International Advanced Course in Liquid Interfaces, Drops and Sprays (LIDESP)

A Five Day Course in Darmstadt, Germany, 5-10 May, 2014
Center of Smart Interfaces, Technische Universität Darmstadt
http://pcwww.liv.ac.uk/~vbertola/Lidesp

International Course Directors
A. Amirfazli, V. Bertola, M. Marengo
Hosting Directors
C. Tropea, B. Weigand

COURSE DESCRIPTION

LIDESP is an International Advanced Course on the Interface, Drops and Liquid Sprays Physics, which is held every year in different locations around the world. The core of the lecture plan is provided by three well-known and highly recognized experts in the field: Prof. Amirfazli, York University, Toronto, Canada, Prof. Bertola, University of Liverpool, UK, Prof. Marengo, University of Bergamo, Italy. They not only deliver part of the instructional module, but also every year, depending on the venue, different modules of the program are taught by local experts, under the coordination of Host Directors. The first edition will be held at the Technische Universität Darmstadt, at the Center of Smart Interfaces, in collaboration with the **EU COST Action Group** *Smart and green interfaces – from single bubbles and drops to industrial, environmental and biomedical applications*, and the DFG Collaborative Research Center **SFB-TRR 75** – *Droplet Dynamics under Extreme Ambient Conditions*.

The **knowledge** of the physics of liquid drops and sprays is essential for many applications, from aeronautics (icing) to oil extraction (effervescent spray, drop collisions in pipes), from electronics (spray cooling) to agriculture (pesticide distribution), from microfluidics (droplet management) to painting processes (spray coating), from biology (blood droplets, sterilization) to thermal transfer (condensation in heat exchangers), from chemistry (drying tower) to medical applications.

The course **objective** is to provide the participants with today's detailed knowledge on the physics of drops and sprays based on recent research results and the most updated methods for the prediction of dynamic outcomes, heat transfer, wettability effects, and its applications to technological and industrial areas. Specific attention will be paid to the applications in life science, such as microdroplet management. Application to chemical processes will be dealt with special care in view of the industrial interest towards this component, while the very recent application of drop management in microscale, including microstructured surfaces will be treated in detail.

The course is addressed to scientists, professionals, company engineers, R&D managers and graduate students in the fields of Engineering, Chemistry, Biology, Medicine, Applied and Fundamental Sciences. This course is especially of interest to those dealing with phenomena involving drops and sprays, in order to get acquainted with the traditional background and the most recent developments of this discipline.

COURSE LECTURES

I1 *Introduction and basic concepts.* Gallery of basic phenomena, micro- to macro- scale (molecular dynamics/continuum approaches), contact angle, Young equation - **Amirfazli**

I2 *Introduction to fluid mechanics of liquid interfaces.* Basic equations, liquid film modelling, liquid jet break up, drop oscillations – **Bertola**

I3 *Introduction to drop interactions*. Introduction to drop-drop collision, drop impact on a pool, drop impact on dry and wetted surfaces. - **Marengo**

I4 *Surface tension & measurement techniques.* Equilibrium and dynamic surface tension. De Nouy/Wilhelmy, sessile drop and pendant drop (ADSA), maximum bubble pressure. - **Bonaccurso**

D1 *Dynamics of drops deposited on a surface.* Sessile drops, spreading law, apparent and real contact angles. Drop shedding, contact angle hysteresis - **Amirfazli**

D2 *Drop impact with a solid surface*. Impact regimes, impact models, drop rebound. - **Roisman**

D3 *Drop impact on liquid surfaces*. Morphology. Shallow and thick layers. Crater modelling. Splashing correlations. – **Marengo**

D4 *Drop-drop collision.* Phenomenology and collision regimes. Survey of modelling and simulation results. - **Bertola**

D5 *Heat and mass transfer in drops.* Heat transfer mechanisms. Experimental investigations. Multiscale modeling approaches - **Stephan**

D6 *Drop impact on heated surfaces.* Introduction to drop impact onto heated surfaces. Impact regime maps. Transitions. Dynamic Leidenfrost temperature. Control of secondary atomization and splashing. – **Marengo**

D7 *Survey of Direct Numerical Simulation (DNS) methods for interfacial flow phenomena.* Basic equations. Benchmark solutions. Application to drop-drop collisions. - **Bothe**

D8 *Direct Numerical Simulations (DNS) of drop dynamics*. Introduction to the FS3D (Free Surface 3D) code. Governing equations. Volume of Fluid (VOF) tracking method. Treatment of numerical dissipation and spurious solutions. - **Weigand**

NN1 *Introduction to non-Newtonian fluids*. Constitutive models and practical examples (polymer solutions and melts, gels, etc.). Power-law fluids, viscoplastic fluids, viscoelastic fluids. Non-Newtonian fluid design. Elements of rheological measurements. - **Bertola**

NN2 *Drop impact on soft surfaces and membranes.* Characterisation of soft surfaces. Impact morphology as a function of the surface response. Differences with respect to impacts on solid surfaces - **Bonaccurso**

NN3 *Impact of non-Newtonian drops*. Formation of non-Newtonian droplets by capillary breakup. Impact of power-law and viscoplastic drops on solid surfaces. Impact of dilute polymer solution drops. Dynamic wetting. - **Bertola**

S1 *Physics of sprays and applications.* Spray formation, atomisation models. Evaporation, gas entrainment, impact. - **Marengo**

S2 *Spray characterization*. Measurement of drop size and drop flux densities. Optical techniques. Counting and integral methods. Point and planar techniques. Advantages and disadvantages. – **Tropea**

A1 *Superhydrophobicity.* Application of superhydrophobic surfaces. Cassie-Wenzel and competing theories. Types of SHS and manufacturing techniques. Impact on SHS surfaces. Impalement transition – **Butt**

A2 *Icing and anti-icing techniques.* Formation of ice, morphology. Applications (aircraft, helicopter, wind turbine, cables). Anti-icing and de-icing strategies. – **Amirfazli**

A3 *Spray applications.* Empirical correlations and nozzle selection Atomization technologies (air blast, ultrasound, etc) – **Marengo**

A4 *Application of what you learned in the course:* (a) Inkjet technology: Design of printheads, waveforms, ink formulations (b) Microlens manufacturing, (c) Metal deposition, (d) 3D printing, (e) non-Newtonian sprays. – **Bertola**

LECTURERS

Prof. Alidad Amirfazli

Before joining the York University as the founding Chair of the Department of Mechanical Engineering, Alidad Amirfazli held the Canada Research Chair in Surface Engineering at the University of Alberta, Canada. Amirfazli has produced exciting results in wetting behavior of surfaces, drop adhesion and shedding, understanding and application of superhydrophobic coatings. He has more than 200 scientific contributions, many in prestigious peer reviewed journals; he is the Editor for the Advances in Colloid and Interface Science (IF 6.2). Dr. Amirfazli has been the recipient of the Martha Cook Piper Research prize, Killam Annual Professorship, and Petro-Canada Young Innovator Award. He also served in the board of Professional Engineers of Alberta, and been a consultant with various companies in USA, Europe, and Canada.

Prof. Volfango Bertola

Joined the University of Liverpool in 2011, after holding a Lectureship at the University of Edinburgh (2004-1011) and a Marie Curie Fellowship at the Ecole Normale Supérieure in Paris (2001-2004). In 2009-10 he was Visiting Professor and Lagrange Fellow at Politecnico di Torino (Italy). He has more than 100 scientific publications in the areas of soft matter, multiphase flows, and thermodynamics, including several contributions on non-Newtonian drops and on the dynamic wetting of complex fluids. He has been the recipient of a Royal Academy of Engineering Global Research Award (2009) and the UIT Young Scientist Prize (2001).

Prof. Marco Marengo

Graduated in Physics at the University of Turin cum laude and completed his Ph.D. studies at the Polytechnic of Milan and University of Erlangen with a thesis about “Drop Impingement on Liquid Film”. He was awarded by the Deutscher Akademischer Austauschdienst (DAAD) and by the European Community TMR Program. From 1998 to 2002 he was assistant professor of Thermal Physics at the University of Bergamo and then Associate Professor. From 2003 to 2005 he was the University Responsible for the European Research. He is European Editor of the Journal "Atomization & Sprays". Visiting Professor at the University of Mons-Hainaut since 2005. He published more than 160 scientific papers, many in peer-reviewed journals about liquid sprays, drop impact, heat pipes, building physics. Prof. Marengo has been founder of two spin-off companies and holds seven patents.

Prof. Cameron Tropea
Graduated from the University of Toronto in Engineering Sciences, followed by a Masters degree in Mechanical Engineering (1977). He completed his Dr.-Ing. in Civil Engineering at the Technical University of Karlsruhe (1982) and his Habilitation in Fluid Mechanics at the University of Erlangen-Nürnberg (1991) where he was appointed as Professor of Fluid Mechanics until 1997. This was followed by an appointment to his current chair of Fluid Mechanics and Aerodynamics at the Technische Universität Darmstadt. Currently Editor-in-Chief of the Springer journal Experiments in Fluids, he is also the Head of Center of Smart Interfaces (CSI) since 2007. His research interests include Optical Measurement Techniques in Fluid Mechanics, Interfacial Transport Phenomena, Atomization and Spray Processes and Unsteady Aerodynamics.

Prof. Bernhard Weigand
Professor for Thermodynamics at the University of Stuttgart and the director of the institute for Aerospace Thermodynamics (ITLR) at the faculty of Aeronautics and Geodesy. After his PhD in Darmstadt in 1992 he joined ABB Power Generation in Switzerland where he worked up to March 1999. At ABB he was responsible for the basic development in heat transfer and cooling, as well as for the heat transfer and cooling design for all new gas turbine blades. His current research interests focus on basic droplet dynamics, heat transfer and supersonic combustion. He is the author of about 300 papers, several books and holds about 40 different patent applications or patents.

Prof. Dieter Bothe
Professor at the Department of Mathematics and Head of the research area Mathematical Modeling and Analysis at the Center of Smart Interfaces at Technical University of Darmstadt. After his scientific education at the University of Paderborn, he held the Chair for Mathematics/CCES at the RWTH Aachen University from 2005 to 2009. Dieter Bothe is on the editorial advisory board of the “International Journal of Multiphase Flow”, associated editor of the international journal “Nonlinear Analysis: Real World Applications”, and coordinator of the Priority Programme SPP 1506 "Transport processes at fluid interfaces" of the German Science Foundation (DFG).

Prof. Hans-Jürgen Butt
Studied physics at the Universities of Hamburg and Göttingen. He received his Diploma in 1986. Then he moved to Frankfurt to work in Ernst Bamberg's group at the Max Planck Institute for Biophysics on light induced proton transport of bacteriorhodopsin. After his PhD in 1989 as a postdoc in Santa Barbara with Paul Hansma he got into contact with the newly developed atomic force microscope. From 1990-96 back in Frankfurt as a researcher he studied biological objects with AFM. In this period the work on surfaces in particular on surface forces became a central issue. In 1996 he went to the institute for physical chemistry at the Johannes Gutenberg-University in Mainz as associate professor. There he focussed on the physics and chemistry of interfaces. Three years later he joined the University of Siegen as full professor for physical chemistry. In 2002 he followed a call to the Max Planck Institute for Polymer Research in Mainz, where he is a director. His work focuses on the experimental physics of interfaces.

Prof. Peter Stephan
Professor of Technical Thermodynamics, director of the eponymous institute, and co-director of the Center of Smart Interfaces at Technische Universität Darmstadt. He was a Marie-Curie Research Fellow at the EU Joint Research Centre in Ispra, Italy, from 1989 to 1992, and received his Ph.D. in 1992 from the University of Stuttgart. From 1992 to 1997 he was working as a senior process engineer and R&D manager in the Daimler-Benz group. Since 1997 he is at Technische Universität Darmstadt. His main fields of research are boiling heat transfer, microscale heat and mass transfer, interfacial phenomena, heat pipe technology, and thermal system analysis. He received the IIR Sadi Carnot Prize in 1995, the SFT Prize for Excellence in Heat Transfer Research in 2002, and the HTSJ Nukiyama Memorial Award in 2012. He is president of the German Heat and Mass Transfer Association.

Prof. Ilia Roisman
Privat Dozent at the Institute of Fluid Mechanics, Technische Universität Darmstadt, Germany. He received his D. Sc. At the Technion – Israeli Institute of Technology, Haifa, Israel in 1998. Among his research interest are hydrodynamics and heat transfer in multiphase, capillary flows flows, atomization, wetting and icing. The methods include theoretical analysis, numerical simulations and experiments. He is an author of more than 40 journal publications. In 2010 he has received the “STAB-Forschungspreis für Strömungsmechanik” award for development of the theoretical models for drop wall collision.

Dr. Elmar Bonaccurso
Research group leader at the Cener of Smart Interfaces of the Technsiche Universität Darmstadt, Germany. He did his Habilitation at the University of Mainz, Germany in 2008 and he received his PhD at the University of Siegen, Germany. His main research interests are in the areas of interfacial and capillary phenomena, static and dynamic wetting, and atomic force microscope investigations. He is author of approx. 70 journal publications. In 2007 he received the Richard Zsigmondy Prize of the German Colloid Society for his works on evaporating microdroplets.

REGISTRATION FEES (Euros)

Academic (tenure, post-doc, researcher)	1000€
Ph.D students	800€
Industry (VAT to be added)	1200€
COST/SFB up to 9/5 participants	500€

The fees include lunches and coffee breaks. Registration deadline: **31st March 2014**. Maximum number of participants: **40**. Special requests for accomodation will be considered by the CSI organization staff.

TO REGISTER: Applicants should register online at LIDESP Website

VENUE

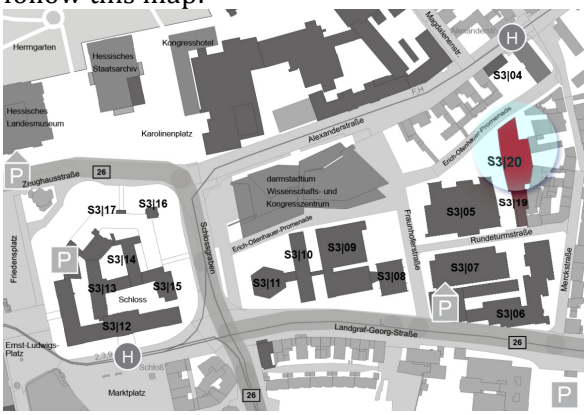
The workshop will take place at

Seminar Room 18, Building S3|20
Technische Universität Darmstadt
Rundeturmstraße 10
64283 Darmstadt, Germany

How to find us (public transport)
1) Take Buslines F or H and exit at stop "Alexanderstrasse".
2) Take either tram 2,3 or 9 and exit at stop "Schloß"

Here's a link for the public transport info system:
http://www.rmv.de/auskunft/bin/jp/query.exe/en#focus
As destination type: "Darmstadt Alexanderstraße/TU", „Darmstadt Schloß"

From either „Schloß" or „Alexanderstrasse" please follow this map:



TU Darmstadt Campus
Information on the Center of Smart Interfaces:
www.csi.tu-darmstadt.de

Building can be reached via either via Merckstraße or Fraunhoferstraße.

The seminar room in building S3|20.

Building S3|20 seen from Rundeturmstraß

FURTHER INFO: Prof. Marco Marengo, marco.marengo@unibg.it