INVITED LECTURERS

- **A. ALÙ**, CUNY - City University of New York, NY, US
- **C. ARGYROPOULOS**, The Pennsylvania State University, University Park, PA, US
- **P. BEN-ABDALLAH**, Institut d'Optique, CNRS, Paris, FR
- **G. BENENTI**, Università dell'Insubria, Como, IT
- **S.-A. BIEHS**, Carl von Ossietzky University of Oldenburg, DE
- **S. CAMPBELL**, University College, Dublin, IE
- **S.G. CASTILLO LOPEZ**, Universidad National Autónoma de México, MX
- **H.B. CHAN**, HKUST, Hong Kong, CN
- **D. DEAN**, University of Bordeaux, FR
- **N. FABBRI**, CNR-INO Istituto Nazionale di Ottica, Firenze, IT
- **J. FEIST,** UAM - Universidad Autónoma de Madrid, ES
- **S. FAN**, Stanford University, CA, US
- **C. HENKEL**, Universität Potsdam, DE
- **A. IMPARATO**, University of Trieste, IT
- **Q. JIANG**, Shanghai Jiao Tong University, CN
- **A. KITTEL**, Carl von Ossietzky University of Oldenburg, DE
- **M. KRÜGER**, University of Göttingen, DE
- **G. LANDI**, University of Rochester, US
- **B.J. LEE,** KAIST, Daejeon, KR
- **S. MAJUMDAR**, University of Paris-Saclay and CNRS, FR
- **S. MANN**, University of Amsterdam, NL
- **P. REDDY**, University of Michigan, Ann Arbor, MI, US
- **P. RODRÍGUEZ LÓPEZ,** Universidad Rey Juan Carlos, Madrid, ES
- **T. SHEGAI**, Chalmers University of Technology, Göteborg, SE
- **S. SHEN**, Carnegie Mellon University, Pittsburgh, PA, US
- **M.G. SILVEIRINHA**, Instituto Superior Técnico, Universidade de Lisboa, PT
- **J. SPLETTSTÖSSER**, Chalmers University of Technology, Göteborg, SE
- **S. VOLZ**, IIS, The University of Tokyo, JP

M. ANTEZZA – M. CENTINI – G. DE CHIARA
DIRECTORS OF THE COURSE

A. LANZARA – M.G. PALMA – B. SPAGNOLO
DIRECTORS OF THE SCHOOL

A. ZICHICHI
EMFCSC FOUNDER

“Fluctuations in Light-Matter Interactions: Quantum and Thermal Emerging Regimes”

17th Course of the International School of Nonequilibrium Phenomena

Ettore Majorana Foundation and Centre for Scientific Culture

Erice, Sicily — March 29 – April 3, 2026

Welcome

It is with great enthusiasm and a deep sense of scientific purpose that we welcome you to this Workshop and School, hosted by the **Ettore Majorana Foundation and Centre for Scientific Culture** in the extraordinary setting of Erice, Sicily. We have conceived this event as a space for rigorous inquiry, open exchange, and the kind of creative scientific encounter that only happens when the right people gather in the right place.

The topic we have chosen is, in our view, one of the most compelling at the frontier of modern physics: the nature and consequences of ***fluctuations*** in light–matter interaction, spanning from deep quantum regimes to thermal non-equilibrium conditions. These phenomena are at the very heart of how energy, information, and correlations flow through physical systems at the nanoscale and beyond.

We have structured the program around a constellation of themes that we believe are both foundational and forward-looking. The **Casimir effect** confronts us with the reality of quantum vacuum forces, whose subtlety and power are still revealing new surprises decades after their prediction. **Near-field radiative heat transfer** has emerged as a transformative research area, with the potential to redefine thermal management in nanoscale devices and energy conversion technologies. **Quantum thermodynamics** is reshaping our most basic notions of work and heat in the presence of quantum coherence. And **quantum nanophotonics**, at the crossroads of all these themes, is opening radically new ways to control light and matter at their most fundamental level.

We are proud to have gathered a remarkable cohort of invited speakers, theorists and experimentalists, senior scientists and rising stars, whose contributions over the coming days will, we are confident, inspire new questions and new collaborations. We have equally designed this school to be fully accessible to PhD students and postdoctoral researchers: the future of these fields is in your hands, and we hope you leave Erice with not only new knowledge, but new scientific friendships and ambitions.

Thank you for being here. We wish you a stimulating, enriching, and memorable week.

Mauro Antezza • Marco Centini • Gabriele De Chiara

Directors of the Workshop

PROGRAMME

Sun
- Arrival & Registration
- 19:30–21:30 Dinner
- 21:30–0.00 Marsala

Mon
- 08:00–08:50 Breakfast
- Opening Remarks
- 09:10–09:50 A. Alù
- 09:50–10:30 S. Fan
- 10:30–11:00 Coffee Break
- 11:00–11:40 P. Ben-Abdallah
- 11:40–12:20 S. Mann
- 12:20–13:00 M. Krüger
- 13:00–15:00 Lunch
- 15:00–15:40 B.J. Lee
- 15:40–16:20 Sheng Shen
- 16:20–16:50 Coffee Break
- 16:50–17:30 Pramod Reddy
- 17:30–18:10 Achim Kittel
- 19:30–21:30 Dinner
- 21:30–0.00 Poster Marsala

Tue
- 08:00–08:50 Breakfast
- 09:00–09:40 M. Silveirinha
- 09:40–10:20 J. Feist
- 10:20–11:00 P Rodríguez Lopez
- 11:00–11:30 Coffee Break
- 11:30–12:10 C. Henkel
- 12:10–12:50 H. B. Chan
- 12:50–13:30 T. Shegai
- 13:30–15:30 Lunch
- 15:30–16:10 Q. Jiang
- 16:10–16:50 D. Dean
- 16:50–17:20 Coffee Break
- 17:20–18:00 S. Majumdar
- 18:00–18:40 J. Splettstösser
- 19:30–21:30 Dinner
- 21:30–0.00 Poster Marsala

Wed
- 07:00–07:40 Breakfast
- 08:00–18:30 Excursion
- 20:00–22:00 Banquet
- 22:00–0.00 Poster Marsala

Thu
- 08:00–08:50 Breakfast
- 09:00–09:40 G. Benenti
- 09:40–10:20 G. Landi
- 10:20–10:50 Coffee Break
- 10:50–11:30 S. Campbell
- 11:30–12:10 A. Imparato
- 12:10–12:50 N. Fabbri
- 12:50–14:50 Lunch
- 14:50–15:30 C. Argyropoulos
- 15:30–16:10 S.G. Castillo Lopez
- 16:10–16:40 Coffee Break
- 16:40–17:20 S.-A. Biehs
- 17:20–18:00 S. Volz
- Closing Remarks
- 19:30–21:30 Dinner
- 21:30–0.00 Poster Marsala

Fri
- Departure

Detailed Program

Sunday, March 29, 2026

08:00 - 18:30	Arrival Day & Registration - Arrival Day & Registration
19:30 - 21:30	Dinner
21:30 - 23:55	Marsala

Monday, March 30, 2026

07:30 - 08:50	Breakfast
09:00 - 09:10	Opening Remarks
09:10 - 09:50	**Fluctuation Driven Radiation Mediated by Space and Space-Time Metamaterials** **Alù, Andrea** – CUNY - City University of New York (USA)
09:50 - 10:30	**TBA** **Fan, Shanhui** – Stanford University (USA)
10:30 - 11:00	Coffee break
11:00 - 11:40	**Thermal Photonics in Nonreciprocal Many-Body Systems and Programing Heat Transfer by Floquet Interference** **Ben-Abdallah, Philippe** – Institut d'Optique, CNRS (FR)
11:40 - 12:20	**Kirchhoff's law for time-varying materials** **Mann, Sander** – University of Amsterdam (NL)
12:20 - 13:00	**Theory of thermal transport via photons** **Krüger, Matthias** – University of Göttingen (DE)
13:00 - 15:00	Lunch
15:00 - 15:40	**Maximizing plasmon heat transfer in Nanoscale Metallic Films** **Lee, Bong Jae** – KAIST (KR)
15:40 - 16:20	**Metamaterials based Pixelated Thermal Signature Control** **Shen, Sheng** – Carnegie Mellon University (USA)
16:20 - 16:50	Coffee break
16:50 - 17:30	**Energy Transfer and Conversion in Nanoscale Gaps** **Reddy, Pramod** – University of Michigan (USA)
17:30 - 18:10	**Precise Measurements from the Near Field to the Extreme Near Field in Ultra High Vacuum** **Kittel, Achim** – Carl von Ossietzky University of Oldenburg (DE)
19:30 - 21:30	Dinner
21:30 - 23:55	Marsala & Poster

Tuesday, March 31, 2026

07:30 - 08:50	Breakfast
09:00 - 09:40	**Fluctuation-Induced Hall-like Forces in a Chiral Gain Environment** **Silveirinha, Mario G.** – Instituto Superior Técnico, Universidade de Lisboa (PT)
09:40 - 10:20	**Connecting nanophotonics with quantum optics** **Feist, Johannes** – UAM - Universidad Autónoma de Madrid (ES)
10:20 - 11:00	**Electromagnetic Transport Coefficients and the Kubo Formalism** **Rodríguez López, Pablo** – Universidad Rey Juan Carlos (ES)
11:00 - 11:30	Coffee break
11:30 - 12:10	**Anomalous dispersion forces and heat transfer: mesoscopic superconductivity and magnetic fluctuations** **Henkel, Carsten** – Universität Potsdam (DE)
12:10 - 12:50	**Measurement of the geometry dependence of Casimir forces using nanoscale gratings** **Chan, Ho Bun** – HKUST - Hong Kong (CN)
12:50 - 13:30	**Casimir self-assembly for tunable optical microcavities** **Shegai, Timur** – Chalmers University of Technology (SE)
13:30 - 15:30	Lunch
15:30 - 16:10	**Alter Vacuum Quantum Fluctuations with Altermagnet** **Jiang, Qingdong** – Shanghai Jiao Tong University (CN)
16:10 - 16:50	**Dielectric response and viscosity due to dipolar interactions** **Dean, David** – University of Bordeaux (FR)
16:50 - 17:20	Coffee break
17:20 - 18:00	**Dynamically Emergent Correlations** **Majumdar, Satyanarayan** – University of Paris-Saclay and CNRS (FR)
18:00 - 18:40	**Energy-conversion of hot carriers energy-filtering and feedback** **Splettstösser, Janine** – Chalmers University of Technology (SE)
19:30 - 21:30	Dinner
21:30 - 23:55	Marsala & Poster

Wednesday, April 1, 2026

07:00 - 07:40	Breakfast
08:00 - 18:30	**Excursion Day:** Excursion to the ancient Greek Temples of Segesta, a visit through the historic city of Palermo, and the splendid Monreale Cathedral
20:00 - 22:00	Conference Banquet
22:00 - 23:55	Marsala & Poster

Thursday, April 2, 2026

07:30 - 08:50	Breakfast
09:00 - 09:40	**Optimal control of a dissipative micromaser quantum battery in the ultrastrong coupling regime** **Benenti, Giuliano** – Università dell'Insubria (IT)
09:40 - 10:20	**Quantum trajectories and feedback control** **Landi, Gabriel** – University of Rochester (US)
10:20 - 10:50	Coffee break
10:50 - 11:30	**Ergotropy transport in a one-dimensional spin chain** **Campbell, Steve** – University College Dublin (IE)
11:30 - 12:10	**Information engine fueled by first--passage times** **Imparato, Alberto** – University of Trieste (IT)
12:10 - 12:50	**Spin-based diamond devices for quantum thermodynamics** **Fabbri, Nicole** – CNR-INO Istituto Nazionale di Ottica (IT)
12:50 - 14:50	Lunch
14:50 - 15:30	**Controlling and Enhancing Quantum and Thermal Radiation with Nanophotonics** **Argyropoulos, Christos** – The Pennsylvania State University (USA)
15:30 - 16:10	**Momentum and spectral bandgaps: shaping the near-field radiative heat transfer between plasmonic hypercrystals** **Castillo Lopez, Shunashi Guadalupe** – Universidad National Autónoma de México (MX)
16:10 - 16:40	Coffee break
16:40 - 17:20	**Near-field heat transfer in non-reciprocal nanosystems** **Biehs, Svend-Age** – Carl von Ossietzky University of Oldenburg (DE)
17:20 - 18:00	**Low-Dimensional Polaritons Thermal Radiation** **Volz, Sebastian** – IIS, The University of Tokyo (JP)
18:00 - 18:10	Closing Remarks
19:30 - 21:30	Dinner
21:30 - 23:55	Marsala & Poster

Friday, April 3, 2026

08:00 - 08:50	Breakfast
09:00 - 18:30	Departure Day - Departure Day

INVITED LECTURES

Abstract Collection

Fluctuation Driven Radiation Mediated by Space and Space-Time Metamaterials

Andrea Alu*†[1]

[1]City University of New York [New York] (CUNY) – 217 East 42 St, New York, NY 10017, United States

Abstract

Vacuum and thermal fluctuations underpin phenomena at all scales, which are at the basis of ubiquitious sources of electromagnetic radiation. Recent interest in spatially structured and/or time-varying media has revealed emerging landscapes of wave-matter interactions, where Floquet phenomena in space and time offer promising routes to engineer optical responses beyond those of natural materials. Photonic engineering can endow random fluctuations with spatial and temporal coherence, while space-time modulations can break reciprocity, mimic motion and enable ultrafast frequency and energy exchanges. In this talk, I discuss the powerful opportunities emerging by seeding space and space-time metamaterial responses with fluctuations. Quantum and thermal responses may be largely modified and pushed beyond the limits of conventional material systems, with opportunities for applications across a wide range of photonic technologies, from photon generation to energy extraction and conversion.

*Speaker

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Controlling and Enhancing Quantum and Thermal Radiation with Nanophotonics

Christos Argyropoulos*[1]

[1]The Pennsylvania State University (PSU) – United States

Abstract

The field of nanophotonics has significantly evolved and matured during the last years mainly due to the rapid improvement in nanotechnology fabrication capabilities. In addition, currently we are able to accurately model and analyze very complex nanophotonic systems with dimensions ranging from nano to angstrom scales. Nanophotonics promise to efficiently control and engineer classical and quantum light and heat radiation at the nanoscale leading to the practical exploration of various emerging linear, nonlinear, and quantum optical effects along with thermal control processes. In my talk, I will present our recent findings on nanophotonic systems with new functionalities and how they are connected to several relevant nascent fields in optics, such as metamaterials/metasurfaces, nanoantennas, optical chirality, quantum single photon emitters, thermal radiation manipulation, and plasmonics. The presented new photonic nanostructures will find applications in quantum communications and computing, low-threshold nanolasers, thermal emission and radiative cooling, all-optical switches and mixers, compact magnet-free nonreciprocal optical filters, and efficient chiral sensors and polarizers.

Keywords: nanophotonics, plasmonics, quantum optics, thermal radiation, metasurfaces

*Speaker

Thermal Photonics in Nonreciprocal Many-Body Systems and Programing Heat Transfer by Floquet Interference

Philippe Ben-Abdallah*[1]

[1]Laboratoire Charles Fabry – Laboratoire Charles Fabry, Institut d'Optique Graduate School (IOGS), CNRS DR4, CNRS, Université Paris Sud, Université Paris Saclay – 2, Avenue Augustin Fresnel 91127 Palaiseau Cedex, France

Abstract

In the first part of this lecture, I will discuss thermal photonics in non-reciprocal many-body systems (1) composed of magneto-optical materials. Under temperature gradients and spatially varying magnetic fields, these systems exhibit out-of-equilibrium radiative phenomena that constitute thermal analogs of condensed-matter effects such as the thermal Hall effect (2,3) and the inverse spin Hall effect (4), highlighting new opportunities for spin-caloritronic control of photonic heat currents. In the second part, I will present a phase-programmable mechanism for radiative heat transport based on interference between elastic and inelastic Floquet scattering channels induced by time-modulated permittivities (5). By controlling the modulation phases, this approach enables directional heat currents, reversible heat pumping, and reconfigurable splitting of radiative flux in many-body networks (6,7), opening new perspectives for programmable thermal photonic circuits.

References

(1) S.-A. Biehs, R. Messina, P. S. Venkataram, A. W. Rodriguez, J. C. Cuevas, and P. Ben-Abdallah, Rev. Mod. Phys. 93, 025009 (2021).

(2) P. Ben-Abdallah, Phys. Rev. Lett. 116, 084301 (2016).

(3) A. Ott, P. Ben-Abdallah, and S.-A. Biehs, Phys. Rev. B 97, 205414 (2018).

(4) P. Ben-Abdallah, Phys. Rev. Lett. 134, 113804 (2025).

(5) R. Yu and S. Fan, Time-modulated near-field radiative heat transfer, PNAS 121, e2401514121 (2024).

(6) P. Ben-Abdallah, Interference-controlled radiative heat transport in time-modulated networks, arXiv:2601.01945

(7) R. Messina and P. Ben-Abdallah, Many-Body Floquet Theory for Radiative Heat Transfer in Time-Modulated Systems, Phys. Rev. B, 113, 035404 (2026).

Keywords: Near, field, Non, Hermitian Systems, Time, Modulated Media

*Speaker

Optimal control of a dissipative micromaser quantum battery in the ultrastrong coupling regime

Giuliano Benenti*[1,2], Maristella Crotti[1,2], Luca Razzoli[3,4], Luigi Giannelli[5,6], and Giuseppe Falci[5,6]

[1]Center for Nonlinear and Complex Systems, Dipartimento di Scienza e Alta Tecnologia, Università degli Studi dell'Insubria – Italy
[2]INFN - Sezione di Milano – Italy
[3]Dipartimento di Fisica 'Alessandro Volta', Università di Pavia – Italy
[4]INFN - Sezione di Pavia – Italy
[5]Dipartimento di Fisica e Astronomia 'Ettore Majorana', Università di Catania – Italy
[6]INFN Sezione di Catania – Italy

Abstract

We investigate the open-system dynamics of a micromaser quantum battery operating in the ultrastrong coupling (USC) regime. The battery consists of a quantized harmonic mode that sequentially interacts, via the Rabi Hamiltonian, with a stream of qubits acting as chargers. The counter-rotating terms active in the USC regime substantially enhance the charging speed; however, they also induce unbounded energy growth and lead to highly mixed cavity states. This behavior is suppressed by dissipation during the interaction, which drives the system toward a steady state with finite energy and ergotropy. We then investigated the management of the stored ergotropy by optimal control theory, showing that the interplay between ultrastrong coupling and dissipation enables both enhanced charging performance and long-term stability against losses of micromaser quantum batteries.

*Speaker

Near-field heat transfer in non-reciprocal nanosystems

Svend-Age Biehs*†[1]

[1]Institute of Physics, Carl von Ossietzky University of Oldenburg (UOL) – Ammerländer Heerstr. 114-118, 26129 Oldenburg, Germany

Abstract

The non-reciprocal material properties of magneto-optical materials (MOM) and Weyl-semimetals (WSM) arising from time-reversal symmetry breaking have intriguing consequences for heat radiation, including persistent heat currents (1) and persistent heat fluxes (2). I will discuss the nature of the persistent heat flux and the relation between the Hall effect for thermal radiation (3, 4) and the persistent heat current (5), as well as the vacuum-induced Feynman paradox (6). Furthermore, I will review the possibility of rectifying nanoscale radiative heat fluxes by means of non-reciprocal surface waves (7, 8) and demonstrate that WSMs enable the realization of very large rectification ratios (9, 10). In this context, I will discuss how the spin-spin coupling mechanism can be used for dynamical thermal routing between a planar substrate and two nanoparticles employing the WSM Co3Sn2S2 (11). Finally, I present the possibility to employ synthetic electric and magnetic fields instead of real magnetic fields via frequency modulations, resulting in a breakdown of detailed balance (12) and non-reciprocal radiative heat fluxes (13) within the framework of a quantum Langevin and master equation approach.

1. L. Zhu and S. Fan, "Persistent Directional Current at Equilibrium in Nonreciprocal Many-Body Near Field Electromagnetic Heat Transfer," Phys. Rev. Lett. **117**, 134303 (2016).

2. A. Ott, P. Ben-Abdallah, and S.-A. Biehs, "Circular heat and momentum flux radiated by magneto-optical nanoparticles," Phys. Rev. B **97**, 205414 (2018).

3. P. Ben-Abdallah, "Photon Thermal Hall Effect," Phys. Rev. Lett. **116**, 084301, (2016).

4. A. Ott, S.-A. Biehs, P. Ben-Abdallah, "Anomalous photon thermal Hall effect," Phys. Rev. B **101**, 241411 (2020)(R).

5. S.-A. Biehs and I. Latella, "On persistent energy currents at equilibrium in non-reciprocal systems," JQSRT **347**, 109660(2025).

6. S.-A. Biehs and I. Latella, "Feynman paradox induced by vacuum and thermal fluctuations," arXiv:2509.08711.

7. A. Ott, R. Messina, P. Ben-Abdallah, S.-A. Biehs, "Radiative thermal diode driven by nonreciprocal surface waves," Appl. Phys. Lett. **114**, 163105 (2019).

*Speaker

†Corresponding author: s.age.biehs@uni-oldenburg.de

8. A. Ott and S.-A. Biehs, "Thermal rectification and spin-spin coupling of non-reciprocal localized and surface modes," Phys. Rev. B **101**, 155428 (2020).

9. Y. Hu, H. Liu, B. Yang, K. Shi, M. Antezza, X. Wu, and Y. Sun, "High-rectification near-field radiative thermal diode using Weyl semimetals," Phys. Rev. Mat. **7**, 035201 (2023).

10. A. Naeimi and S.-A. Biehs, "Efficiency and Mechanism of heat flux rectification with non-reciprocal surface waves in Weyl-Semi-Metals," Phys. Rev. Materials **9**, 045201(2025).

11. A. Naeimi and S.-A. Biehs, "Dynamical thermal near-field routing with the non-reciprocal Weyl semi-metal Co3 Sn2 S2," Appl. Phys. Lett. **127**, 101601(2025).

12. S.-A. Biehs and G.S. Agarwal, "Breakdown of detailed balance for thermal radiation by synthetic fields," Phys. Rev. Lett. **130**, 110401, (2023).

13. S.-A. Biehs, P. Rodriguez-Lopez, M. Antezza, G.S. Agarwal, "Nonreciprocal heat flux via synthetic fields in linear quantum systems," Phys. Rev. A **108**, 042201(2023).

Keywords: near field heat transfer, nonreciprocal media, heat flux rectification, surface waves, nanoparticles, synthetic fields

Ergotropy transport in a one-dimensional spin chain

Steve Campbell*†[1]

[1]University College Dublin [Dublin] (UCD) – Belfield, Dublin 4, Ireland

Abstract

Spin chains are a versatile setting to examine quantum transport phenomena. While an extensive literature exists for state-transfer protocols, less attention has been paid to examining the transport of useful energy, i.e., extractable work as quantified by the ergotropy. By modeling the individual constituents as quantum batteries, we will show that how the manner in which the extractable work appears in the initial state of the first site impacts the chain's ability to transport ergotropy. Depending on the nature of the coupling within the chain, we find that there is a clear quantum advantage when the ergotropy is initially endowed in quantum coherences and demonstrate that this ergotropy is more efficiently transferred.

*Speaker
†Corresponding author: steve.campbell@ucd.ie

Momentum and spectral bandgaps: shaping the near-field radiative heat transfer between plasmonic hypercrystals

Shunashi G. Castillo-López*†[1], Silvia Cortés-López[2], Dulce N. Castillo-López[3], and Ángel Espinoza-Merino[4]

[1]Instituto de Física, Universidad Nacional Autónoma de México (IFUNAM) – Instituto de Física Universidad Nacional Autónoma de México Ciudad de México, C.P. 04510 Mexico, Mexico
[2]Tecnológico Nacional de México/ ITS de Poza Rica – Mexico
[3]Facultad de Ciencias de la Electrónica, Benemérita Universidad Autónoma de Puebla – Mexico
[4]Instituto de Física, Universidad Nacional Autonoma de Mexico – Mexico

Abstract

This study theoretically investigates the near-field radiative heat transfer (NFRHT) between two plasmonic hypercrystals (PlHs). Each PlH is formed by a periodic variation in the dielectric response of a hyperbolic metamaterial (HMM), achieved by incorporating plasmonic f ilms. We analyzed the contribution of the high-k modes of the PlHs to NFRHT, which result in spectral and momentum bandgaps forming in the system's energy transmission coefficient. We found that the heat flux between the PlHs increases up to 480% compared to two homogeneous slabs made of the same HMM due to the inclusion of thin plasmonic layers. We also explored the control of heat transfer by tuning the system's geometrical parameters and the effects of the stacking order of the different phases on the NFRHT.

Keywords: near fied radiative heat transfer, hypercrystals, hyperbolic materials

*Speaker
†Corresponding author: shunashi@fisica.unam.mx

Measurement of the geometry dependence of Casimir forces using nanoscale gratings

H. B. Chan*[1]

[1]the Hong Kong University of Science and Technology – Hong Kong SAR China

Abstract

The Casimir force arises from quantum fluctuations of the electromagnetic field. It leads to an attraction between electrically neutral bodies with a vacuum gap that becomes measureable at nanoscale separations. One of the remarkable properties of the Casimir force is its non-trivial dependence on the shape of the interacting objects. Experiments using the corrugated surface of gratings have demonstrated the deviation of the Casimir force from the proximity force approximation. Here, we present measurements of the Casimir force between two silicon structures, both of which contain rectangular corrugations. By overcoming the alignment difficulties, the two gratings interpenetrate when the separation between them is reduced. Our data shows that at certain separations, the proximity force approximation utterly breaks down. We will also present measurements of the force gradient between a gold sphere and a silicon oxide grating covered with graphene, where the goal is to enhance the interplay between geometry and temperature effects. This work is partly supported by supported by a grant "CAT" from the ANR/RGC Joint Research Scheme sponsored by the French National Research Agency (ANR) and the Research Grants Council (RGC) of the Hong Kong Special Administrative Region, China (Project No. A-HKUST604/20).

Keywords: Casimir effect in thermal equilibrium

*Speaker

Dielectric response and viscosity due to dipolar interactions

David Dean*[1]

[1]Laboratoire d'Ondes et Matièred'Aquitaine (LOMA) – PRES Université de Bordeaux – Université de Bordeaux, France

Abstract

We consider a stochastic field theory for dipolar interactions in a liquid and their effect on the liquid's complex dielectric function and viscosity. The interactions remove a degeneracy present in the non-interacting dipolar system, leading to two dielectric relaxation times. We derive a Kubo relation for the linear response of a general observable to an advecting flow, and apply it to obtain a closed-form expression for the dipolar contribution to viscosity. The theoretical results are in good agreement with experimental measurements for dipolar liquids, suggesting that stochastic dipolar interactions make the dominant contribution to the viscosity of these liquids.

Keywords: van der Waals interactions, dielectrics, viscosity, stochastic field theory

*Speaker

Spin-based diamond devices for quantum thermodynamics

Nicole Fabbri*[1,2]

[1]Istituto Nazionale di Ottica del Consiglio Nazionale delle Ricerche (CNR-INO) – Italy
[2]European Laboratory for Nonlinear Spectroscopy (LENS) – Italy

Abstract

Spin-based diamond devices, enabled by exquisite quantum control over long-lived spin states and by tailored interaction with their environment, disclose new possibilities for exploring thermodynamics operating at the nanoscales, where fluctuations and quantum effects play a significant role (1). Diamond electronic spins allow implementation of both unitary and non-unitary dynamics, involving exchange of work, heat, or both.
We employed different approaches to quantify the contribution of initial quantum coherence, and nonclassical multi-time correlations in thermodynamic processes. We experimentally demonstrated an end-point measurement (EPM) approach, in which the statistics of energy-change fluctuations are inferred from knowledge of the initial state and the system Hamiltonian. Using this method, we characterized the entropy production associated to quantum coherence in a driven open quantum system (2).

Furthermore, we investigated genuinely nonclassical multi-time correlations in a diamond spin qutrit under a unitary quantum work process, via Kirkwood-Dirac quasiprobability (KDQ) distributions (3). We measured the real part of KDQ via projective measurements, and the full distribution with an interferometric scheme. Interestingly, we observed anomalous work extraction (4) and analyzed the behavior of the first and second moments of work, connecting them with Robertson-Schrödinger uncertainty relation (5).

(1) PRX Quantum 3 (2), 020329 (2022)

(2) npj Quantum Information 9 (1), 86 (2023)

(3) Quantum 7, 1128 (2023)

(4) Physical Review Research 6 (2), 023280 (2024)
(5) npj Quantum Information 10 (1), 115 (2024)

Keywords: spins in diamond, energy distributions, Kirkwood, Dirac quasiprobabilities, anomalous work extraction

*Speaker

Connecting nanophotonics with quantum optics

Johannes Feist*[1]

[1]Departamento de Fisica Teorica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC) – Universidad Autonoma de Madrid, Madrid E-28049, Spain, Spain

Abstract

I will discuss how to connect nanophotonics with quantum optics, i.e., how to obtain a quantum-optics like description in terms of a few discrete modes for the quantum light-matter interaction in arbitrary nanophotonic structures, while still taking into account the full nanophotonic complexity of light propagation and emission. As a natural consequence, this leads to quantum optical models consisting of coupled lossy modes with strong non-Hermitian character, which can be exploited to enable novel applications and protocols in quantum optics. I will then discuss how these ideas can be extended to give direct access to photon correlations of the emitted light resolved in space, frequency, time and polarization for arbitrary electromagnetic environments, while correctly accounting for fully retarded light propagation to the detectors.

*Speaker

Anomalous dispersion forces and heat transfer: mesoscopic superconductivity and magnetic fluctuations

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Abstract

In dispersion force measurements of the van der Waals and Casimir-Polder type, a strange discrepancy between the standard Lifshitz theory and experimental data has emerged across distances between 200 and 500 nm (1). An accurate modelling is achieved when neglecting the finite conductivity of the gold coating, treating it effectively as a superconductor ("plasma model") (2). We review recent attempts to describe this in terms of a nonlocal electric conductivity (3) and elaborate on a model built on electrons moving ballistically on mesoscopic scales (approx 10 nm). Indeed, metal nanoparticles made from gold or silver have a nontrivial magnetic response dubbed giant diamagnetism (4, 5, 6).

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Keywords: Casimir puzzle, dispersion forces, magnetic fluctuations, mesoscopic diamagnetism

Information engine fueled by first–passage times

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Abstract

I will consider the thermodynamic properties of an information engine that uses feedback control to extract work from a manipulated stochastic system.
I will discuss the fluctuation theorems that involve the information associated with the feedback-controlled stochastic trajectories.Such an information turns out to be based on the first-passage-time distribution.
I will then discuss the experimental verification of the above results with a se tup consisting of a cantilever submitted to an electrostatic feedback force.
I will finally show that the fluctuation theorems extend beyond the specific app lication to such an experiment.

Reference:
A. Archambault, C. Crauste-Thibierge, A. Imparato, C. Jarzynski, S. Ciliberto, L. Bellon, Information Engine Fueled by First-Passage Times, Phys. Rev. Lett 135, 147101 (2025)

*Speaker

Alter Vacuum Quantum Fluctuations with Altermagnet

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Abstract

Casimir torque provides a powerful means to convert vacuum quantum fluctuations into rotational motion, with promising applications in nanoelectromechanical systems, nanoscale actuators, and ultrasensitive torque sensors. A long-standing challenge is achieving **active and reversible control** over both the **magnitude and sign** of the torque without relying on dielectric or geometric anisotropy. Here we demonstrate a **fundamentally new mechanism**: an **axially symmetric magnetic field** can generate, tune, and even reverse Casimir torque in a two-dimensional system while preserving in-plane rotational symmetry. This counterintuitive effect is enabled by **altermagnetic materials**, whose combined crystalline and time-reversal symmetry allows magnetic fields to activate otherwise forbidden anisotropic vacuum interactions. Our results establish **time-reversal symmetry breaking as an independent control knob** for Casimir torque and open a new symmetry-based route for engineering vacuum forces at the nanoscale.

Keywords: Casimir effects, Casimir torque, Altermagnet, Symmetry and symmetry breaking

*Speaker

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Precise Measurements from the Near Field to the Extreme Near Field in Ultra High Vacuum

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Abstract

We report on precise measurements of the heat transfer on the nanometer scale by means of a ultra high vacuum (UHV) near-field scanning thermal microscope. This microscope is based on a scanning tunneling microscope which is equipped with a sub-micron sized, coaxial thermocouple. In principle, the microscope is able to measure lateral changes in heat transfer with a spatial resolution of about 5 nm. The conversion factor of the sensor is defined as the thermal flux through the sensor, from a thermal reservoir at its back to its tip apex, divided by the thermopower generated in the sensor's coaxial thermocouple. The achieved accuracy of the conversion factor is about 8% including the precision of each piece of equipment used within the calibration procedure.

The tip and the sample are cleaned in-situ, i. e. under UHV conditions, leading to clean sample surface which can be easily imaged by the STM capabilities of our setup. This can be verified by recording the result of each individual cleaning step. Furthermore, any contamination by various adsorbate substances can be ruled out by imaging the surface topography. To prove this, ultrapure water was applied as a submonolayer to the sample surface in UHV and then imaged. The water contamination on the surface is clearly visible. After ensuring that the surfaces were clean, measurements were taken in the transition from near-field heat transfer to extreme near-field heat transfer.

With the calibrated sensor we perform quantitative measurements of the heat transfer between a sphere (20 um diameter) glued to the coaxial thermocouple sensor and a flat surface. The observed heat transfer between a gold plated sphere and a flat gold surface can be determined for separations of a few nanometers to some hundred nanometers. For large distances, the measurement results of the heat transfer can be described perfectly by the theory of fluctuational electrodynamics combined with the so-called Derjaguin approximation. At smaller distances smaller than about 18 nm, a strong deviation from the theory can be seen. This large deviation was already observed earlier in previous measurements with a sharp NSThM tip. The origin of the peculiarity at shorter distances is still under heavy debate.

Keywords: near, field heat radiation, exrteme near field, coaxial thermocouple ssensor, heat conduction

*Speaker

Theory of thermal transport via photons

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Abstract

It is well known that photons can cause thermal transport between isolated bodies, i.e., via near- and far-field thermal radiation. In this contribution, we theoretically analyze and discuss thermal transport via photons in various situations and setups: i) We introduce thermal radiation between isolated bodies through vacuum. ii) We discuss and analyze the special properties of thermal radiation between non-reciprocal objects. iii) We analyze thermal transport via photons within media in several geometries like a sheet or a sphere, and discuss in which cases it can overcome conductivity by phonons. Last, iv) we discuss thermal transport via photons between nanoparticles in relative motion.

*Speaker

Quantum trajectories and feedback control

Gabriel Landi*[1]

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Abstract

This talk will discuss recent results in describing quantum trajectories, feedback control and thermal machines. The problem will be motivated with a discussion of cooling down a superconducting qubit using an absorption refrigerator. We provide an overview of how to use the toolbox of quantum instruments to provide an extremely general formulation of the problem. And we specialize it to the important case of quantum jumps. In both cases, we introduce the basic ideas behind full counting statistics, which is used to connect quantum dynamics to experimental measurement outcomes. We introduce the notion of stochastic excursions, and how it can be used to understand different mechanisms that contribute to current fluctuations. Finally, we introduce new results from our group on the description of feedback protocols based on quantum trajectories. We highlight a very general formalism, based on generic quantum instruments, and then discuss how these can be specialized to devise novel feedback strategies based on quantum jump detection. These concepts will be illustrated with examples from superconducting qubits, transport across quantum dots and atomic masers.

*Speaker

Maximizing plasmon heat transfer in Nanoscale Metallic Films

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Abstract

The classical size effect poses a significant challenge in microelectronics, where diminished thermal conductivity in thin films results in detrimental thermal accumulation. Emerging research suggests that surface electromagnetic waves can serve as a potent carrier for heat transfer in both polar dielectrics and metals. This talk details our recent experimental and theoretical results on surface-plasmon-enhanced in-plane thermal conductivity within metallic thin films. Furthermore, we delineate the physical conditions necessary for maximizing this plasmonic contribution and demonstrate how strategic modifications to the layer architecture and substrate properties can be leveraged to realize optimal thermal management.

Keywords: Surface plasmon, Inplane heat transfer, nanoscale metal films

*Speaker

Dynamically Emergent Correlations

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Abstract

The goal of this talk is to show that strong correlations between particles may emerge dynamically due to a common stochastically fluctuating environment, even when there is no direct built-in interaction between particles. These correlations grow with time, eventually driving the system into a 'strongly correlated' nonequilibrium stationary state with nontrivial properties. I will demonstrate this in an exactly solvable model of noninteracting Brownian particles in a harmonic trap whose stiffness switches between two values at a constant rate. This model has been recently realized experimentally in optically trapped colloidal particle systems. Experimental results agree very well with theoretical predictions.

Keywords: nonequilibrium systems, emergent correlations, Brownian motions

*Speaker

Kirchhoff's law for time-varying materials

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[1]University of Amsterdam – Netherlands

Abstract

Kirchhoff's law of thermal radiation states that the angle and frequency resolved absorptivity and emissivity of an object are equal. In recent years, metamaterials have demonstrated large control over the absorptivity and emissivity (1,2), in some cases requiring extensions of Kirchhoff's law. For example, Kirchhoff's law has recently been extended to structures where the emitted polarizations are correlated (3). We verify this extension experimentally by demonstrating a direct measurement of the absorptivity and emissivity of a metasurface emitting circularly polarized light, which confirms that the emissivity is the complex conjugate of the absorptivity. Using a nonreciprocal coupled-mode theory we developed (4), we then discuss an extension of Kirchhoff's law to nonreciprocal materials, which shows i) equivalence between absorption in an object and emission from its time-reversed counterpart and ii) that passive, nonreciprocal emitters always satisfy the second law of thermodynamics. Finally, we investigate thermal radiation from time-varying materials. We present a Kirchhoff's law of thermal radiation, which readily enables calculation of the emission through knowledge of the absorption, which often is much easier to obtain. We demonstrate the generalized equivalence between emission and absorption numerically, confirming that indeed the route via absorption provides a much easier way to obtain the emissivity, and present some systems where the standard Kirchhoff's law is violated in unique ways.
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*Speaker

Energy Transfer and Conversion in Nanoscale Gaps

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Abstract

Understanding radiative heat transfer in nanoscale gaps and devices is of great current interest due to the strong potential of nanoscale thermal radiation for creating novel energy conversion devices. In this talk, I will describe ongoing efforts in our group to experimentally elucidate nanoscale (near-field) radiative heat transfer and leveraging it for developing novel energy conversion technologies. Specifically, I will present our recent experimental work where we have developed and employed novel nano positioning platforms and custom-developed microdevices to perform first systematic experiments of near-field radiative heat transfer. Our experiments reveal that radiative heat transfer rates in nanometer sized gaps can exceed those set by the blackbody limit by several orders of magnitude both at room temperature and cryogenic temperatures. Next, I will discuss how such enhancements in radiative heat transfer rates can enable novel thermal devices (thermal diodes and transistors) as well as photonic based energy conversion and refrigeration technologies. Finally, I will briefly outline how these technical advances can be leveraged for converting heat to electricity with high efficiency and high-power output to develop novel energy conversion technologies.

Keywords: Near, field thermal radiation, superconductors, thermal rectification

*Speaker

Electromagnetic Transport Coefficients and the Kubo Formalism

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[2]Université de Montpellier (UM) – Laboratoire Charles Colomb – Laboratoire Charles Coulomb (L2C), UMR 5221 CNRS-University of Montpellier, F-34095 Montpellier, France, France

Abstract

In this talk, we discuss the connection between the electromagnetic polarization operator, the electrical conductivity, and magnetic-field–induced currents in materials described by tight-binding models, focusing on graphene as a paradigmatic example. We extend the celebrated Fukuyama formula for magnetic susceptibility to dynamic and non-local regimes, and we relate the resulting transport coefficients to the polarization and magnetization responses of the material. This framework naturally connects to the corresponding electric and magnetic permittivities.

In the literature, two distinct expressions for the electrical conductivity tensor coexist: one derived from the Kubo formalism and another defined directly in terms of the polarization operator. We show that one of these approaches naturally leads to an interpretation of magnetic-field–induced currents as a plasma-like resonance. This connection is demonstrated explicitly by computing the magnetic susceptibility of graphene and comparing our results with existing findings in the literature.

Keywords: Electric conductivity, Kubo formalism, Graphene, Magnetic susceptibility, Fukuyama Formula

*Speaker

Casimir self-assembly for tunable optical microcavities

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Abstract

Strong light-matter interactions are at the core of many electromagnetic phenomena. In this talk, I will give an overview of several nanophotonic systems which support polaritons – hybrid states of light and matter, as well as try to demonstrate their potential usefulness in applications. I will start with transition metal dichalcogenides (TMDs) and specifically discuss one-dimensional edges in these two-dimensional materials (1-2). I will also discuss the concept of self-hybridization, a scenario in which both light and matter subparts in a polaritonic system are supported by the same (nano)structured material (1-4). We have recently demonstrated such self-hybridization in TMD nanostructures (1-4) and levitating water droplets (4-5) across both electronic and vibrational strong coupling. The latter is interesting, due to abundance of water droplets in natural systems, including mists, fogs, and clouds. Furthermore, I will show that Fabry-Pérot resonators, one of the most important workhorses of nanophotonics, can spontaneously form in an aqueous solution of gold nanoflakes (6-9). This effect is possible due to the intricate balance between attractive Casimir-Lifshitz forces and repulsive electrostatic forces acting between the flakes. There is a hope that this technology is going to be useful for future developments in self-assembly and molecular polaritonics, as well as help develop a unified view of Casimir and strong light-matter coupling phenomena (10).

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Keywords: Casimir, Lifshitz force, optical microcavity, self, assembly, strong light, matter coupling

Metamaterials based Pixelated Thermal Signature Control

Sheng Sheng Shen*[1]

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Abstract

In this talk, I will present several examples for using metamaterials to develop pixelated thermal signature control. Inspired by leafhopper-generated brochosomes, we designed binary metastructures functioning as pixel twins to achieve pixelated thermal signature control at the microscale. In the infrared range, the pixel twins exhibit distinct emissivities, creating thermal counterparts of "0-1" binary states for storing and displaying information. In the visible range, the engineered surface morphology of the pixel twins ensures similar scattering behaviors, which renders them visually indistinguishable, thereby concealing the stored information. In another example, we experimentally demonstrated highly dynamic, pixelated modulation of coherent mid-infrared emission based on an electrically programmable plasmonic metasurface integrated with graphene field effect transistors or chalcogenide-based phase-change materials. The ultrabroad infrared transparency of graphene allows for freeform control over plasmonic meta-atoms, thus achieving coherent mid-infrared states across a broad range of wavelengths and polarizations. The spatial temperature modulation generated by graphene field effect transistors is effectively synergized with the emissivity control by the localized surface plasmon polaritons from gold nanoantennas. This integrated temperature-emissivity modulation of metasurfaces is systematically extended to form a pixelated 2D array, enabling a new approach toward scalable 2D electrical wiring for densely packed, independently controlled pixels.

Keywords: Metamaterials, pixelated, electrically reconfigurable, thermal emission control

*Speaker

Fluctuation-Induced Hall-like Forces in a Chiral Gain Environment

Mario Silveirinha*[1]

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Abstract

Over the past decade, there has been significant interest in nonreciprocal effects in quantum systems. Nonreciprocity can be achieved through various means, such as preparing the system in a chiral quantum state, utilizing nonlinearities, or using an external magnetic field. When a quantum system is prepared in a state that favors specific circularly polarized (chiral) optical transitions, it exhibits remarkable directional properties (1).
In this talk, we will discuss how material gain can foster more robust nonreciprocal interactions. Specifically, we study environments exhibiting "chiral gain" (2, 3, 4). Such environments can be realized in electrically-biased materials with broken inversion symmetry and large Berry curvature dipole. It has been demonstrated that these systems facilitate non-Hermitian responses, with the gain dependent on the polarization handedness (2, 3, 4). We will focus on how chiral gain can be leveraged to tailor optical forces, induce quantum friction and optical instabilities, and control the flow of fluctuation-induced energy in a steady-state regime (5). These results underscore the potential of chiral gain in controlling quantum system behavior.

Acknowledgments: This work is supported in part by the Simons Foundation (award SFI-MPS-EWP-00008530-10), and by national funds through FCT – Fundação para a Ciência e a Tecnologia, I.P., and, when eligible, co-funded by EU funds under project/support UID/50008/2025 – Instituto de Telecomunicações, with DOI identifier .

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*Speaker

Energy-conversion of hot carriers - energy-filtering and feedback

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Abstract

In a solar cell, electron-hole pairs are created due to light-irradiation and can then be separated in order to create a charge current flow thereby generating electrical power. Similarly, hot carrier distributions, resulting from local heating, can be used to generate power via the thermoelectric effect.
The device parameters leading to optimal power production heavily depend on the actual carrier distribution, which in turn can change depending on external conditions. In this talk, I will show two different strategies how to optimise power generation with hot carriers.
First I will show how a combination of several energy filters can potentially improve hot-carrier solar cells in a multi-terminal setting (1). I will then introduce a scheme how to autonomously measure a thermoelectrically induced potential bias and subsequently give feedback on the energy-filter used for power generation (2). This can improve the device performance even if only a distribution of possible environment temperatures is known.

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*Speaker

Low-Dimensional Polaritons Thermal Radiation

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Abstract

Abstract: We introduce a new type of thermal radiation which is confined in two dimensions and can be emitted by thermal waveguides.

Phonons are the quasiparticles of lattice vibrations and represent the primary heat carriers in bulk dielectric materials. The thermal conductivity of dielectric low-dimensional solids is thus typically driven by acoustic phonons and generally reduces with thickness due to surface scattering events (1). Yet, heat transport might reversely be enhanced via hybrid excitations, i.e. surface phonon-polaritons or plasmon-polaritons.

Over the two past decades, substantial research efforts have been devoted to the study of those modes, especially due to their ability to transfer an exalted heat flux through submicron gaps (2). Surface polaritons are essentially evanescent waves in the out-of-plane direction but propagate along the surface of polar dielectrics.

More recently, it has been theoretically proposed that polaritons could also carry an in-plane heat flux, especially in thin films, where those modes cover a large spectrum and have extremely long propagation lengths. Theoretical models predicted that such propagation lengths enable a larger heat conduction via polaritons than via phonons (3,4).

In this seminar, the existence and the properties of those film-polaritons will be demonstrated (5) then the experimental measurement of the corresponding heat flux will be presented (6,7,8). Our recent theoretical investigations confirm the match between measurements and predictions within 5% of inaccuracy (9).

Further measurements investigating thermal radiation of films beyond the reactive near-field will be also introduced. In particular, a debated Super Planckian heat flux was observed (10).

Acknowledgements: This work is supported by CREST JST, Grant JPMJCR19I1.

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Keywords: thermal polaritons, nanofilms, guided radiation

POSTER SESSION

Abstract Collection

Measurement Induced Subradiance

Ipsita Bar*†[1], Aditi Thakar[1], and B Prasanna Venkatesh[1]

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Abstract

Preparing subradiant steady states of collectively emitting quantum two-level emitters (TLEs) is hindered by their dark, weakly interacting nature. Existing approaches rely on patterned driving, local control, or structured environments. We propose a platform-independent protocol based on projective measurements on a single TLE. For permutation-symmetric ensembles, a single measurement yields appreciable occupation of single-excitation subradiant steady states. For generic arrays, repeated measurements on one emitter drive the unmeasured TLEs into a nearly pure state with large overlap with the subradiant Dicke subspace.

Keywords: Subradiance, Measurement, state preparation, Collective Spontaneous emission

*Speaker

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Dielectric response and fluctuation-dissipation-theorem for moving bodies

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Abstract

Casimir forces operate at microscopic scales and are integral to phenomena such as gecko adhesion and functionality of nano-devices. Recent research has unveiled new effects, arising from thermal and mechanical non-equilibrium, such as levitation or propulsive forces capable to driving heat engines, or novel effects tied to optically nonreciprocal materials (1,2). In this contribution we formulate scattering theory for objects in respective motion. Specifically, we find the dielectric response and the fluctuation-dissipation theorem for arbitrary moving bodies. The dielectric response of a moving body is found to be nonlocal in space, optically non-reciprocal, and can also appear as being active. Conversely, it is possible to design an active medium that appears optically passive when in motion. Finally, we derive closed expressions for Casimir forces and heat transfer between moving bodies using scattering theory.

1. Krüger et al., Physical Review B, 2012.
2. Gelbwaser-Klimovsky et al., Physical Review Letters, 2021.

*Speaker

Fluctuating Energy Pathways at Plasmonic Interfaces: Temperature-Dependent Electron–Phonon Relaxation

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Abstract

Ultrafast energy relaxation in plasmonic nanostructures is typically described by the two-temperature model, where photoexcited electrons transfer energy to the lattice through electron–phonon coupling. However, in metal–semiconductor heterostructures, interfacial electronic processes may introduce additional energy dissipation pathways.

Here, we investigate the temperature dependence of electron–phonon relaxation in plasmonic heterostructures composed of Gold nanoparticles supported on Titanium dioxide using femtosecond transient absorption spectroscopy. By comparing Au/TiO with Au/SiO-supported and bare Au nanoparticles, we isolate the role of the metal–semiconductor interface. We find that the effective electron–phonon relaxation time in Au/TiO decreases from 4.2 ps at 30 ◦C to 3.5 ps at –90 ◦C, whereas no temperature dependence is observed for Au/SiO or bare Au nanoparticles.

This counterintuitive acceleration indicates the presence of a temperature-dependent interfacial energy dissipation pathway, likely associated with hot-carrier injection and enhanced interfacial energy transfer. These results highlight the importance of interfacial processes in governing ultrafast plasmonic energy relaxation.

*Speaker

Numerical Investigation of Nanofluid Natural Convection in a Corrugated-Wall Square Cavity Using a Meshless Method

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Abstract

Natural convection of nanofluids in confined geometries plays a crucial role in thermal management systems. This work presents a numerical investigation of natural convection in a square cavity filled with an AlO–water nanofluid, with particular emphasis on the influence of wall corrugation, Rayleigh number (Ra), and nanoparticle volume fraction (). The governing equations are solved using a meshless radial basis function (RBF) method coupled with the artificial compressibility technique. The study evaluates temperature distribution, flow structure, and heat transfer performance under different geometrical and physical configurations. Results indicate that temperature remains nearly uniform within the cavity core, while strong gradients develop near the heated wall. As the Rayleigh number increases, convective effects become dominant, intensifying circulation strength. Moreover, increasing the nanoparticle volume fraction enhances heat transfer performance. The average Nusselt number reaches its maximum value in the presence of wall corrugation, with enhancements of approximately 32% and 6% for single and double wavy walls, respectively, compared to a regular flat wall. These findings highlight the combined influence of nanoparticle concentration and wall geometry on flow dynamics and thermal efficiency. The study demonstrates the effectiveness of the meshless approach and provides valuable insights for optimizing nanofluid-based thermal systems.

Keywords: Natural convection, Nanofluid, Square cavity, Corrugated wall, Meshless method, Radial basis function

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The role of polarization field terms in models for cavity quantum materials

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Abstract

Constructing models for cavity quantum materials requires careful introduction of the light-matter coupling. In general, one must introduce additional matrix elements from the material wavefunctions, which are often unknown for tight-binding models. The Peierls substitution is often used to avoid introducing these additional parameters in the multi-site dipole gauge, however the contributions from inter-band dipole moments can play an important role. We present a toy model of a dipole in a cavity as a multi-band system with two sites, and we couple the system under a uniform field in the Coulomb, dipole, and multi-site dipole gauges. By tuning the cavity field to the dominant dipole moment transitions, we can investigate the role of the inter-band polarization field terms and the accuracy of the Peierls substitution for one-band models. We also review the performance of orbital transitions in each gauge and the resulting breakdown of gauge invariance.

*Speaker

The Collisional Charging of a Transmon Quantum Battery

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Abstract

Motivated by recent developments in the field of multilevel quantum batteries, we present the model of a quantum device for energy storage with anharmonic level spacing, based on a superconducting circuit in the transmon regime. It is charged via the sequential interaction with a collection of identical and independent ancillary two-level systems. By means of a numerical analysis, we show that, in case these ancillas are coherent, this kind of quantum battery can achieve remarkable performances in terms of the control of the stored energy and its extraction in regimes of parameters within reach in nowadays quantum circuits.

Keywords: quantum battery, transmon superconducting circuit, collisional model

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Scalable bio-inspired temperature-adaptive coating for all-season radiative thermal management

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Abstract

Passive daytime radiative cooling (PDRC) effectively dissipates terrestrial heat into outer space through the atmospheric transmission window (ATW, 8–13 μm)(1, 2). However, conventional PDRC materials with static high solar reflectance inevitably exacerbate heating energy consumption during cold winters, creating a "winter penalty" for building energy efficiency(3). In this work, we present a scalable, bio-inspired Temperature-Adaptive Radiative Cooling Coating (TARCC) to resolve the conflict between summer cooling and winter heating. Drawing inspiration from the thermoregulatory skin of the Namibian chameleon, we established a dynamic spectral regulation framework by integrating thermochromic microcapsules with a hierarchical particle matrix. The resulting coating achieves a passive, self-adaptive switching mechanism: it exhibits a solar-reflective white state (~93% reflectance) above 25∘C to achieve a subambient temperature drop of 6.5 K, while transitioning to a solar-absorptive dark state (50% reflectance) below 20∘C to yield a 4.3 K temperature rise. Crucially, the TARCC maintains robust broadband emissivity (~94%) within the ATW across all states to ensure continuous radiative heat dissipation capability. Field tests and global energy simulations demonstrate that, compared with static PDRC coatings, this dynamic approach can save up to 20% of annual energy in mid-latitude regions and increase thermally comfortable hours by 55%. Our findings offer a cost-effective, easy-to-construct strategy for smart radiative heat transfer control in building envelopes.

*Speaker

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Adiabatically driven dissipative many-body quantum spin systems

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Abstract

We explore the evolution of a strongly interacting dissipative quantum Ising spin chain that is driven by a slowly varying time-dependent transverse field. This system possesses an extensive number of instantaneous (adiabatic) stationary states which are coupled through non-adiabatic transitions. We analytically calculate the generator of the ensuing slow dynamics and analyze the creation of coherences through non-adiabatic processes. For a certain choice of the transverse field shape, we show that the system solely undergoes transitions among classical basis states after each pulse. The concatenation of many of such pulses leads to an evolution of the spin chain under a many-body dynamics that features kinetic constraints. Our setting not only allows for a quantitative investigation of adiabatic theorems and non-adiabatic corrections in a many-body scenario. It also directly connects to many-body systems in the focus of current research, such as ensembles of interacting Rydberg atoms which are resonantly excited by a slowly varying laser pulse and subject to dephasing noise.

Keywords: Adiabatic dynamics, many body open quantum systems

*Speaker

Detecting zero-point fluctuations with stochastic Brownian oscillators

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Abstract

High-quality quantum oscillators are preferred for precision sensing of external physical parameter because if the noise level due to interactions with the environment is too high, metrological information can be lost due to quantum decoherence. On the other hand, stronger interactions with a thermal environment could be seen a resource for new types of metrological schemes. We present a general amplification strategy that enables the detection zero-point fluctuations using low-quality quantum oscillators at finite temperature. We show that by injecting a controllable level of multiplicative frequency noise in a Brownian oscillator, quantum deviations from the virial theorem can be amplified by a parameter proportional to the strength of the frequency noise at constant temperature. As an application, we suggest a scheme in which the virial ratio is used as a witness of the quantum fluctuations of an unknown thermal bath, either by measuring the oscillator energy or the heat current flowing into an ancilla bath. Our work expands the metrological capacity of low-quality oscillators and can enable new measurements of the quantum properties of thermal environments by sensing their zero-point contributions to system variables

Keywords: vacuum, fluctuations, Brownian motion, multiplicative noise, virial

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Fluctuational Quantum Electrodynamics of Dispersive Time-Varying Media

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Abstract

In this work, we set forth a theory of fluctuational quantum electrodynamics of dispersive time-varying media.
We derive new trace formulas for the Green's tensor of time-varying materials and show that both gain and loss must be accounted for to give a proper definition of the local density of states. Furthermore, we prove that the decay-excitation rate of a quantum emitter, calculated within a fully quantum mechanical model, coincides with the classical calculation of the power radiated by a harmonic point dipole.
Lastly, we apply our formalism to the case of a periodically time-modulated metallic slab. We show that in the vicinity of the air-metal interface, a probe quantum emitter gets spontaneously excited from its ground state, resulting in the negative quenching of the spontaneous emission.

Keywords: Fluctuational Electrodynamics, Macroscopic Quantum Electrodynamics, Light, Matter Interactions, Time, Varying Media

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Directional control of thermal photonics for energy applications

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Abstract

Thermal radiation is a spontaneous process emitted by all objects with a temperature above 0 K, characterized as an unpolarized, broadband, and omnidirectional phenomenon(1). Directional control of far-field thermal emission plays a key role in effective heat exchange and energy transport, offering significant potential for applications in thermal camouflage(2), directional heat sources(3), and radiative cooling(4, 5). In this work, we present a systematic framework for the directional manipulation of thermal emission, including ultra-broadband control, synergistic polar-azimuthal regulation, and dynamic tuning. By establishing a universal method based on effective medium theory (EMT)(6), we demonstrate strong directional radiation (emissivity $>$ 0.8 at 80∘±5∘) across an ultra-broad spectral range of 5-30 μm using only two constituent materials(7). Furthermore, we achieve simultaneous control over radiation wavelength and angle while maintaining high-Q factors by integrating Fabry-Pérot bound states in the continuum (F-P BICs) with epsilon-near-zero (ENZ) materials(8). By combining gradient-doped InAs with an anisotropic spacer, we realize an ultra-broadband unidirectional thermal emitter capable of concurrent polar (
theta: 55∘-79∘) and azimuthal (ϕ: 163.5∘-196.5∘) regulation(9). Finally, we showcase the potential application of angular control by designing an asymmetric thermal emitter for sub-ambient daytime radiative cooling of vertical surfaces. This design achieves a temperature approximately 2.5∘C below ambient temperature, corresponding to a temperature reduction of about 4.3∘C and 8.9∘C compared with a silica-polymer hybrid radiative cooler and commercial white paint, respectively(4). Our findings provide comprehensive approaches and guidance for the development of directional thermal radiation and its potential application in advanced energy management systems.

Keywords: Thermal photonics, directional thermal radiation, radiative cooling

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