Department of Mechanical Engineering
Indian Institute of Technology Kanpur
Kanpur 208016
India

Heat Transfer Laboratory @IITK

Overview of Research Activities

(Updated: February 2011)

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Present research focus

Experimental heat transfer with a focus on issues related to phase-change phenomena in mini/micro systems

Development of internet based experiments

Key words

Liquid-Vapor Phase Change Phenomena

Heat Pipes/ Pulsating Heat Pipes/ Thermosyphons

Flow and Heat Transfer in Narrow Channels

Dropwise Condensation

Oscillating Taylor bubble flows

Passive cooling techniques

Energy Systems

Nanofluids

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Research laboratory development

Clean Air Conditioned Laboratory Space (200 m^2)

Major equipment

- **High Speed Infrared Thermographic Camera (FIST)**
- **200 W Laser micromachining station**
- **Turbo-molecular / Diffusion vacuum pumps (3)**
- **Helium leak detector**
- **15mW He-Ne Laser, Optical Bench**
- **Optical microscope**
- **Air flow facility (wind tunnel)**
- **Constant temperature baths (4)**
- **High speed/ Precision NI-DAQ systems (5)**
- **Color and Monochrome CCD camera (2)**
- **Digital video/still camera (2)**
- **Vacuum oven**

Fabrication Workshop

- Table Top CNC Machine
- Conventional Lathe Machine
- Milling and Radial Drilling Machine
- Arc/Gas Welding; Brazing station
- Air Compressor

Accessories

- PCs (10); Work Stations (2)
- Fire fighting equipment
- Photo copier, Overhead beamer
- Aquaguard/ Refrigerator
- Online UPS, Voltage Stabilizers

Laboratory photographs

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Sponsored research – Completed Projects

• Project # 1 (Completed) **PRINCIPAL INVESTIGATOR**

Modernization of Refrigeration and Air Conditioning Laboratory (ME) and Research Initiation in Microscale Multi-phase Systems

Indian Institute of Technology Kanpur (Faculty initiation grant)

Budget: INR 10 lacs Time: 1 Year (May 2005-April 2006)

• Project # 2 (Completed) **PRINCIPAL INVESTIGATOR**

Development of Pulsating Heat Pipe Based Space Radiators

Indian Space Research Organization

Budget: INR 15 lacs Time: 3 Years (May 2005-April 2008)

• Project # 3 (Completed) **CO-INVESTIGATOR**

Drop-wise Condensation on an Inclined Surface Exposed to a Vapor Flux (with Dr. K. Muralidhar)

Board of Research in Nuclear Sciences

Budget: INR 40 lacs Time: 4 Years (May 2005-April 2009)

• Project # 4 (Completed) **PRINCIPAL INVESTIGATOR**

Design and Development of Novel Pulsating Heat Pipe Based Compact Heat Exchangers

Department of Atomic Energy Young Scientist Award

Board of Research in Nuclear Sciences

Budget: INR 10 lacs Time: 3 Years (April 2006-March 2009)

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Sponsored research – Ongoing Projects

• Project # 5 (Ongoing) **CO-INVESTIGATOR**

(with Dr. D. Kunzru, Dr. S. Panda and Dr. P. K. Panigrahi)
Micro-devices for Process Applications
Department of Science and Technology
Budget: INR 500 lacs Time: 5 Years (April 2006-March 2011)

• Project # 7 (Ongoing) **PRINCIPAL INVESTIGATOR**

Pulsating Heat Pipe Based Compact Heat Exchangers for Passive Heat Removal
Department of Atomic Energy
Budget: INR 80 lacs Time: 4 Years (January 2009-December 2012)

• Project # 8 (Ongoing) **PRINCIPAL INVESTIGATOR**

Development of Internet based Heat Transfer Laboratory
Ministry of Human Resource Development
Budget: INR 50 lacs Time: 1 Year (April 2009-March 2010)

• Project # 9 (Ongoing) **PRINCIPAL INVESTIGATOR**

Thermo-hydrodynamics of Oscillating Taylor Bubble Flows
INDO-FRENCH Center for Promotion of Advanced Scientific Research (CEFIPRA)
Budget: INR 80 lacs Time: 3 Years (May 2009-April 2012)

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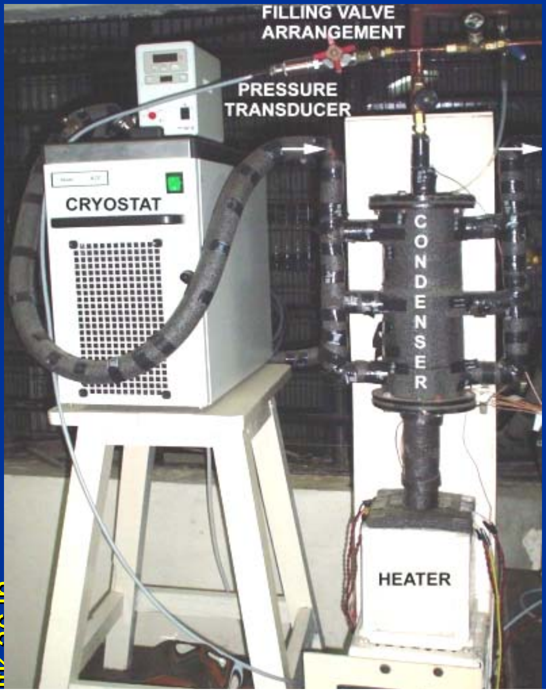
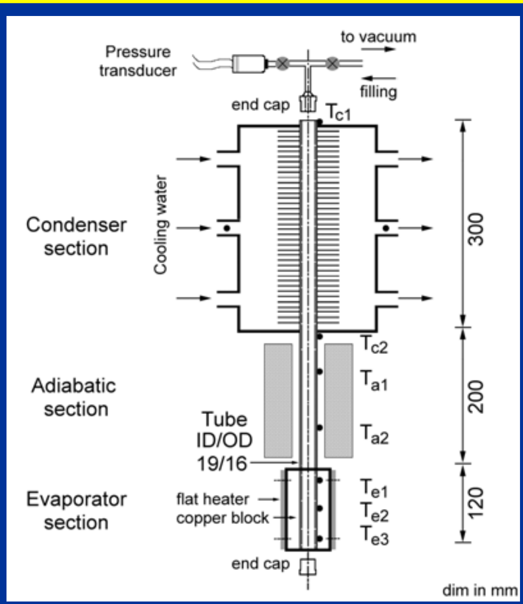
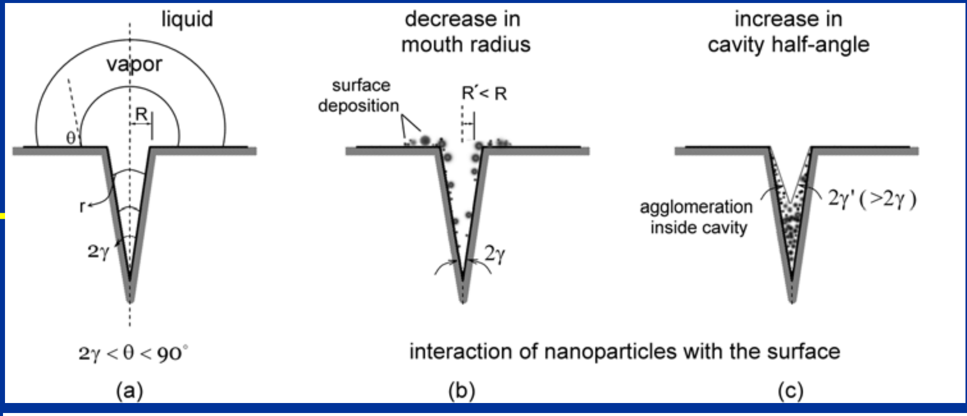
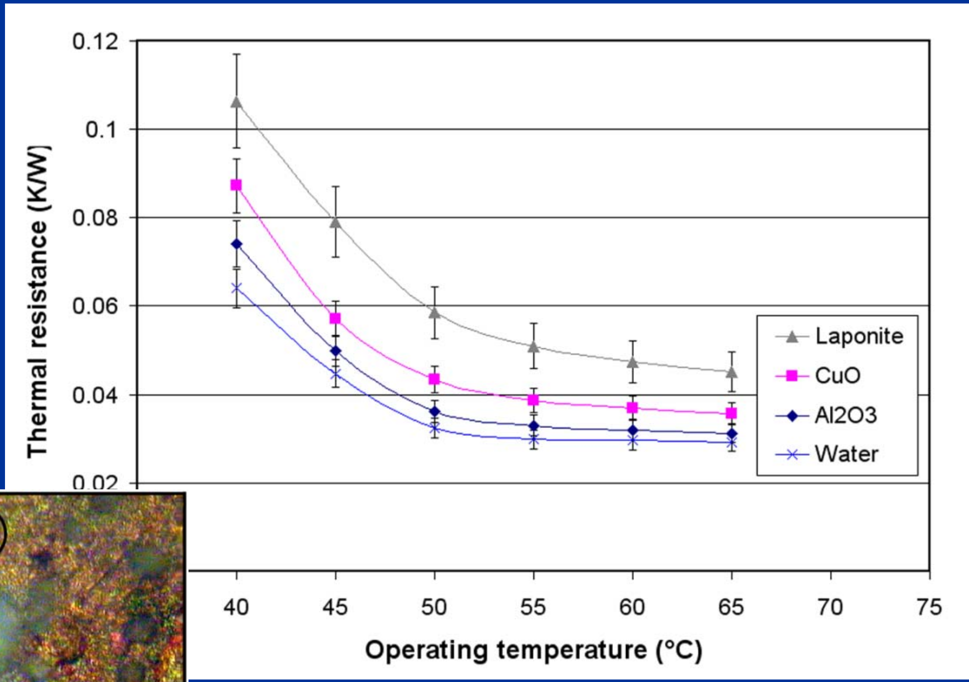
Research Update/Overview

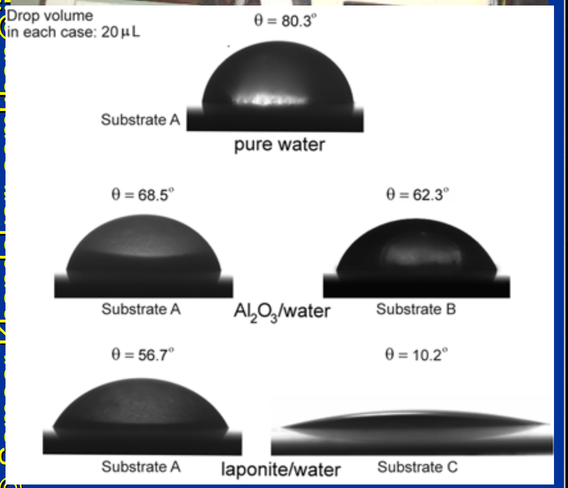
Nanofluids under pool boiling

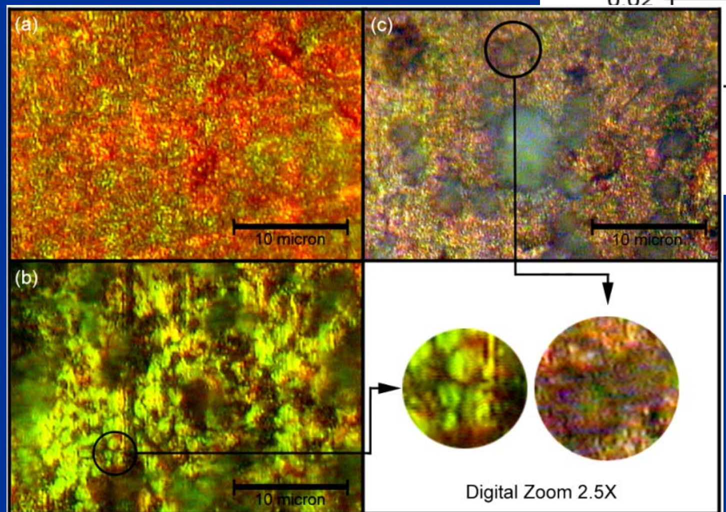












Most downloaded paper for nearly a year

Pulsating heat pipes as radiators

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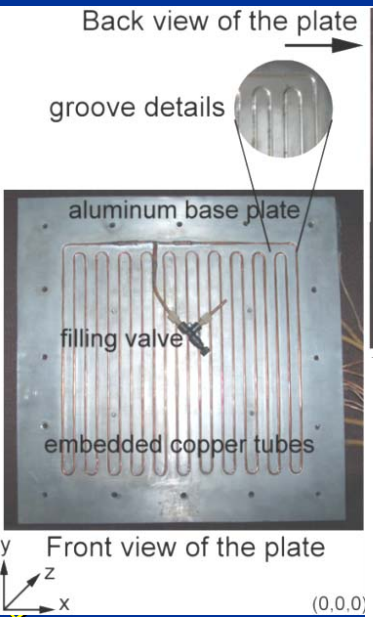
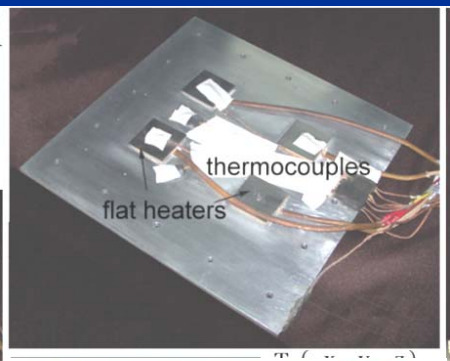
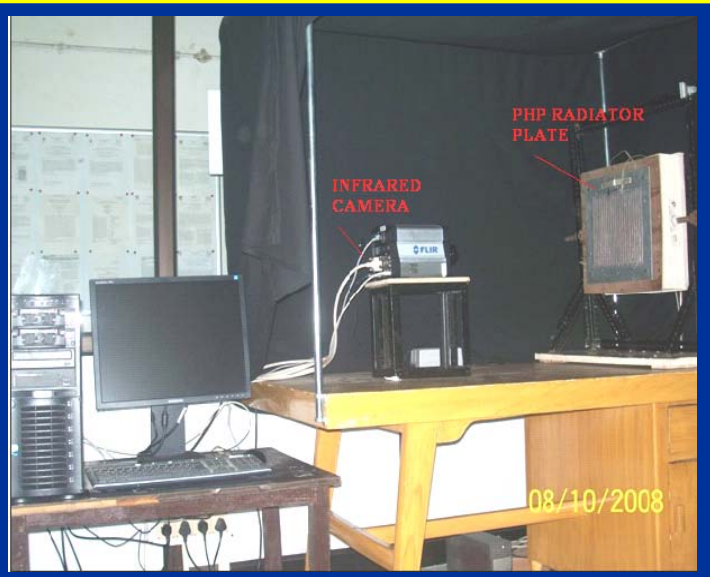
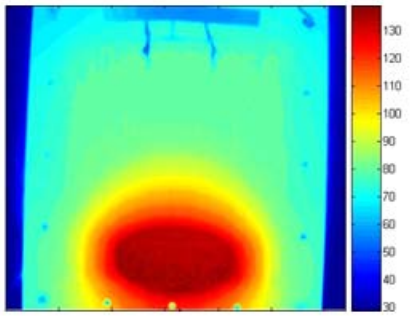
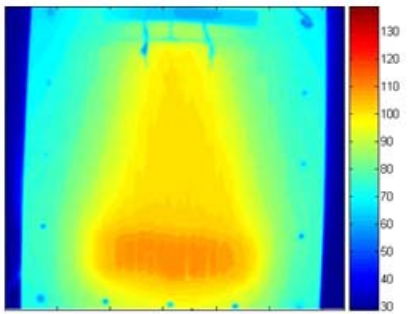








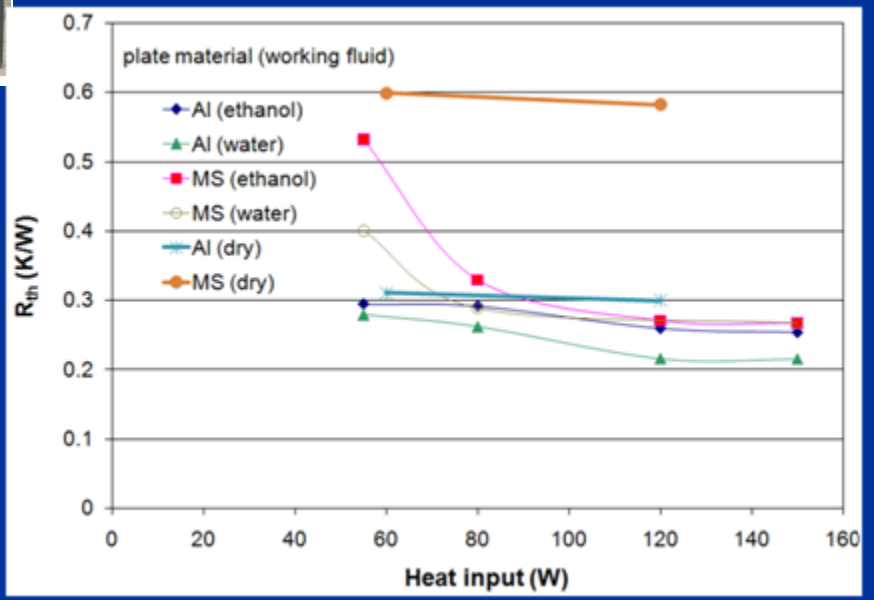
(a)



(b)

Proof of concept done for ISRO

Infrared Thermography



Power Electronics Cooling
Pulsating Heat Pipes

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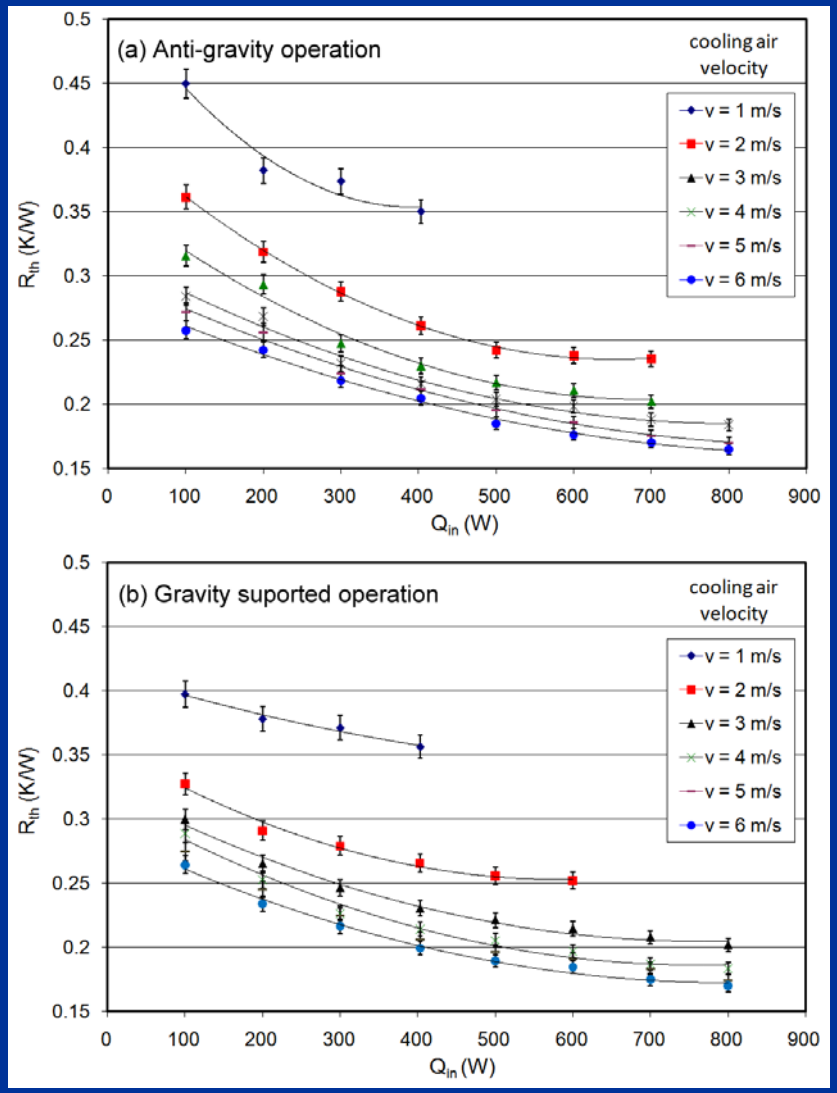

PHP details

Base area : 100 mm X 100 mm

Height : 92 mm

Rows : 8

Columns : 14

Turns : 112 on each side

Pipe OD : 3.0 mm

Pipe ID : 2.0 mm

Photograph of the PHP

Air flow facility details

Section : Rectangular

height (H) - 135 mm

width (W) - 156 mm

length (L) - 2000 mm

Air velocity : 0.2 - 6 m/s

Fully developed turbulent flow

Dropwise condensation
Liquid Crystal Thermography

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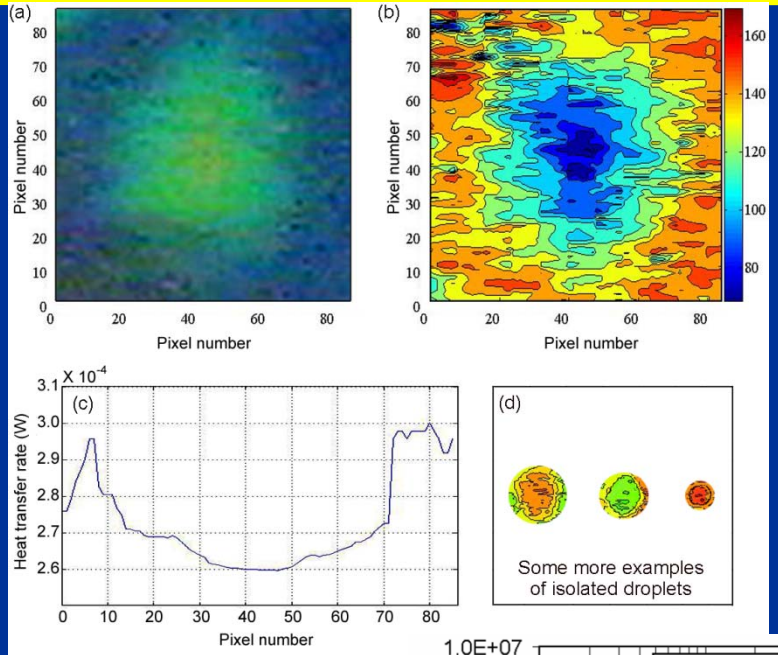
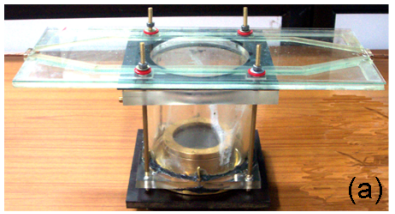
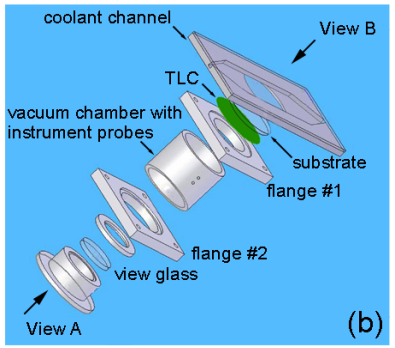
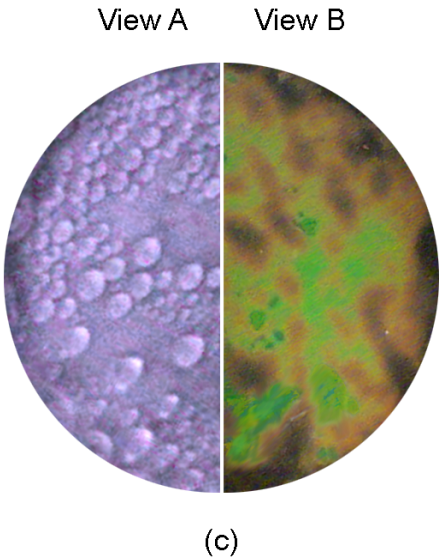
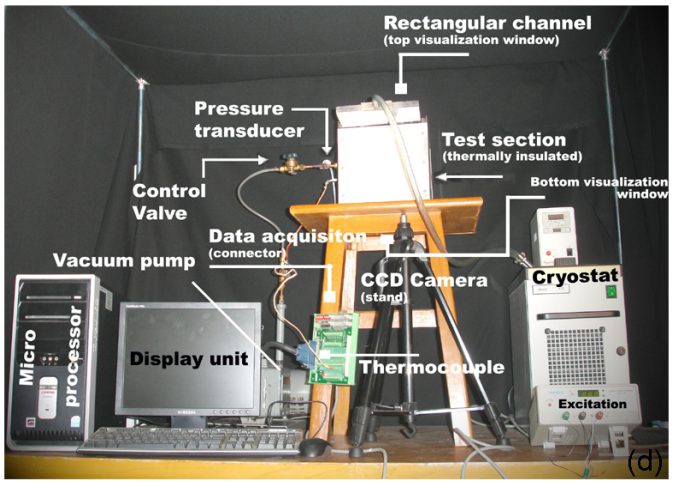


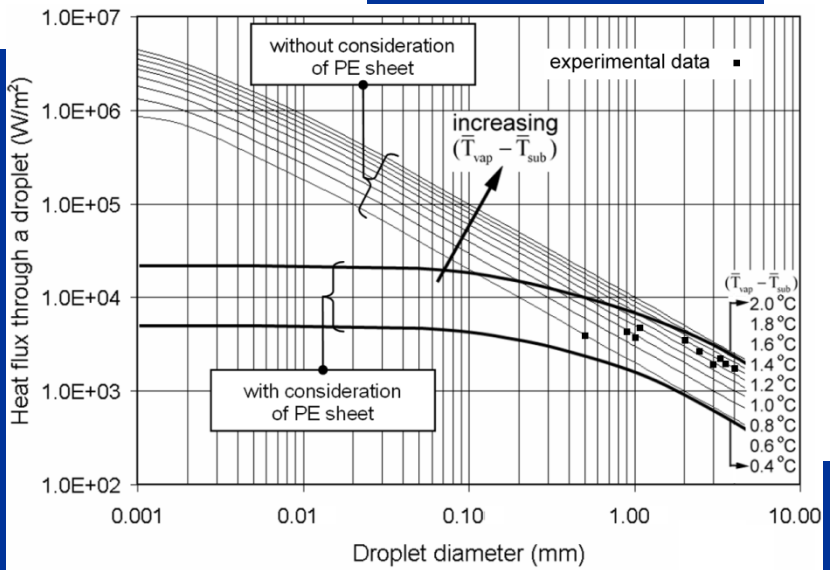
Heat flux through single droplets











Overall heat transfer coefficient

Liquid crystal thermography of condensing droplets

Dropwise condensation Simulation and Experiments

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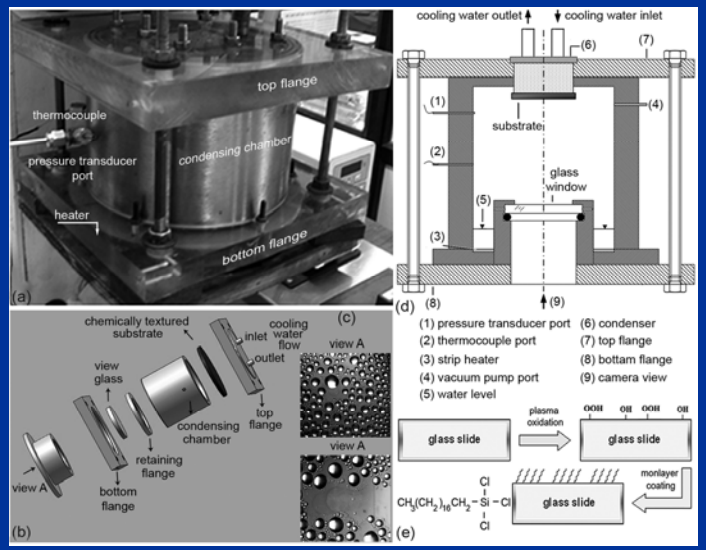

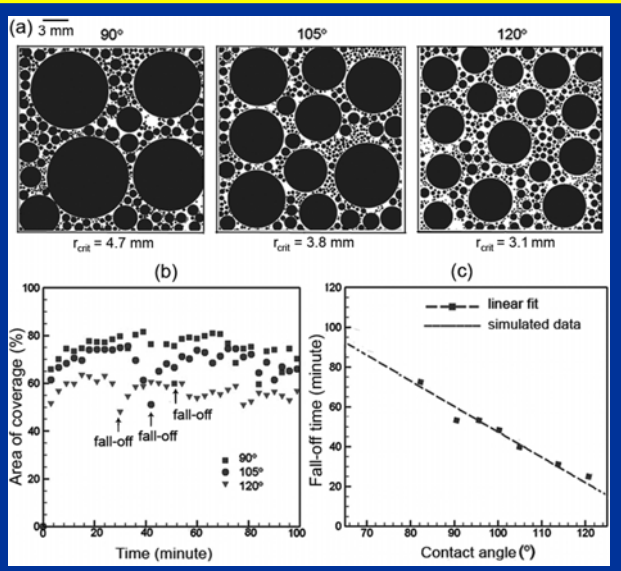

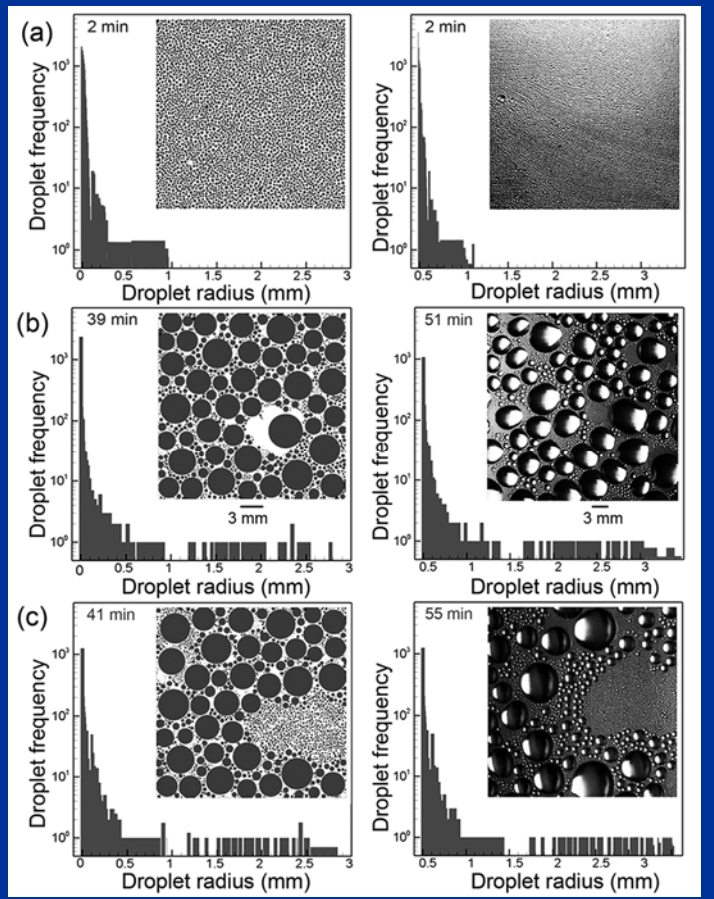

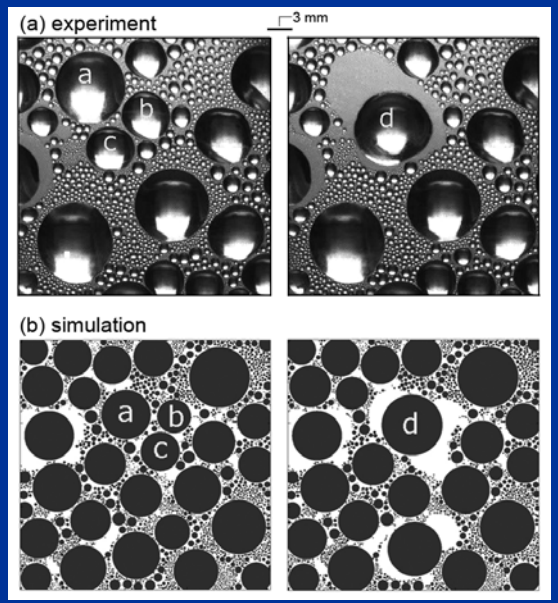

- Atomistic modeling
- Chemically textured surfaces
- Ensemble of droplets
- Coalescence studies

Numerical simulation of pendant drops

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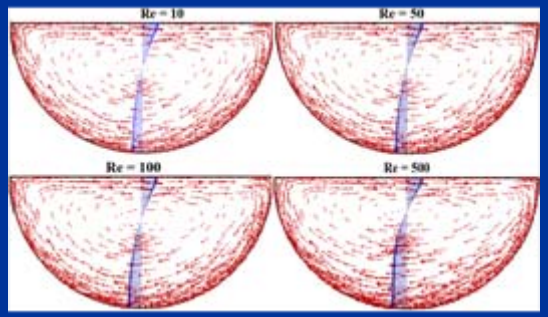
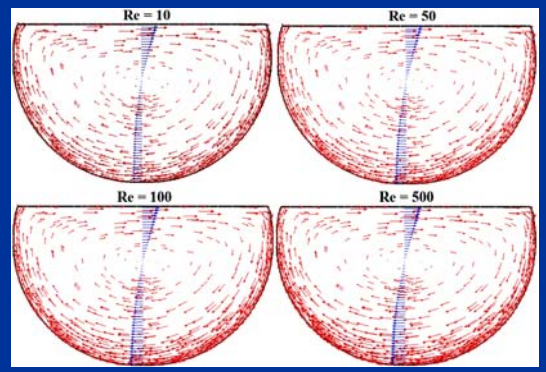
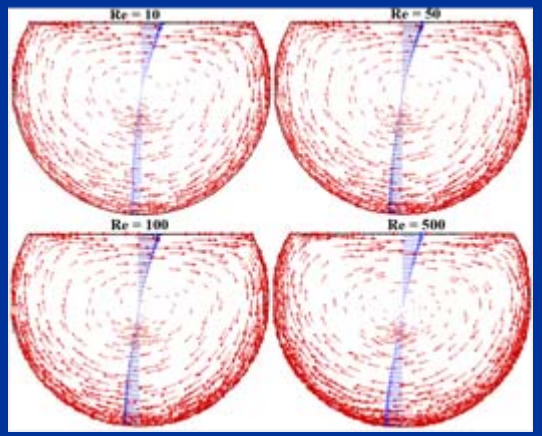
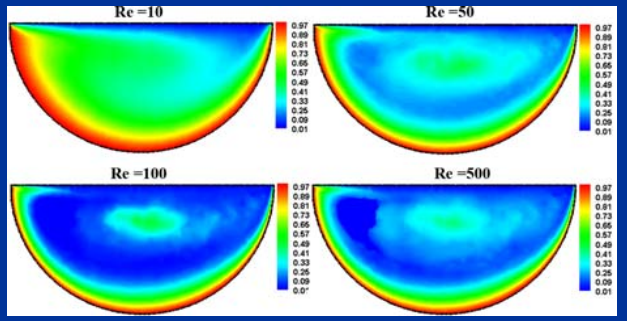
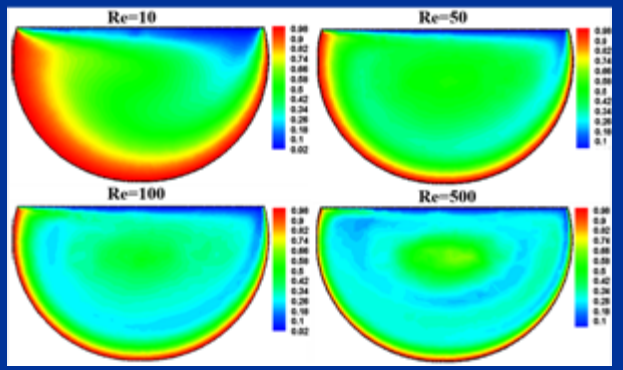


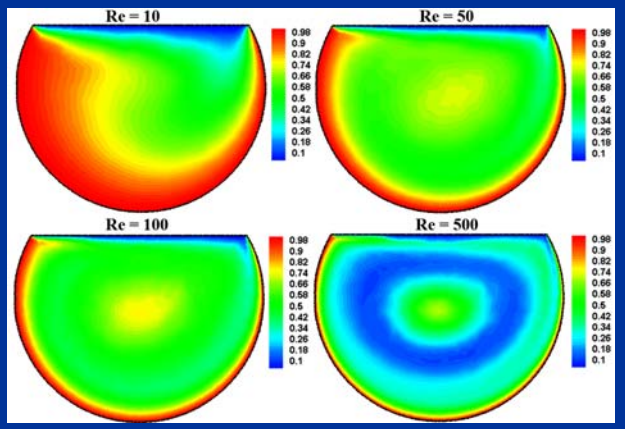




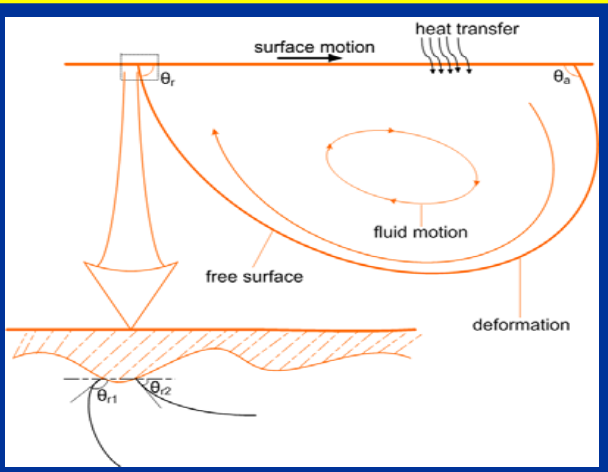
Velocity contours

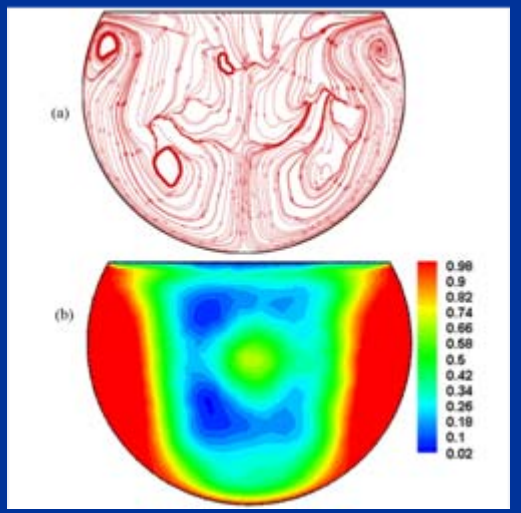






Temperature contours





3D Navier-Stokes + Energy Equation Solver for droplets sliding on a textured surface

Flow boiling in micro channels (Aim: Hydrogen production)

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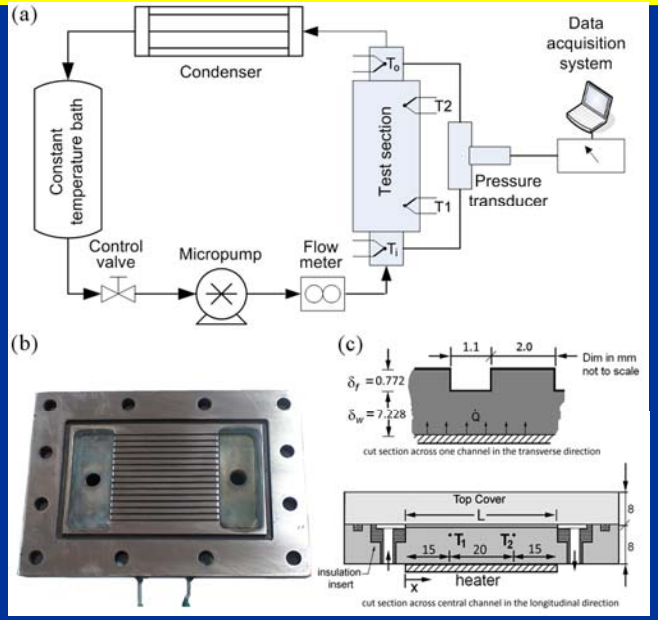
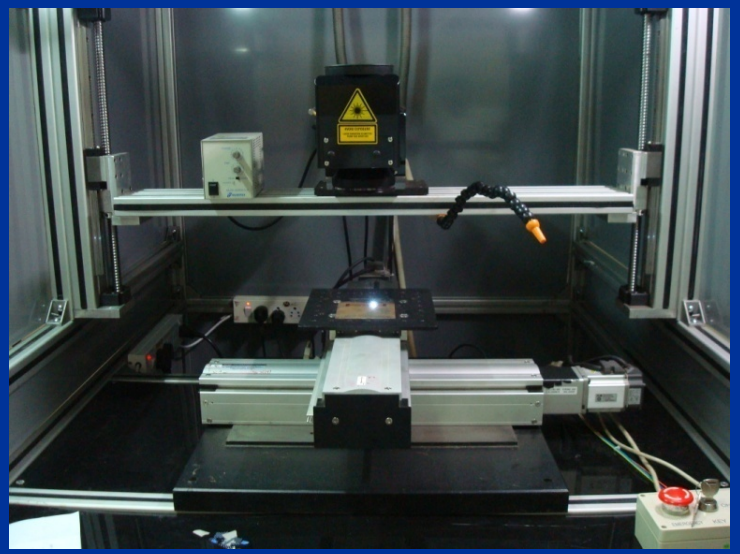
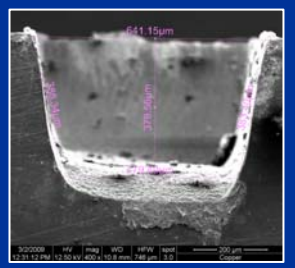


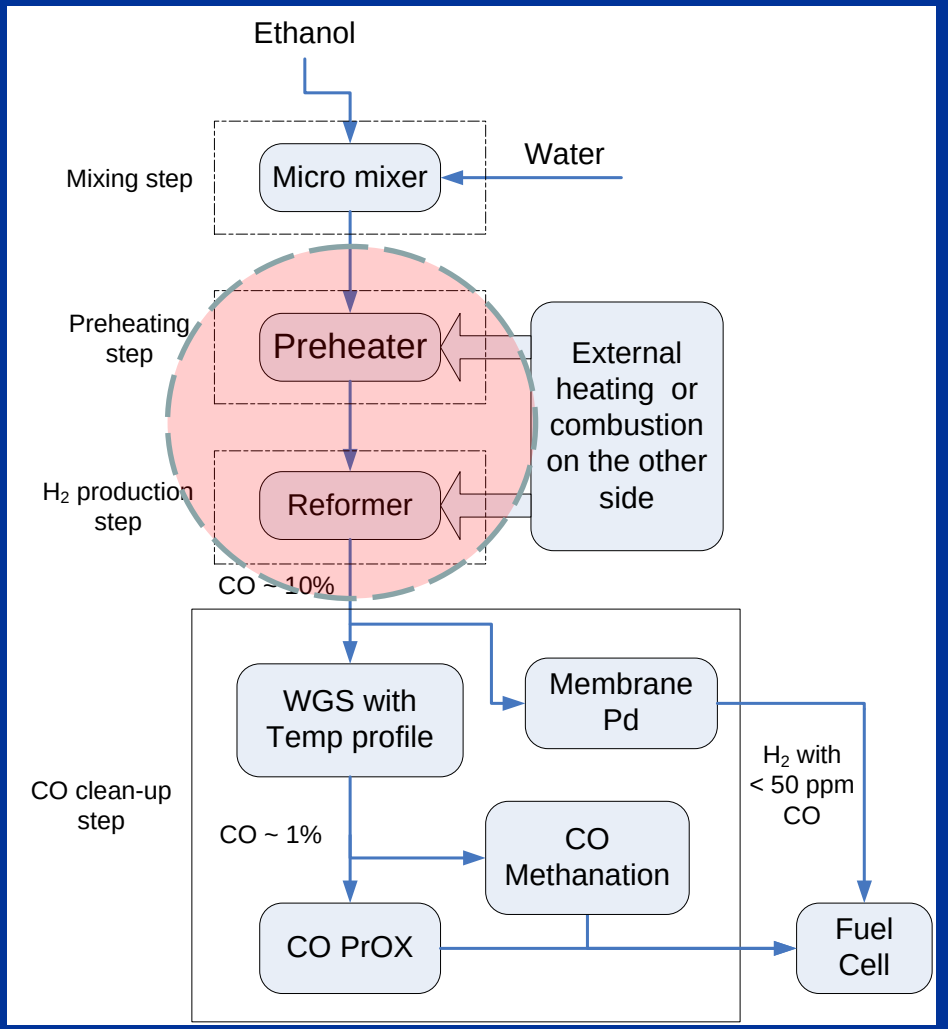
Mixture boiling
Visualization
Nusselt number
Axial back conduction





400 μm

Laser micromachining



Liquid crystal thermography of developing single-phase flows

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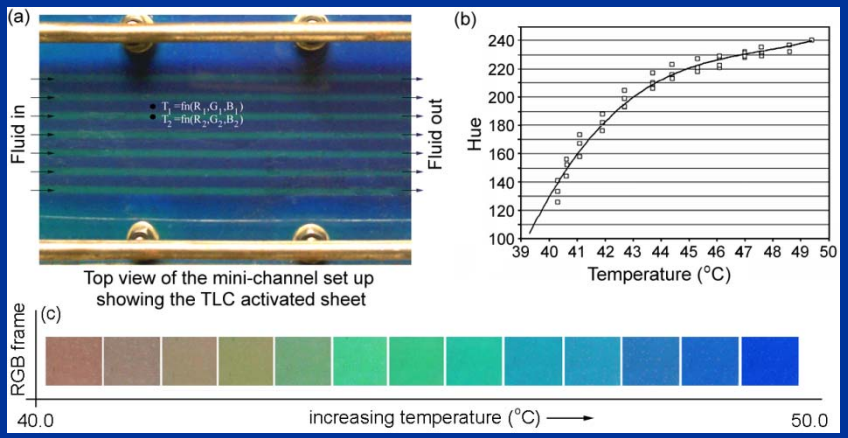
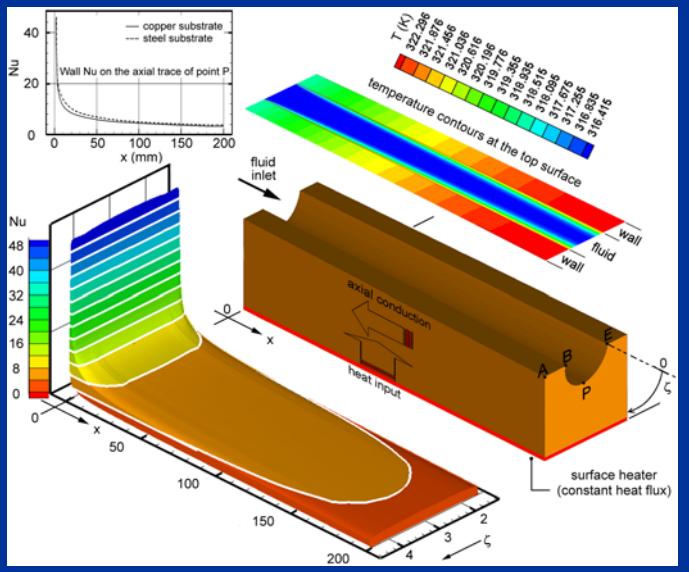
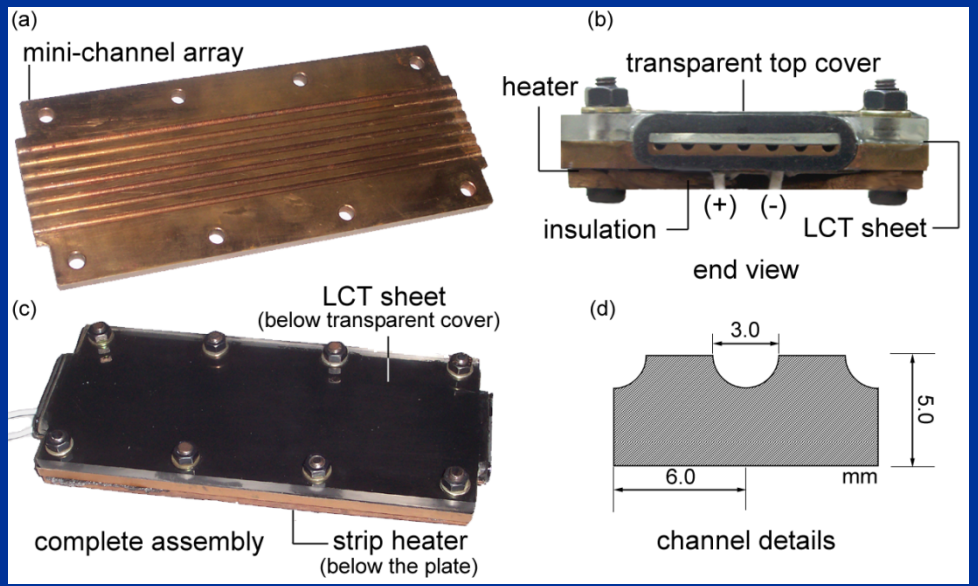
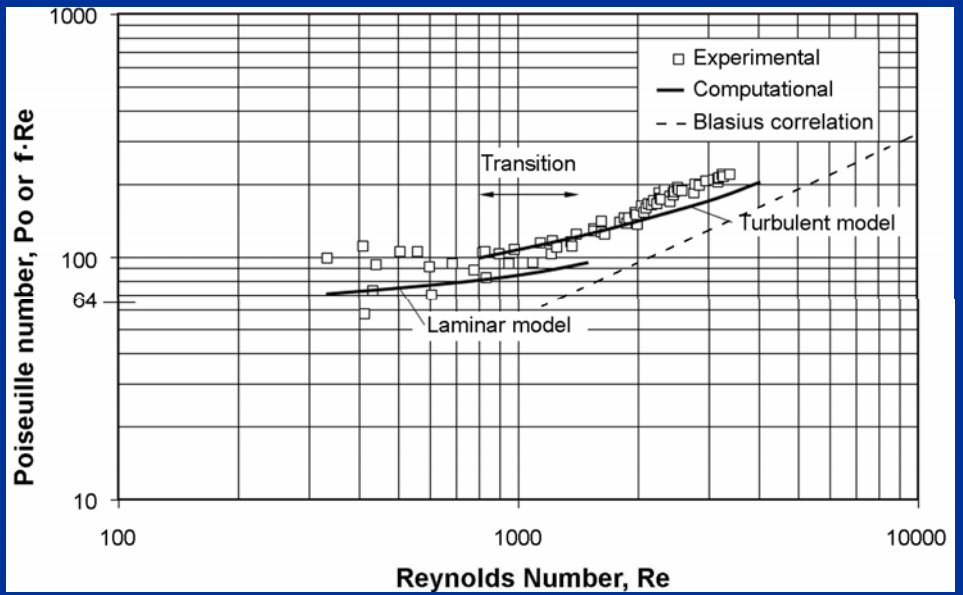


Minichannels
~ 0.5 -3.0 mm





Simultaneously developing flows



Remote Access Laboratory (Internet based experiments)

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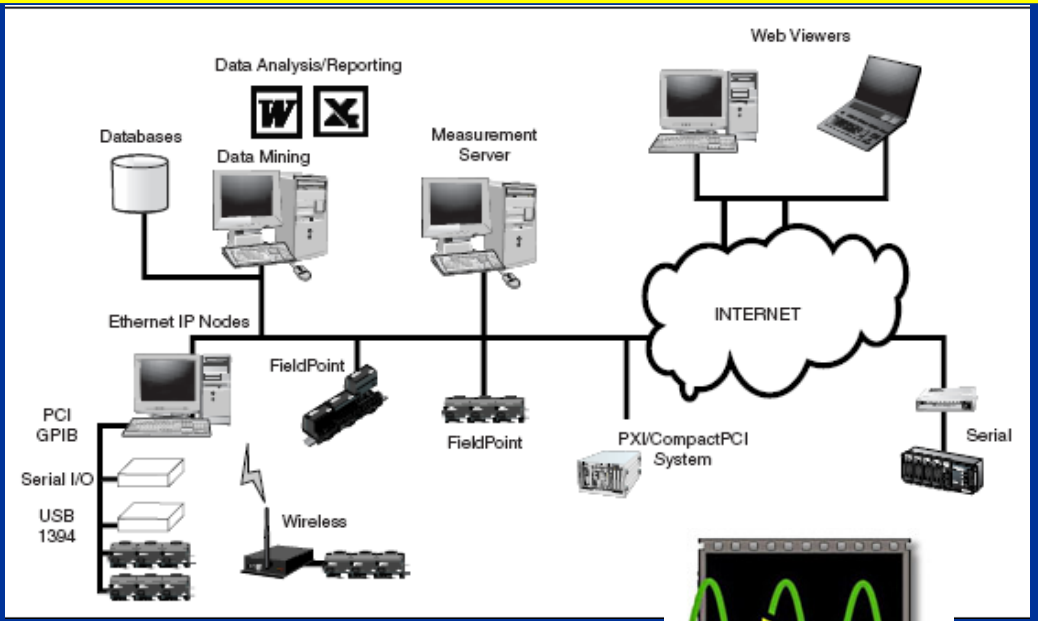
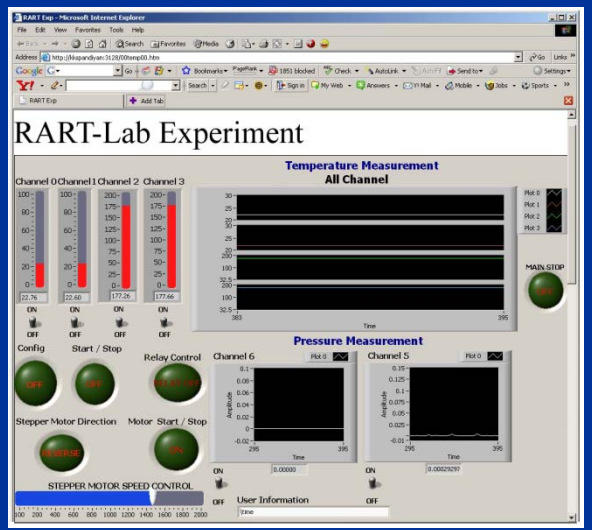
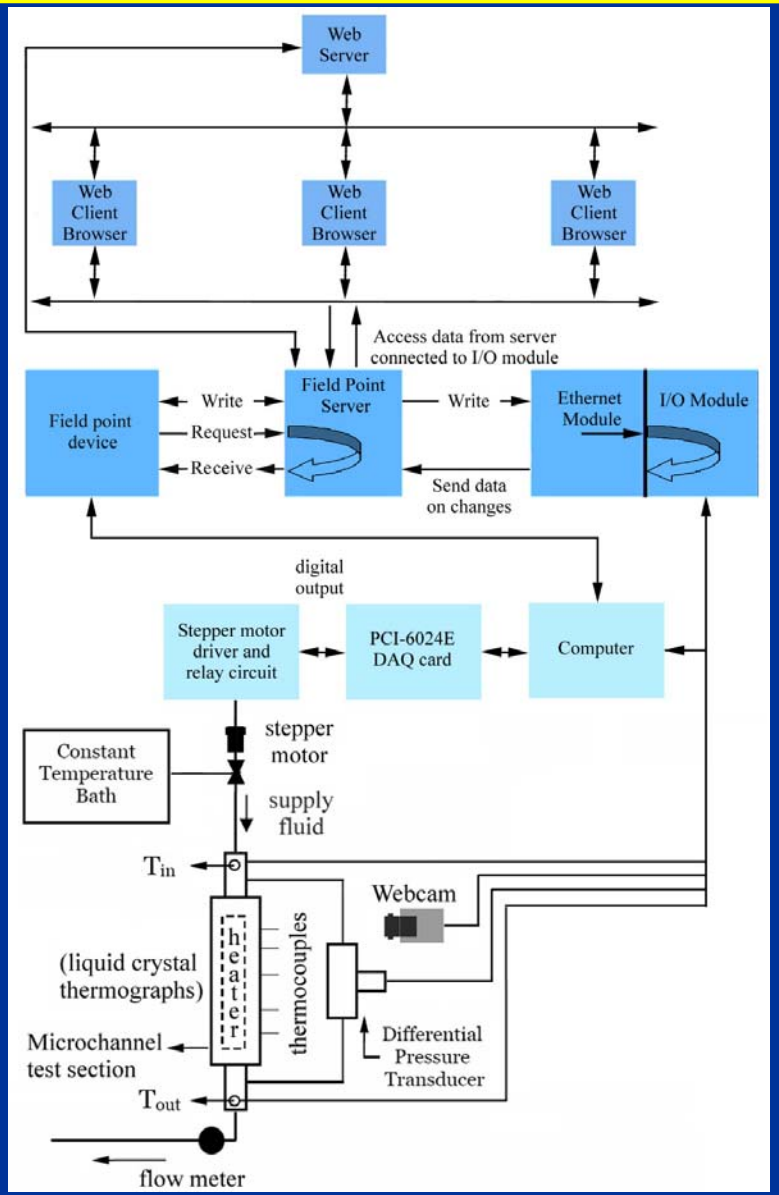




LabVIEW®

This development has led to a large sponsored project from MHRD



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Ongoing doctoral research

Ph.D. theses advising

- **Ongoing students: 03**

Title 1: Flow boiling of ethanol-water mixtures in narrow channels.

Title 2: Droplet dynamics on textured engineered surfaces.

Title 3: Pulsating flow in micro-channels.

Faculty colleagues

Dr. K. Muralidhar, Professor

Dr. P. K. Panigrahi, Professor

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Collaboration/ Sponsors

- **International**

CETHIL, INSA de Lyon, France (Sponsored Project Partner)

IKE, Uni-Stuttgart, Germany (Student Exchange)

University of Bergamo, Italy (Student Exchange)

- **National**

Bhabha Atomic Research Center, Mumbai

Indian Space Research Organization

Department of Science and Technology

Ministry of Human Resource and Development

Defense Research and Development Organization

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Recent publications (2010-2011)

- Sikarwar B. S., Khandekar S., Agrawal S., Kumar S. and Muralidhar K., Dropwise Condensation Studies on Multiple Scales, Heat Transfer Engineering, Special Issue: Advances in Heat Transfer, accepted for publication, 2011.
- Moharana M. K., Agarwal G. and Khandekar S., Axial Conduction in Single-phase Simultaneously Developing Flow in a Rectangular Mini-channel Array, International Journal of Thermal Sciences, DOI: 10.1016/j.ijthermalsci.2011.01.017, January 2011.
- Hemadri V. A., Gupta A., Khandekar S., Thermal Radiators with Embedded Pulsating Heat Pipes: Infra-red Thermography and Simulations, Applied Thermal Engineering, DOI: 10.1016/j.applthermaleng.2011.01.004, January 2011.
- Moharana M. K., Peela N. R., Khandekar S. and Kunzru D., Distributed Hydrogen Production from Ethanol in a Microfuel Processor: Issues and Challenges, Renewable and Sustainable Energy Reviews, Vol. 15, pp. 524-533, 2011.
- Sikarwar B. S., Battoo N. K., Khandekar S. and Muralidhar K., Dropwise Condensation underneath Chemically Textured Surfaces: Simulation and Experiments, ASME Journal of Heat Transfer, Vol. 133, Issue 2, pp. 021501 (1-15), 2011.
- Das S. P., Nikolayev V. S., Lefevre F., Pottier B., Khandekar S. and Bonjour J., Thermally Induced Two-phase Oscillating Flow inside a Capillary Tube, International Journal of Heat and Mass Transfer, Vol. 53, pp. 3905-3913, 2010.
- Khandekar S., Panigrahi P. K., Lefevre F. and Bonjour J., Local Hydrodynamics of Flow in a Pulsating Heat Pipe: A Review, Frontiers in Heat Pipes, Vol. 1, pp. 023003(1-20), 2010.

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Recent publications (2008-2009)

- Revellin R., Lips S., Khandekar S. and Bonjour J., Local Entropy Generation for Saturated Two-phase Flow, Energy-The International Journal, Vol. 34, Issue 9, pp. 1113-1121, 2009.
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Summary and Conclusions

- Understanding heat/fluid flow in micro- and mini channels is vital for further development of enhanced heat transfer components
- Nano technology is coming up fast and many unexplored areas are emerging
- Micro/Mini/Pulsating heat pipes are excellent passive enhancement devices
- Adequate correlations/ models for microscale heat transfer phenomena not available
- New measurement techniques for microchannel devices
- Increased efforts are necessary

You are welcome to join hands in these exciting research activities

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Thank you