



Department of Mechanical Engineering  
Indian Institute of Technology Kanpur  
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India

# Activity Report during May 2009 to April 2014

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## In this presentation...

- Quick background information
- Academic and research achievements
- Teaching and outreach activities
- Administrative activities
- Summary of major contributions
- Outlook

All data are for the last five years, 2009 – 2014  
(since the last promotion)



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## Background information

- 1989 - 1993** • **B. E. (Mechanical Engineering)**, Government Engineering College, Jabalpur (MP).
- 1994 - 1998** • Worked as marine power plant engineer on board sea-going merchant ships SULZER engines, ~ 11000 BPH, Diesel, Two-Stroke, Auxiliary Boiler.
- 1998 - 2000** • **M. Tech. (Thermo-fluid Sciences)**, Indian Institute of Technology Kanpur.  
*Thesis title: Numerical Modeling of Packed Bed Type Catalytic Converter for Small Two-Stroke Petrol Engines and its Experimental Validation*  
*Sponsored by Indian Oil Corporation Limited (IOCL)*
- 2000 - 2004** • **Ph. D.**, University of Stuttgart, Stuttgart, Germany, 2004.  
*Thesis title: Thermo-Hydrodynamics of Closed Loop Pulsating Heat Pipes*  
*Sponsored by Deutsche Forschungsgemeinschaft (DFG)*
- 2004 - 2009** • Assistant Professor, Department of Mechanical Engineering, IIT Kanpur
- 2009 -** • Associate Professor, since May 2009



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# Phase-change Thermal Systems Laboratory

## Key words

Liquid-Vapor Phase Change Phenomena  
Heat Pipes/ Pulsating Heat Pipes/ Thermosyphons  
Oscillating/Pulsating Taylor Bubble Flows  
Microscale Heat Transfer Measurements  
Passive Cooling Techniques  
Dropwise Condensation  
Energy Systems  
PCM



Laser confocal microscope



Thermal diffusivity system



Infra-red camera



High-speed camera

## Research focus

**Microscale heat transfer with a focus  
on phase-change phenomena in  
thermal systems  
(Active and passive devices)**

## Research approach

**Build dedicated experiments to discern  
complex multi-physics phenomena  
Multi-scale CFD/CHT simulations**



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# Research, Achievements and Publications Record (2009-2014)



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## Academic achievements (last five years)

- P. K. Kelkar Research Fellowship from IIT Kanpur (October 2009 - September 2012).
- Recipient of DAAD Research Fellowship, 2011.
- Prof. K. N. Seetharamu Young Researcher Award, Indian Heat Mass Trans. Soc., 2010.
- 10 keynote lectures/talks in international conferences.
- Invited professor at KAIST, Korea (2014), INSA-Lyon (2008, 2012), Uni-Darmstadt (2011)
- One book published *Dropwise Condensation on Inclined Textured Surface*, by Springer (with Dr. K. Muralidhar).
- One edited book finalized, *Nanoscale and Microscale Transport Phenomena: Theory and Applications*, by Springer (in print; with Dr. Yogesh M. Joshi).
- Associate Editorship of three journals (i) Heat Pipe Science and Technology, (ii) Interfacial Phenomena and Heat Transfer, (iii) Frontiers in Heat Pipes.
- Invited Member of Academic Senate of IIIT-DM, Jabalpur and GEC, Amravati (MS)
- Member of the international Heat Pipe Committee.

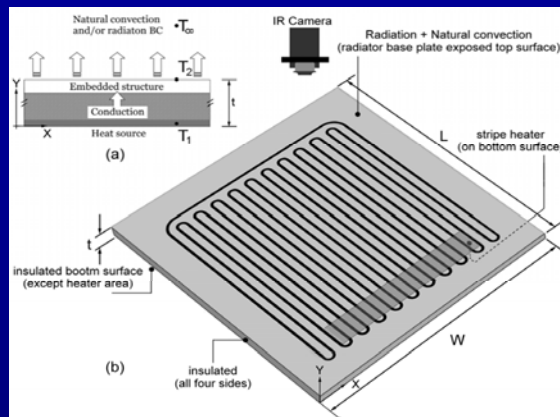
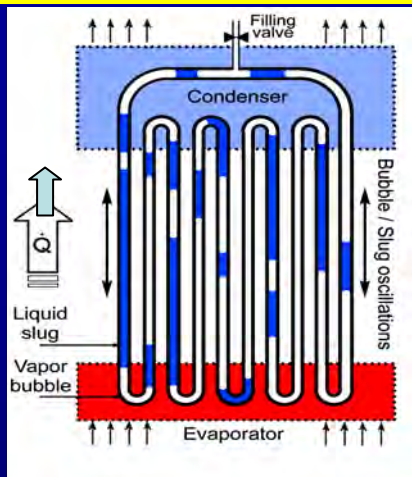


## Knowledge dissemination - Summary (2009 - 2014)

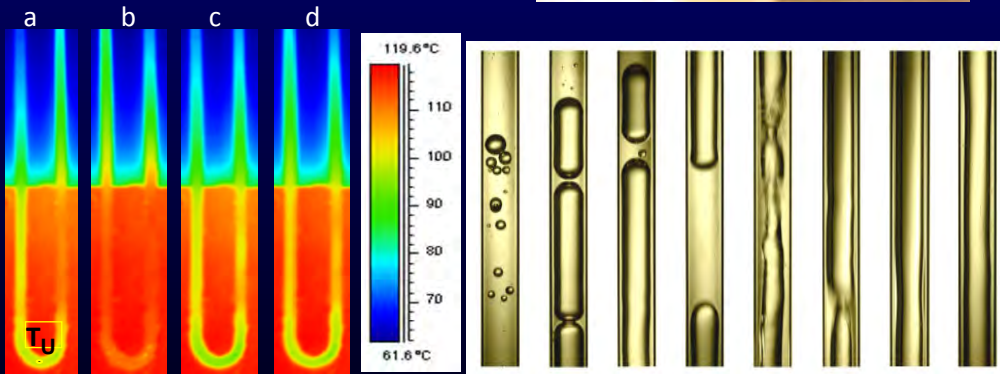
- |   |                   |
|---|-------------------|
| • International peer reviewed journals        | 30 papers         |
| • International peer reviewed conferences     | 45 papers         |
| • Book published                              | 01 (Springer)     |
| • Edited book (in print)                      | 01 (Springer)     |
| • Book chapter (published)                    | 01 (Narosa)       |
| • Book chapter (manuscript submitted)         | 02 (Springer)     |
| • Conference proceedings in print (as Editor) | 01 (Begell House) |
| • Provisional patent applications             | 05                |
| • Keynote lectures/invited talks              | 10                |



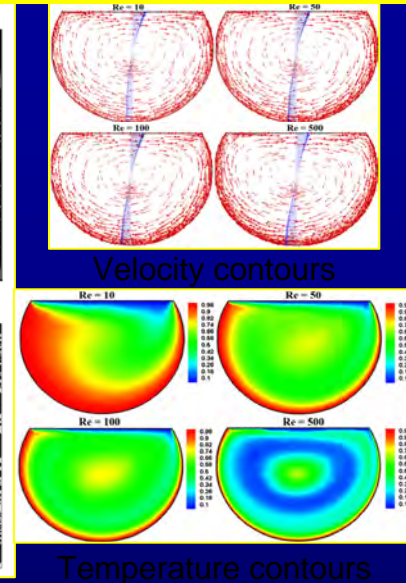
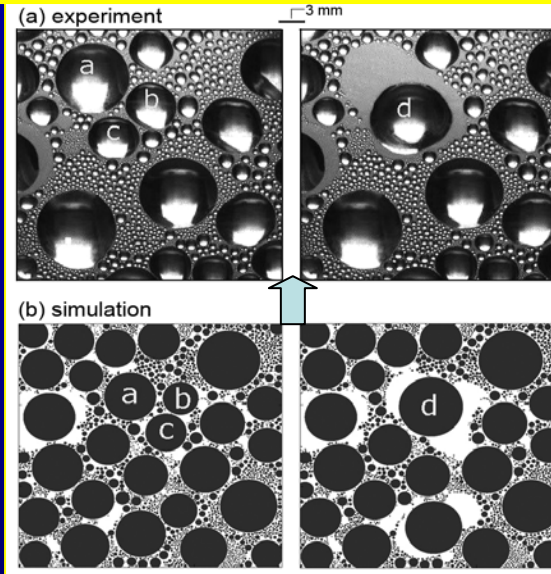
# A collage of research activities



- ISS thermal platform/ radiator
- Passive containment cooling
- Power electronics cooling
- Hydrogen-recombiner cooling

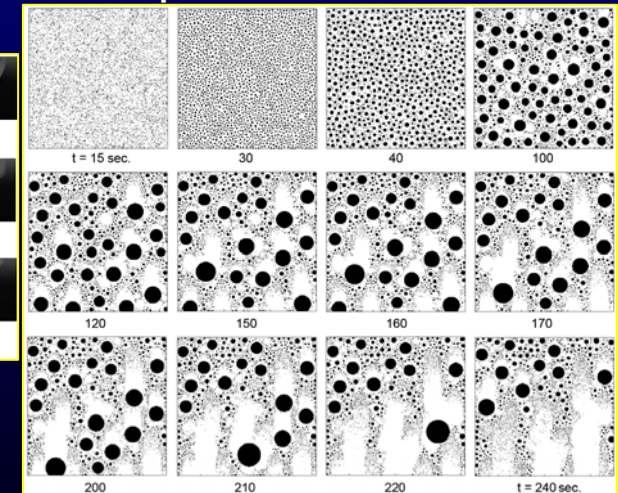
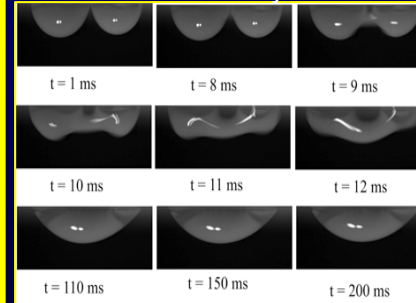


Development of pulsating heat pipes for various applications (space and terrestrial)



## Hierarchical model of droplet condensation

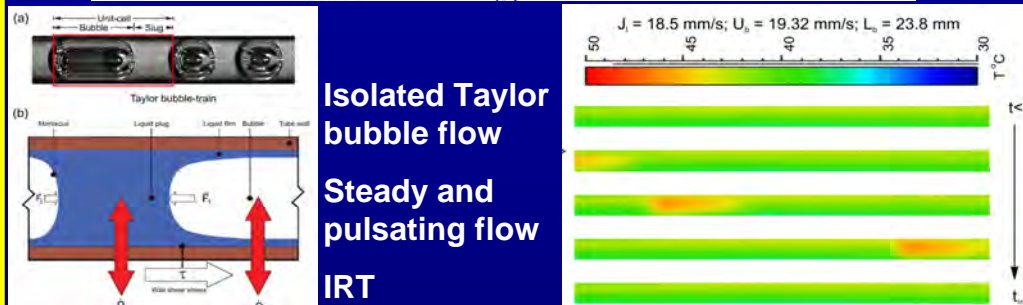
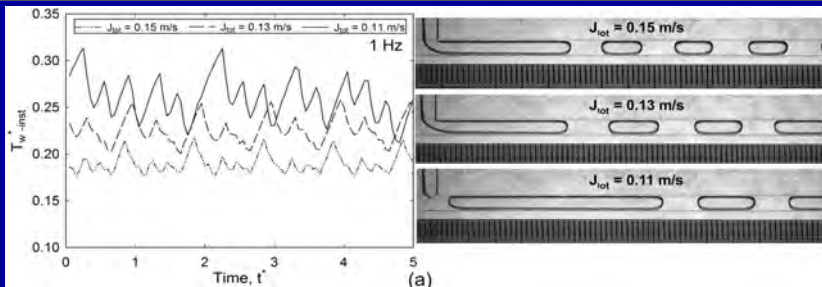
### Coalescence dynamics



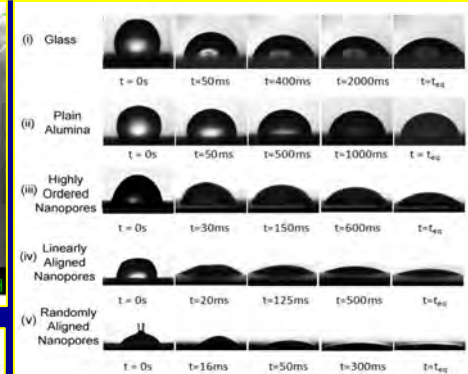
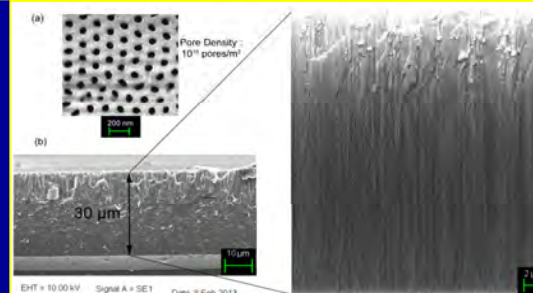
Laser Uranium Enrichment

Dropwise condensation and droplet coalescence on textured surfaces and multi-scale modeling



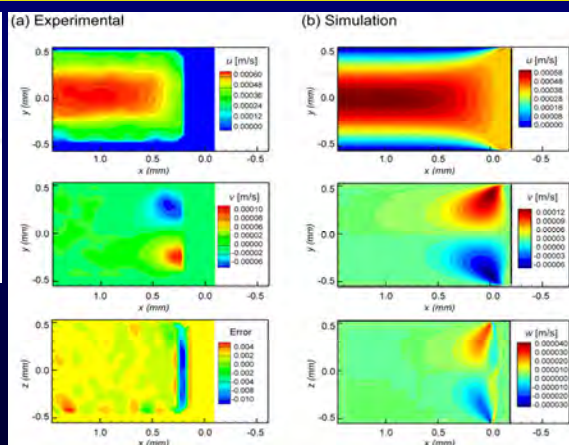
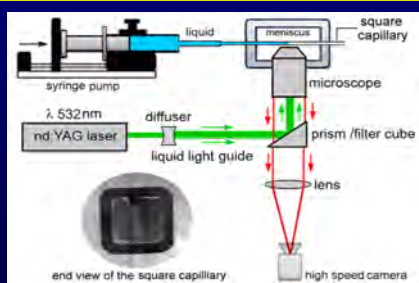


Local transport phenomenon in steady and pulsating Taylor bubble flows



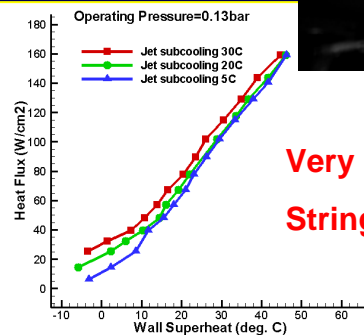
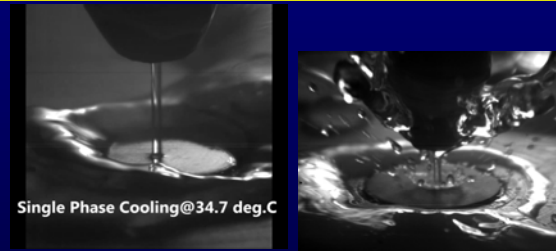
Evaporation  
Droplet spreading  
Wetting transitions  
Contact line motion  
Phy/Chem structuring

Evaporative heat transfer near three-phase contact lines on textures surfaces

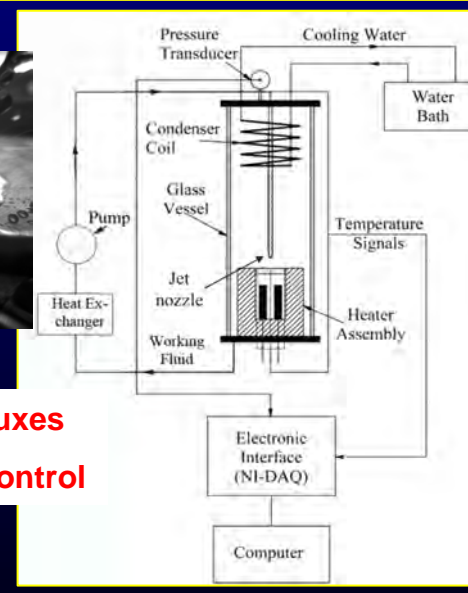


Micro-PIV  
Confocal microscopy  
Infra-red Thermography

Local thermo-hydrodynamics in steady and oscillating confined menisci

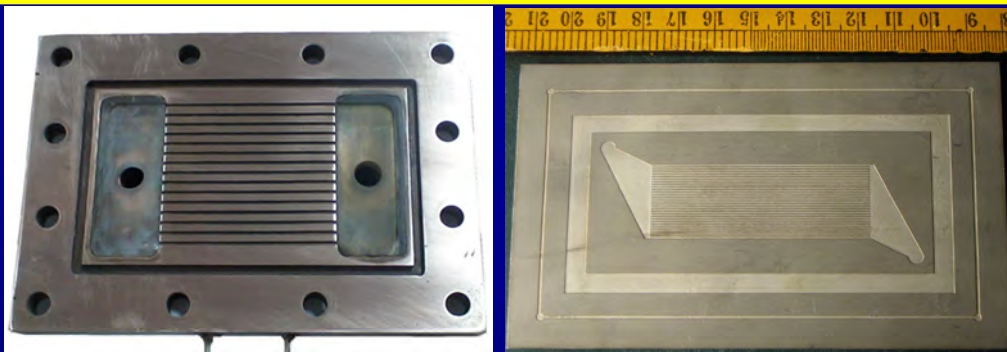


Very high heat fluxes  
Stringent temp control



Boiling jet cooling on structured surfaces for thermal management of laser weapons

# A collage of research activities



Isolated microchannels and microchannel array (100 to 300 microns)



Flow boiling in laser micro-machined channels



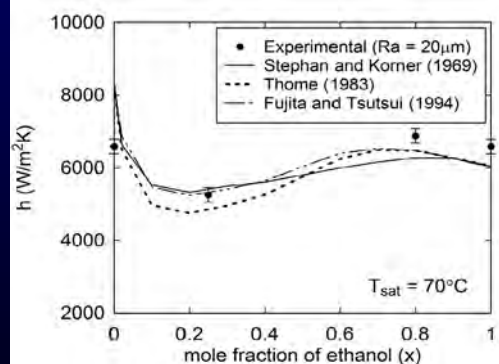
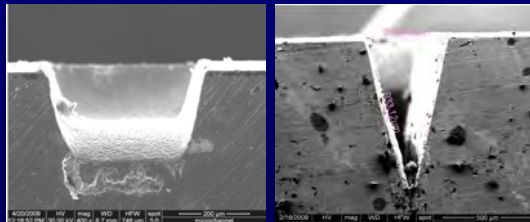
Ra = 20 μm



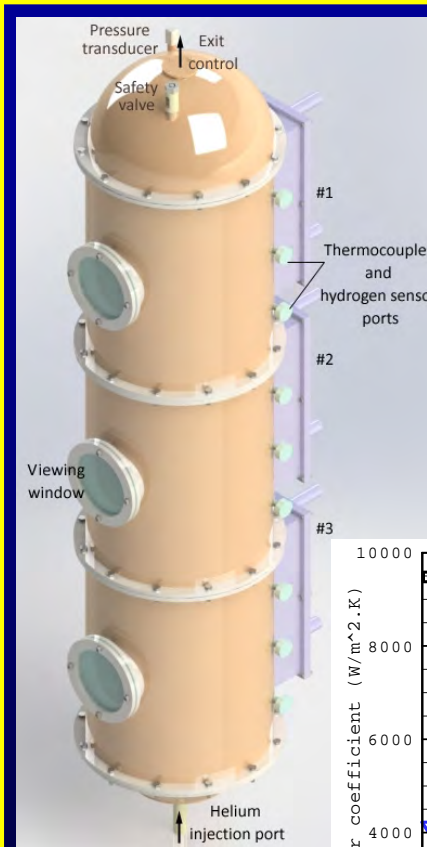
Pool boiling on textured surfaces



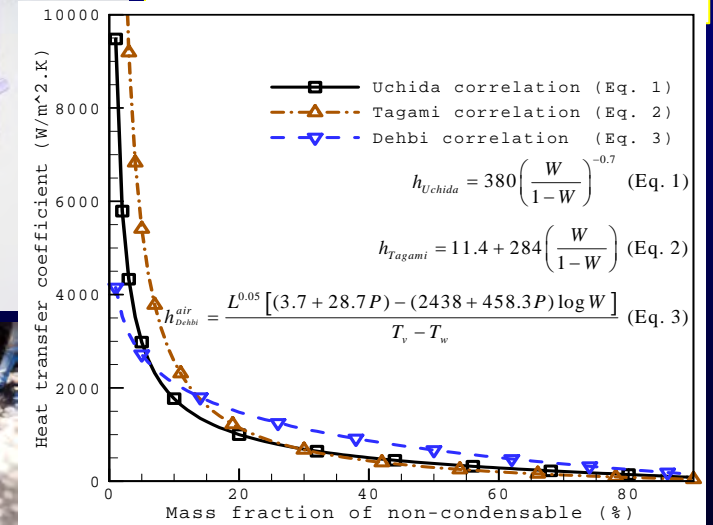
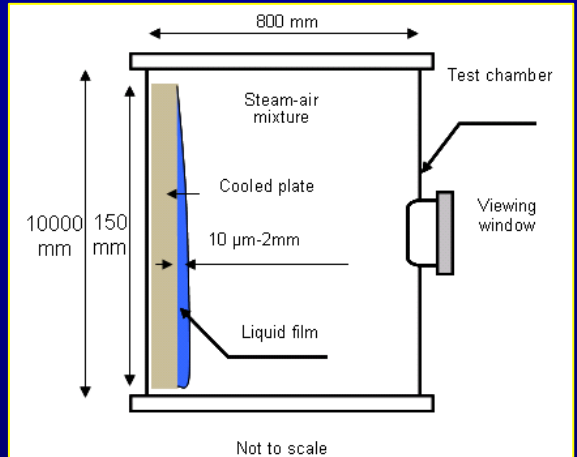
Ra = 0.8 μm



Flow boiling and pool boiling ethanol-water mixtures for H<sub>2</sub> generation micro-reactor



Steam condensation in the presence of hydrogen/air



Effect of air on HTC (at 1 atm, ΔT = 49°C)

Passive cooling and steam-hydrogen management inside nuclear reactor containments





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# A few publications...



Sameer Khandekar

Second Edition  
**Introduction to  
 Micromachining**



Editor  
**V. K. Jain**

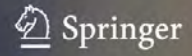


For Sale in India, Pakistan, Bangladesh, Nepal, Bhutan and Sri Lanka

SPRINGER BRIEFS IN APPLIED SCIENCES AND TECHNOLOGY  
 THERMAL ENGINEERING AND APPLIED SCIENCE

Sameer Khandekar  
 Krishnamurthy Muralidhar

**Dropwise  
 Condensation on  
 Inclined Textured  
 Surfaces**



Keyw  
 Fully  
 Arbitrary cross-sectional ducts

23

**machining in  
 engineering**

Kumar Moharana  
 Mechanical Engineering  
 Indian Institute of Technology Kanpur  
 Mechanical Engineering  
 Indian Institute of Technology Rourkela

ASME Journal of Heat Transfer



Developed  
 circular



doubly-connected ducts of arbitrary  
 technique in which the condition  
 is matched by a collocation tech-  
 nique for (a) singly-connected ducts  
 a variety of complicated singly-  
 connected ducts. The perimeter of  
 the doubly-connected duct is arbitrary  
 while the internal core perimeter is  
 circular. The perimeter of the  
 singly-connected duct is arbitrary  
 while the internal core perimeter is  
 arbitrary.



## M.Tech. / Ph. D. thesis advising

### M. Tech. theses advising (last 5 years)

- **Completed: 20 (05 as co-advisor)**
- **Ongoing students: 03 (w.e.f. summer 2014)**

### Ph.D. theses advising

- **Ongoing students: 05 (01 as co-advisor)**

Title 1: Evaporation in Loop Heat Pipe

Title 2: Taylor Bubble Dynamics: Local effects

Title 3: Condensation in Nuclear Containments

Title 4: Passive Hydrogen Recombiner

Title 5: Dynamics of Micro-droplets (as Co-advisor)

### Doctoral degree awarded

**04 (02 as co-advisor)**

Balkrishna Mehta**	2014	Local thermo-hydrodynamics of Oscillating Flows in Mini-/Micro Channels
Basant Sikarwar	2013	Modeling Dropwise Condensation underneath Inclined Textured Surfaces
Manoj K. Moharana	2012	Thermo-hydrodynamics of Internal Convective Flows in Mini-/ Micro Channels
Mauro Mamei	2012	Pulsating Heat Pipes: Numerical Modeling and Experimental Assessment (with Uni-Bergamo, Italy)

\*\* : Final defense in June 2014 (one report awaited)



## Intellectual property generation/ Patents

- 1. Nano-porous microtubes for heat and mass exchange applications,** Invention ID: IN-875089, selected for patenting (Intellectual ventures), filing in progress, November 2013 (Doctoral Research).
- 2. Compact Air Cooling Unit based on Film Evaporation on Nano-structured Alumina,** submitted to SIIC, March 2014 (BTP work).
- 3. Bicycle Mounted Solar Energy Harvester,** submitted to SIIC, March 2014 (BTP work).
- 4. Shape Memory based Taylor Bubble Sensor,** disclosure filing under process, April 2014 (Masters Research).
- 5. Inverse Heat Transfer Based Thermal Boundary Condition Sensor for Nuclear Containment Application,** disclosure filing under process, May 2014 (Masters Research) .





## Sponsored research summary

- **Total sponsored projects handled so far: 13 (11 completed and 02 ongoing)**

- **Sponsored Research work during 2004 - 2009**

05 projects worth about Rs. 1.6 crores  
(IITK/ISRO/DAE/DST)

- **Sponsored Research during the last five years (2009 - 2014)**

06 (Completed) + 02 (Ongoing) projects worth about Rs. 4.0 crores  
(DAE/DST/MHRD/CEFIPRA/IRDE/Private)

- **Sponsored project submitted under consideration (in the 12<sup>th</sup> planned project)**

03 projects worth about Rs. 3 crores

BARC – 2.2 crores (submitted, approval in process) – **Nuclear Safety**

Powergrid – 0.8 crore (submitted, under review) – **Thermal Energy Storage**



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## Sponsored research projects (Ongoing)

- **Project # 1**

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 2010-April 2014)

- **Project # 2**

CO-INVESTIGATOR

**(with Dr. K. Muralidhar)**

**Statics and Dynamics of Micro-droplets Formed on Textured Surfaces during Condensation**

Board of Research in Nuclear Sciences

Budget: INR 25 lacs Time: 3 Years (July 2012 – June 2015)



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## Sponsored research projects (2009-2014)

- **Project # 1**

CO-INVESTIGATOR

(with Dr. D. Kunzru, Dr. S. Panda and Dr. P. K. Panigrahi)

**Micro-devices for Process Applications**

Department of Science and Technology (DST)

Budget: INR 500 lacs Time: 5 Years (April 2006-March 2011)

- **Project # 2**

PRINCIPAL INVESTIGATOR

**Pulsating Heat Pipe Based Compact Heat Exchangers  
for Passive Heat Removal**

Department of Atomic Energy (DAE)

Budget: INR 80 lacs Time: 4 Years (January 2009-December 2012)

- **Project # 3**

PRINCIPAL INVESTIGATOR

**NMEICT: Development of Internet based Heat Transfer Laboratory**

Ministry of Human Resource Development (MHRD)

Budget: INR 50 lacs Time: 1 Year (April 2009-March 2010)

- **Project # 4**

PRINCIPAL INVESTIGATOR

**Design of Heat Transfer Module for a Specified Control Volume using Heat Pipes**

Defense Research and Development Organization (DRDO)

Budget: INR 5 lacs Time: 0.5 Years (January 2011-June 2011)



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# Teaching and Outreach Activities



## Teaching experience (Regular courses)

### • Course instructor

- Heat and Mass Transfer ☀  
(ME 341: UG compulsory)
- Fluid Mechanics & Rate Processes ☀  
(ESO212: UG compulsory)
- Microscale Thermal Engineering  
(SE381: Science elective)
- Liquid-Vapor Phase-Change ☀  
(ME 639: PG elective)
- Internal Combustion Engines ☀  
(ME359: UG elective)
- B. Tech. Project – I and II  
(ME451, ME452: UG compulsory)
- Design Project  
(DES698: PG Compulsory)

### • Course tutor/ Laboratory Instructor

- Technical Arts Laboratory ☀  
(TA 201: UG compulsory)
- Heat Transfer Laboratory  
(ME 471: UG compulsory)
- Thermodynamics ☀  
(ESO 202: UG compulsory)

### • QIP/CDTE activity

#### **Industrial Heat Transfer Systems with Passive Phase-change**

In-house training to about 80 industry participants at Mumbai and Delhi.

This course has been repeated twice

☀ **Student reaction survey score > 3.5/4.0**





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## Extension activities

### Organization of International Conferences

- **Conference Chairman**  
17th International Heat Pipe Conference during October 14-17, 2013 at IIT Kanpur.
  - first time in India
  - 40<sup>th</sup> year of the conference (jubilee)
  - 128 participants from 21 countries
- **Member, Organizing Committee**  
5th International Conference on Fluid Mechanics and Fluid Power to be held in December 2014.

### Continuation Education Workshops:

- Coordinator: One week Technician Training Programs (two) for the local industry, 2013.
- Coordinator - International Workshop, Phase-change Thermal Systems, 2012.
- Co-Convener - One-Day Workshop on Virtual Laboratories, IIT Kanpur, 02012.
- Mentor, USID Gurukul - International Winter School for Participatory, Collaborative and Immersive Learning Experience, 2011.
- Coordinator – QIP course Transport in Phase-change and Reacting Systems, 2011.
- Co-Chairman: Golden Jubilee Energy Conclave 2010: Eight Day Workshop on Energy, 2010.
- Resource person for many workshops on NPTEL/Virtual Labs across North India.



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# Overview of Administrative Activities



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## Administrative experience (2009 – 2014)

### National Level Administrative Assignments:

- Institute PIC of Virtual Laboratory (NMEICT) Project funded by MHRD.
- External expert member of IIT-BHU central workshop development committee.

### Institute/Departmental Level Administrative Assignments (Ongoing)

- PIC: Refrigeration and Air-conditioning, Institute Works Department (IWD).
- Head, Central Workshop and Coordinator, Tinkering Laboratory.
- Member of Institute Space, Planning and Allocation Committee (ISPAC).
- Member of the Institute Research and Development Committee (IRDC).
- Member, Green Cell, February 2014.
- Co-PI: Multi-disciplinary Innovation Laboratory (with Dr. B. Phani, Dr. D. Phillip).
- Editorial Board member of the Institute Hindi Magazine: Antas
- Member, Departmental Post Graduate Committee – DPGC (two terms).
- Coordinator of the Refrigeration/AC Laboratory w. e. f August 2005 - ongoing.



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## Administrative experience (2009 – 2014)

### Institute/ Department Level Administrative Assignments (completed)

- Member of the Institute Industrial Collaboration Advisory Group (ICAG), 2012-2014.
- Member of the advisory group to the Dean, Resources and Alumni, 2010-2012.
- Member of the Institute Social Responsibility Committee, 2012-2013.
- Member, Institute Environmental Advisory Committee, 2011-2012.
- Vice-Chairman, SPIC-MACAY National Convention, held during June 01-06, 2010.
- Coordinator, 'Golden Jubilee Open House', held on 8th February, 2010.
- Co-Chairman, 'Golden Jubilee Energy Conclave - 2010', held during January 8-15, 2010.
- Member, Board of Governors, Alumni Association, IIT Kanpur, April 2010 - March 2012.
- Treasurer, Alumni Association, IIT Kanpur - April 2008 - March 2010.
- Departmental coordinator NPTEL (National Program for Technology Enhanced Learning)
- Member, Departmental Under-Graduate Committee – DUGC, 2011-2012.
- Convener of B. Tech. Project Evaluation Committee, June 2010 - May 2012 (two terms).
- Member of FIST research grant coordination committee.



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# Summary and Outlook





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## Summary of major contributions

Last five years have been very satisfying in terms of professional and personal development

- Book published by Springer: Dropwise condensation on Inclined Textured Surfaces
- Established a very vibrant international RnD collaboration and funding; International student/ Professors/ researchers visits/ exchange in both directions (Indo-French and Indo-Italian).
- Successful organization of the 17th International Heat Pipe Conference at IIT Kanpur.
- PhD thesis of Italian joint doctoral student Mauro Mameli, awarded the best thesis award by the Italian Union of Thermodynamics.
- National and international Key Note/Invited lectures on - Pulsating Heat Pipes and Dropwise Condensation on Textured Surfaces.
- Filing of patents from BTech Projects, MTech and doctoral research.
- Establishment of Tinkering Laboratory and up-gradation of Central Workshop facilities.
- MoU with JK Center for Technician Training, Kanpur, and follow up workshops/visits.
- Several initiatives as PIC/ Air-conditioning, IWD.
- Student reaction survey score of above 3.0 in UG/PG courses.



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## Outlook

### **Research/ Development/ Consultancy - Immediate action items:**

- Signing a MoU with the European Space Agency for collaborative research on Pulsating Heat Pipes (spade work in this direction is already ongoing) experiment to be installed on International Space Station (in 2015 - 2018).
- Augmenting the ongoing Indo-French collaboration on microscale thermal systems with industry participation from both India and France. Preliminary contacts have been already made with Thales Avionics, Atherm Company and Golden Star Heat Pipe Pvt. Ltd. (Meeting May 24<sup>th</sup>, 2014).
- Following up with BRNS/ BARC – RSD on conducting dedicated experiments on passive cooling of nuclear power plant containments (TPDM next week!).
- Submitting an Indo-Italian project with University of Bergamo, Italy.
- More patents and aggressive IP protection activity.



## Outlook

### Teaching and Outreach activities

- Completion of the edited volume of new book titled: Nanoscale and Microscale Phenomenon: Fundamentals and Applications (Springer)
- Bringing out the proceedings of 17<sup>th</sup> IHPC, Begell House
- Working on a development of a new course on 'Thermal Management of Electronics'
- Video generation and repository of two-phase flow and heat transfer phenomena
- Creating an Indian thematic research group on phase-change thermal management.

### Administration

- Recruitment of more personnel in the Central Workshop/ Tinkering Laboratory.
- Procurement of new machines for the Central Workshop/ Tinkering Laboratory.
- Safety awareness in ME Department and IWD.
- Improving the information system of IWD/ related to AC plants.
- New central AC lines/plants/network.
- Energy audit and formulation of AC/HVAC policy (For Green Cell).



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- Institute administration
- Department of Mechanical Engineering
- Graduate students
- National funding agencies
- International funding agencies
- Colleagues and friends
- Family members

# Thank you