechnique  
LadHyX  
91128 Palaiseau  
France  
clanet@ladhyx.polytechnique.fr
11. **Annie COLIN**  
LOF, unité mixte CNRS / Rhodia /  
Bordeaux-I 178, avenue du Dr Schweitzer  
F-33608 Pessac, France  
Bordeaux  
France  
Annie.COLIN-  
EXTERIEUR@eu.rhodia.com
12. **Vincent CRAIG**  
Department of Applied Mathematics  
Research School of Physical Sciences and  
Engineering  
Australian National University  
ANU Campus  
Canberra ACT 0200  
Australia  
cnce.craig@anu.edu.au
13. **Sissy DE BEER**  
Dept. Science and Technology  
Physics of Complex Fluids  
University of Twente  
PO Box 217  
7500AE Enschede  
Netherlands  
s.j.a.debeer@tnw.utwente.nl
14. **Jan EIJKEL**  
University of Twente  
PO Box 217  
7500 AE Enschede  
Netherlands  
j.c.t.eijkel@utwente.nl
15. **Marc FERMIGIER**  
Laboratoire PMMH ESPCI  
10 rue Vauquelin  
75231 Paris Cedex 05  
France  
marc.fermigier@espci.fr
16. **Joel KOPLIK**  
Benjamin Levich Institute for Physico-  
Chemical Hydrodynamics  
City College of CUNY  
140th Street & Convent Avenue  
New York NY 10031  
United States  
koplik@sci.ccny.cuny.edu
17. **Serge LEMAY**  
Delft University of Technology  
Kavli institute for nanoscience  
Lorentzweg 1  
2628 CJ Delft  
Netherlands  
S.G.Lemay@tudelft.nl
18. **Frieder MUGELE**  
Physics of Complex Fluids  
Faculty of Applied Physics  
University of Twente  
Postbus 217  
7500 AE Enschede  
Netherlands  
f.mugele@utwente.nl
19. **Roland NETZ**  
Physik Department (T37)  
Technische Universitaet Muenchen  
James Franck Strasse  
85748 Garching  
Germany  
netz@ph.tum.de
20. **Ignacio PAGONABARRAGA MORA**  
Departament de Física Fonamental  
Facultat de Física  
University of Barcelona  
Martí i Franquès, 1  
08028 Barcelona  
Spain  
ipagonabarraga@ub.edu

21. **Elisa RIEDO**  
School of Physics  
Georgia Institute of Technology  
837 State Street  
Georgia Atlanta 30332-0430  
United States  
elisa.riedo@physics.gatech.edu
22. **Mauro SBRAGAGLIA**  
University of Tor Vergata  
Via della Ricerca Scientifica  
00133 Roma  
Italy  
sbragaglia@roma2.infn.it
23. **Todd SQUIRES**  
Chemical Engineering Dept.  
University of California  
Mail Code 5080  
CA 93106-5080 Santa Barbara  
United States  
squires@engineering.ucsb.edu
24. **Derek STEIN**  
Brown University  
182 Hope Street  
Providence RI 02912  
United States  
derek\_stein@physics.brown.edu
25. **Abraham STROOCK**  
Cornell University  
360 Olin Hall  
Ithaca NY 1485  
United States  
ads10@cornell.edu
26. **Olga I. VINOGRADOVA**  
Nano- & Microfluidics/Institute for Polymer  
Research  
Max-Planck-Institut für Polymerforschung  
Ackermannweg 10  
55128 Mainz  
Germany  
vinograd@mpip-mainz.mpg.de
27. **David WEITZ**  
Department of Physics  
Harvard University  
29 Oxford Street  
Cambridge MA 02138  
United States  
weitz@seas.harvard.edu
28. **ShangJiong YANG**  
University of Twente  
PO Box 217  
7500 AE Enschede  
Netherlands  
s.j.yang@tnw.utwente.nl
29. **Julia Yeomans**  
Condensed Matter Theory: Soft and  
Biological Matter  
Rudolf Peierls Centre for Theoretical  
Physics  
1 Keble Road  
Oxford  
United Kingdom  
j.yeomans1@physics.ox.ac.uk