Scientific Report

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NEW TRENDS IN NONLINEAR DYNAMICS: HEAT CONTROL AND THERMO-ELECTRIC EFFICIENCY (HEAT2010)

Ettore Majorana Center, Erice, Sicily, Italy
October 23-28, 2010

Directors: Fabio Marchesoni, Giulio Casati, and Heiner Linke

SUMMARY

This meeting successfully facilitated the interaction of scientists from several communities who work on fundamental and applied questions related to heat transfer and heat engines, respectively, but who usually do not interact directly. The goal was to create interactions between the engineers and scientists who work with applied aspects of thermodynamics and thermoelectricity, with the physics community who is primarily concerned with the fundamental aspects of thermodynamics. One aim was to give direction to the fundamental research while making the applied community aware of the advances in fundamental understanding.

More than 50 delegates heard and discussed 28 oral presentations and 12 posters during four days of sessions (for details, see the attached workshop program).

SCIENTIFIC CONTENT AND DISCUSSION AT THE EVENT

Experts in the applied development of high-performance thermoelectric materials (including Shakouri and Terasaki) and cryogenic cooling devices (Meschke, Giazotto) informed about trends in advanced thermoelectric structures and associated scientific challenges, including the suppression of unintended heat flow. Imry and Nitzan introduced novel phenomena to be expected in molecular devices, and developed associated the theory.

Several experimentalists (Cahill, Shi, Bourgeois) and theorists (Mahan, Dhar, Sinha, Volz, Saito) discussed progress and challenges in understanding heat flow in nanostructures where the Fourier law is not valid and non-equilibrium effects must be considered. Of particular interest are opportunities to use nanoscale phenomena to rectify heat flow (Lepri, Terasaki).

Thermoelectrics are in essence heat engines, and their optimization, as well as the development of new thermal-to-electric power conversion strategies, require an improved understanding of the fundamental laws governing nanoscale heat engines and their efficiency and maximum power output. Related progress was reported and discussed by Esposito, Segal, Benenti, Prosen. Fundamental questions of the source of irreversibilities in microscopic and quantum systems was discussed, among others, by Hänggi and Mahler.

ASSESSMENT OF THE RESULTS AND IMPACT

A key feature of the workshop was the intensive interaction between experimentalists and theorists that created new interfaces for the exchange and development of novel concepts for efficient energy conversion. In addition to the creation of new, individual collaborations, a key outcome of the meeting is thus the creation of a basis for the more direct interaction between fundamental theory in nonlinear dynamics on the one hand, and experimentalists and engineers on the other hand. This is expected to lead to the development of new concepts, and potentially breakthroughs, in thermal-to-electric energy conversion and heat management.

It will take some time to evaluate the more specific outcomes in terms of new collaborations created and novel directions in this research field. However, it was clear that the interaction between more applied and more fundamental scientists was highly appreciated, and it seems very likely that new collaborations were created.

PROGRAM

Saturday 23th

Arrivals

Sunday 24th

09:00 – 09:40 **D. Cahill** (Urbana, US)
Heat conduction across interfaces with molecular layers: solids, liquids, and vapors
09:40 – 10:20 **O. Bourgeois** (Grenoble, France)
Thermal conductance of suspended nanostructures in diamond and silicon
10:20 – 11:00 **A. Dhar** (Bangalore, India)
Heat conduction in disordered harmonic lattices with energy conserving noise

11:00 – 11:30 *Coffee Break*

11:30 – 12:10 **M. Meschke** (Helsinki, Finland)
Heat transport and cooling in superconducting and metallic nanostructures
12:10 – 12:50 **F. Giazotto** (Pisa, Italy)
Heat transport in superconducting nanostructures and two dimensional electron gas systems

Lunch

15:00 – 15:40 **P. Hänggi** (Augsburg, Germany)
Hot quantum system interacting with cold one: The chronicle of mutual equilibration

15:40 – 16:20 **K. Saito** (Tokyo, Japan)
Dimensionality dependence of phononic transport

16:20 – 16:50: *Coffee break*

16:50 – 17:30 **G. Mahler** (Stuttgart, Germany)
Thermodynamics of small systems: Emergence of irreversibility
17:30 – 18:10 **D. Rossini** (Pisa, Italy)
Thermalization and ergodicity in many-body open quantum systems

Monday 25th

09:00 – 09:40 **Y. Imry** (Weizmann, Israel)
Thermal transport and thermoelectric coefficients near the Anderson transition and in molecular junctions
09:40 – 10:20 **S. Volz** (Paris, France)
Controlling heat conduction in nanostructured materials to enhance the thermoelectric figure of
10:20 – 11:00 **J. Gemmer** (Osnabruck, Germany)
From ballistic to hopping transport in topologically disordered quantum systems

11:00 – 11:30 *Coffee break*

11:30 – 12:10 **C. G. Smith** (Cambridge, UK)
Cooling an electron gas below the lattice temperature using quantum dot energy levels
12:10 – 12:50 **L. Gammaitoni** (Perugia, Italy)
ZeroPower: a Europa-wide initiative for nanoscale energy management

Lunch

15:00 – 15:40 **G. Mahan** (Penn State, US)
Heat flow in nanostructures
15:40 – 16:20 **X. Zotos** (Heraklion, Greece)
Open issues on the transport phenomena of 1D quantum magnets

16:20 – 16:50 *Coffee break*

16:50 – 17:30
Poster highlights
17:30 – 19:00
Poster session

20:30 *Social dinner*

Tuesday 26th

09:00 – 09:40 **A. Shakouri** (UCSC, US)
Transient charge and energy transport in thermoelectric devices

09:40 – 10:20 **L. Shi** (Austin, US)
Thermal transport and thermoelectric energy conversion in nanostructured and complex materials

10:20 – 10:50 *Coffee break*

11:30 – 12:10 **M. Esposito** (Brussels, Belgium)
Finite-time efficiency of small devices
11:30 – 12:10 **G. Benenti** (Como, Italy)
Microscopic mechanism for increasing thermoelectric efficiency

14:00 – 20:00 *Lunch and Excursion*

Wednesday 27th

09:00 – 09:40 **I. Terasaki** (Nagoya, Japan)
Oxide thermal rectifier and oxide thermoelectric device
09:40 – 10:20 **S. Sinha** (Urbana, US)
Disorder driven thermal transport in hard and soft matter

10:20 – 10:50 *Coffee break*

10:50 – 11:30 **A. Nitzan** (Tel Aviv, Israel)
Heating, heat conduction and cooling in molecular junctions
11:30 – 12:10 **D. Segal** (Toronto, Canada)
Heat engines and thermal conduction: An information theory model

Lunch

15:00 – 15:40 **J.-L. Pichard** (Saclay, France)
Thermal enhancement of interference effects in quantum point contacts
15:40 – 16:20 **T. Prosen** (Ljubljana, Slovenia)
On some exactly solvable cases of far from equilibrium transport in many-body quantum chains

16:20 – 16:50 *Coffee break*

16:50 – 17:30 **S. Lepri** (Florence, Italy)
Nonreciprocal wave propagation in a nonlinear system
17:30 – 18:10 **H. Linke** (Lund, Sweden)
Nonlinear thermoelectric effects in semiconductor nanostructures

18:10 *Closing*

Thursday 28th

Departures

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