

# XIII<sup>th</sup> RENCONTRES DU VIETNAM

Nanophysics: from Fundamentals to Applications

Quy Nhon, July 30<sup>th</sup> – August 5<sup>th</sup>, 2017

## ICISE

(International Centre for Interdisciplinary Science and Education)

### Welcome to ICISE

Wishing you a pleasant and productive stay in Vietnam

## **General information**

### **Registration**

The registration of the Conference will take place on Sunday July 30<sup>th</sup> at 5pm at Seagull Hotel.

Khách Sạn Hải Âu - Seagull Hotel

Address: 489 An Dương Vương, Quy Nhơn, Bình Định

Phone: +84 256 3846 377

Please register as soon as you arrive at the hotel, fill in an ARRIVAL FORM and hand it to the conference secretaries.

All payments must be completed by Tuesday August 1<sup>st</sup> evening. The accommodation fee should be paid to the conference secretariat by cash or credit card (not be paid directly to the hotel). Our conference secretariat is located at ICISE, open from 8:30 to 12:00 and from 13:00 to 17:30.

### **Welcome Cocktail**

All participants, their families and guests are invited to have a welcome drink at 19:00 on Sunday, July 30<sup>th</sup> at Seagull Hotel. Buffet dinner will be served at 19:30.

### **Meals**

Please do not forget to wear your badge and bring along with you the meal coupons, provided to you at registration time.

Alcoholic or soft drinks will be charged to your hotel account. If you are sharing a room, please find an arrangement with your room mate for both your telephone and beverage bills.

Breakfast will be served at your hotel: you will need the daily coupon provided by the hotel (together with your room key).

Lunch for participants will be served at 12:30 at ICISE.

Accompanying persons can have lunch at ICISE center or at the Seagull hotel. To get lunch at the Seagull hotel, please tick your name on the paperboard in the hotel lobby, the day before. Lunch at the hotel will be served from 12:30 to 13:00 (no lunch will be served after 13:15). To get lunch at ICISE center, please be there at 12:30 sharp. You can go there by taxi (10-15 minutes, cost: ~ 100.000VND), see the address below.

Dinner: dinner will be at the Seagull Hotel at 19:00.

Please let us know your preference (vegetarian, vegan ...) so that we can inform the hotel, and mention it to the waiter too.

### **The conference venue: ICISE**

The conference venue is located at ICISE (International Centre for Interdisciplinary Science and Education):

Trung Tâm Quốc tế Khoa học và Giáo dục Liên Ngành (ICISE)

Address: Quốc lộ 1D, khu vực 2, phường Ghềnh Ráng, Thành phố Quy Nhơn, tỉnh Bình Định

Bus departures from the Seagull hotel to ICISE:

The first bus will leave 45 minutes before the session starts, the last will leave 30 minutes before the session starts. You can also go by yourself *via* the main road by taxi (10-15 min, it costs about 100 000 - 150 000 VND depending on the taxi's waiting time and rate).

It is also possible to walk to and from the ICISE center following the coastline road about 6 km.

Tea and coffee will be served during the breaks at the cafeteria of ICISE.

### Useful information

**Internet:** WIFI is available at the ICISE. Password is ICISE20130812 for guests. Wifi is available almost anywhere in Vietnam: for example, you can get wifi access in any local cafes if you ask waiters for the password.

**Beach time:** There are shower rooms and changing rooms at the beach of the ICISE center. Your laptops – NOT YOUR OWN BELONGINGS – can be stored in the conference room. Bring along your towel, bathing suit and sun screen if you want to swim.

(At the hotel beach, local people use to swim during sunrise (05:30 - 06:30 am): you should try that too!)

### Prepaid Mobile phone and 3G internet SIM card:

Prepaid SIM card for phone and internet data is relatively cheap in Vietnam. Vinaphone, Mobilfone and Viettel are three phone and internet providers who provide a Tourist SIM card which costs around 200000 VND or 10 USD. These tourist SIM cards offer you around 50 minutes international call, 100 minutes domestical call, free text messages, 3G internet connection (depending on the provider). These SIM cards can be bought at the airport, electronic or phone shops. Please check the details here if you're interested:

<http://www.3gvinaphone.pro.vn/2016/07/tourist-sim-vinaphone.html>

**Telephone:** If you share a room, please keep track of your calls because there is only one telephone per room and the billing is done for each room. Telephone bills should be settled before you leave.

**Banking facilities:** Exchange currency service is available at the hotel reception, local bank branches or any jewellery shops. ATM machines can be found on the opposite side of the hotel.

**Departure to the airport:** Buses to the airport will be organized at the end of the conference. For early departures, please contact the conference secretaries to arrange a taxi transfer.

**DON'T FORGET TO GET BACK YOUR PASSPORT AT THE HOTEL RECEPTION DESK BEFORE YOU LEAVE!**

**Special announcements :** A paperboard in ICISE entrance hall, near the Secretaries' office, will be used for special announcements. For accompanying persons, a paper board will be placed in the hotel reception hall. Please check it regularly. Suggestion: The accompanying person can take a taxi to go to the Center ICISE to enjoy the beach, have a swim or to rest in the park.

**Directions to ICISE in Vietnamese to show to the taxi driver: (Fare: about 5 USD)**

<p>Trung tâm Quốc tế Khoa học và Giáo dục Liên ngành (ICISE) Phường Ghềnh Ráng</p> <p>1. Từ đường Tây Sơn, đi theo QL 1D, đến trạm Kiểm Dịch, rẽ trái.</p> <p>2. Cuối đường nhựa, Trung tâm Quốc tế Khoa học ICISE nằm bên tay phải</p>
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**Emergency contacts :**

You can call us any time if you have any emergency request including pick up, medical help...  
Hotel: +84 256 3846 37

Schedule

Nanophysics : from fundamental to applications reloaded, XIIth. Rencontres du Vietnam, Quy-Nhon 2017					
Aug.	Monday 31	Tuesday 1	Wednesday 2	Thursday 3	Friday 4
8h30					
9h00		Ensslin, Klaus Gefen, Yuval		Berciaux, Dario	Fève, Gwendal
9h30	opening session	Hakonen, Pertti break		Schönenberger, Christian	Rouilleau, Preden
10h00	Molenkamp, Laurens	Hashisaka, Masayuki	EXCURSION	Governale, Michele	Waintal, Xavier
10h30	Stern, Adiel	Sim, Hong-Seun		break	concluding remarks
11h00	Avraham, Nurit	Wang, Ning		Meyer, Julia	
11h30	Akmerov, Anton	Ilani, Shahal		Sano Yasuhisa	
12h00	Bachtold, Adrian			Kobayashi, Kensuke	
				Splettstoesser, Janine	
13h30	Kato, Takeo	Cleland, Andrew		König, Jurgen	
14h00	Blanter, Yaroslav	Egger, Reinhold		Mora, Christophe	
14h30	Belzig, Wolfgang	Estève, Daniel		Finkelstein, Gleb	
15h00	Bobkova, Irina	Kiselev, Mikhail	PARALLEL SESSIONS		
15h30	break	break		POSTER SESSION	
16h00	Chandrasekhar, Venkat	Loss, Daniel			
16h30	Cong Bach, Thahn	Martinek Jan			
17h00					

PARALLEL SESSIONS	
A-Wednesday	B-Wednesday
13h30	Assaf Badih
13h50	Dufouleur Joseph
14h10	Tchoumakov Serguei
14h30	Plaçais Bernard
15h20	break
15h40	Trifunovic Luka
16h00	Choi Sang-Jun
16h20	Ohtsuki Tomi
16h40	Winkler Roland
	Hata Tokuro

PARALLEL SESSIONS	
C-Wednesday	D-Wednesday
13h30	Parmentier François
13h50	Han Cheolhee
14h10	Roussel Benjamin
14h30	Suzuki Takatumi
15h20	break
15h40	Cabart Clément
16h00	Park Hee Chul
16h20	Filippone Michele
16h40	Delagrègne Raphaëlle
	Guo Hua Zhong

Posters	
Asad Qudsia	
Borin Artem	
Chen Shuwei	
Goremykina Anna	
Hasegawa Masahiro	
He Jianhong	
Ivashko Artem	
Iwakiri Shuichi	
Liu Wei	
Mukai Risa	
Nguyen, Duc-Long	
Nguyen, Hang	
Nguyen, Van-Khoe	
Okayama Shinya	
Shim Jeongmin	
Wang Ruey-Tay	
Yuce Cem	

Click on a speaker's name to read the corresponding abstract

# Detailed Program

Detailed program - click on a title to see the full abstract

## Sunday, July 30, 2017

TIME	EVENT
19:00 - 20:00	Cocktail

## Monday, July 31, 2017

TIME	EVENT
09:30 - 10:00	Opening session
10:00 - 12:00	Topological Metals/Insulators/Superconductors, Weyl/Dirac/Majorana Fermions - T. Martin
10:00 - 10:30	<a href="#">Topological Physics in HgTe-based Quantum Devices</a> - <b>Laurens Molenkamp</b> , <i>Physikalisches Institut (EP3) Universität Würzburg</i>
10:30 - 11:00	<a href="#">Topological superconductivity between one and two dimensions</a> - <b>Ady Stern</b> , <i>Weizmann Institute of Science</i>
11:00 - 11:30	<a href="#">Visualizing Fermi arcs and coexisting surface states of weak and crystalline topological insulator</a> - <b>Nurit Avraham</b> , <i>The Weizmann Institute of science</i>
11:30 - 12:00	<a href="#">Engineering Majoranas</a> - <b>Anton Akhmerov</b> , <i>Kavli Institute of Nanosciences</i>
12:00 - 12:30	Nanodevices, Nanoelectronics, Nanospintronics, Nanoelectromechanics - T. Martin
12:00 - 12:30	<a href="#">Electro-mechanical resonators based on graphene</a> - <b>Adrian Bachtold</b> , <i>The Institute of Photonic Sciences</i>
12:30 - 13:30	Lunch
13:30 - 15:30	Nanodevices, Nanoelectronics, Nanospintronics, Nanoelectromechanics - P. Hakonen
13:30 - 14:00	<a href="#">Heat transport via a local two-state system</a> - <b>Takeo Kato</b> , <i>Institute for Solid State Physics, The University of Tokyo</i>
14:00 - 14:30	<a href="#">Brillouin light scattering in optomagnonics</a> - <b>Yaroslav Blanter</b> , <i>Kavli Institute of Nanoscience, Delft University of Technology</i>
14:30 - 15:00	<a href="#">Ground-state cooling a mechanical oscillator by spin-dependent transport and Andreev reflection</a> - <b>Wolfgang Belzig</b> , <i>University of Konstanz</i>
15:00 - 15:30	<a href="#">Spin-orbit induced triplet correlations and magnetoelectrics in superconducting heterostructures</a> - <b>Irina Bobkova</b> , <i>Institute of Solid State Physics RAS</i>
15:30 - 16:00	Coffee break
16:00 - 17:00	Nanodevices, Nanoelectronics, Nanospintronics, Nanoelectromechanics - P. Hakonen
16:00 - 16:30	<a href="#">Superconductivity, Magnetism, Anisotropy and Memory: The Remarkable Properties of the Conducting Gas at the (111) LaAlO<sub>3</sub>/SrTiO<sub>3</sub> Interface</a> - <b>Venkat Chandrasekhar</b> , <i>Northwestern University</i>

16:30 - 17:00 [Size dependent effects in ordered ultrathin ferroic films](#) - **Cong Bach Thanh**, VNU University of science

## Tuesday, August 1, 2017

TIME	EVENT
08:30 - 09:00	<b>Graphene and 2D materials - G. Finkelstein</b>
08:30 - 09:00	<a href="#">Confinement in 2D materials</a> - <b>Klaus Ensslin</b> , Solid State Physics Laboratory, ETH Zürich
09:00 - 10:00	<b>Quantum Hall effect - G. Finkelstein</b>
09:00 - 09:30	<a href="#">Spin Phase Transition at the Edge of a QH System</a> - <b>Yuval Gefen</b> , Weizmann Institute of Science
09:30 - 10:00	<a href="#">Fractional quantum Hall effect and Wigner crystallization in suspended Corbino graphene disk</a> - <b>Pertti Hakonen</b> , Aalto University School of Science
10:00 - 10:30	<b>Coffee break</b>
10:30 - 12:30	<b>Quantum Hall effect - G. Finkelstein</b>
10:30 - 11:00	<a href="#">Fractional quasiparticles in the breakdown regime of a microscopic integer quantum Hall system</a> - <b>Masayuki Hashisaka</b> , Tokyo Institute of Technology
11:00 - 11:30	<a href="#">Topological vacuum bubbles of anyons</a> - <b>Heung-Sun Sim</b> , Department of Physics, Korea Advanced Institute of Science and Technology
11:30 - 12:00	<a href="#">Title: Odd-integer quantum Hall states and giant spin susceptibility in p-type few-layer WSe<sub>2</sub></a> - <b>Ning Wang</b> , Department of Physics and the Center for Quantum Materials, the Hong Kong University of Science and Technology
12:00 - 12:30	<b>Quantum Dots and Nanowires - G. Finkelstein</b>
12:00 - 12:30	<a href="#">Imaging the Quantum Wigner Crystal of Electrons in One-Dimension</a> - <b>Shahal Ilani</b> , Weizmann Institute of Science
12:30 - 13:30	<b>Lunch</b>
13:30 - 15:30	<b>Quantum technologies, Quantum Information, Cavity QED - K. Ensslin</b>
13:30 - 14:00	<a href="#">Hybrid quantum systems: Outsourcing superconducting qubits</a> - <b>Andrew Cleland</b> , University of Chicago
14:00 - 14:30	<a href="#">From Majorana box qubits to topological Kondo physics</a> - <b>Reinhold Egger</b> , University of Duesseldorf
14:30 - 15:00	<a href="#">Quantum microwaves in a strong coupling circuit QED regime</a> - <b>Daniel Esteve</b> , Service de Physique de l'Etat Condensé, CEA Paris-Saclay, CNRS, Université Paris-Saclay
15:00 - 15:30	<a href="#">Landau - Zener interferometry in multi-level systems</a> - <b>Mikhail Kiselev</b> , The Abdus Salam International Centre for Theoretical Physics
15:30 - 16:00	<b>Break</b>
16:00 - 17:00	<b>Quantum technologies, Quantum Information, Cavity QED - K. Ensslin</b>
16:00 - 16:30	<a href="#">From Majorana- to Parafermions in Single and Double Nanowires</a> - <b>Daniel Loss</b> , University of Basel
	<a href="#">Aharonov-Bohm and Aharonov-Casher effects of nonlocal and local Cooper</a>

16:30 - 17:00 [pairs](#) - **Jan Martinek**, Institute of Molecular Physics, Polish Academy of Sciences

## Wednesday, August 2, 2017

TIME	EVENT
08:30 - 12:30	<b>Excursion</b>
12:30 - 13:30	<b>Lunch</b>
13:30 - 14:50	<b>Graphene and 2D materials - J. Meyer</b>
13:30 - 13:50	<a href="#">Real-space and plane-wave combination for electronic structure of two-dimensional materials</a> - <b>Van-Nam Do</b> , Hanoi university of Science and Technology
13:50 - 14:10	<a href="#">Role of Strain for Manipulating Valley-Isospin in Graphene Nanoribbons</a> - <b>Nojoon Myoung</b> , Institute for Basic Science
14:10 - 14:30	<a href="#">Electron-state Tuning of MoS2 Thin Film by Electrostatic and Chemical Doping</a> - <b>Thanh Cuong Nguyen</b> , International Center for Young Scientists, National Institute for Materials Science
14:30 - 14:50	<a href="#">Charge transport and low frequency noise in bilayer graphene</a> - <b>Sheng-Shiuan Yeh</b> , Institute of Physics, National Chiao Tung University
13:30 - 14:50	<b>Topological Metals/Insulators/Superconductors, Weyl/Dirac/Majorana Fermions - F. von Oppen</b>
13:30 - 13:50	<a href="#">Negative longitudinal magnetoresistance in the topological regime of Pb1-xSnxSe</a> - <b>Badih Assaf</b> , Fédération de recherche du département de physique de l'Ecole Normale Supérieure
13:50 - 14:10	<a href="#">Transport properties of spin-helical Dirac fermions in disordered quantum confined systems</a> - <b>Joseph Dufouleur</b> , Leibniz Institute for Solid State and Materials Research - IFW Dresden (Dresden, Germany)
14:10 - 14:30	<a href="#">Massive surface states of topological materials</a> - <b>Sergueï Tchoumakov</b> , Laboratoire de Physique des Solides
14:30 - 14:50	<a href="#">Topological confined massive surface states in strained bulk HgTe probed by RF compressibility</a> - <b>Bernard Plaçais</b> , Laboratoire Pierre Aigrain
13:30 - 14:50	<b>Nanodevices, Nanoelectronics, Nanospintronics, Nanoelectromechanics - A. Bachtold</b>
13:30 - 13:50	<a href="#">Thermospin effects in superconducting heterostructures</a> - <b>Alexander Bobkov</b> , Institute of Solid State Physics RAS
13:50 - 14:10	<a href="#">Enhanced performance of three-terminal thermoelectric devices</a> - <b>Ora Entin-Wohlman</b> , Tel Aviv University, Ben Gurion University
14:10 - 14:30	<a href="#">Thermoelectric transport through quantum dot-quantum point contact systems</a> - <b>Thanh Nguyen</b> , Institute of Physics
14:30 - 14:50	<a href="#">Top-gating control of the 2-DEG at the LAO/STO interface</a> - <b>Cheryl Feuillet-Palma</b> , Laboratoire de Physique et d'Etude des Matériaux
13:30 - 14:50	<b>Electron Quantum Optics / Quantum Hall effect - X. Waintal</b>
13:30 - 13:50	<a href="#">Quantum transport in graphene p-n junctions in the quantum Hall regime</a> - <b>François Parmentier</b> , Service de Physique de l'Etat Condensé

13:50 - 14:10	<a href="#">Topological vacuum bubbles in a non-Abelian anyon interferometer</a> - <b>Cheolhee Han</b> , Korea Advanced Institute of Science and Technology
14:10 - 14:30	<a href="#">Signal processing for electron quantum optics</a> - <b>Benjamin Roussel</b> , Laboratoire de Physique de l'ENS Lyon
14:30 - 14:50	<a href="#">Leviton in a Kondo quantum dot</a> - <b>Takafumi Suzuki</b> , Graduate School of Engineering, University of Tokyo
14:50 - 15:20	<b>Coffee break</b>
15:20 - 17:00	<b>Graphene and 2D materials - J. Meyer</b>
15:20 - 15:40	<a href="#">Lower critical dimension of the symplectic symmetry class in the Anderson localisation problem: Borel-Pade re-summation of the beta-function.</a> - <b>Keith Slevin</b> , Osaka University
15:40 - 16:00	<a href="#">Unusual Shubnikov-de Haas oscillations in <math>\hat{I}_{\pm}</math>-(BEDT-TTF)<sub>2</sub>I<sub>3</sub> organic metal</a> - <b>Emilie Tisserond</b> , Laboratoire de Physique des Solides d'Orsay
16:00 - 16:20	<a href="#">Generation and detailed evaluation of spin-orbit interaction in graphene induced by transition metal dichalcogenides</a> - <b>Taro Wakamura</b> , Laboratoire de Physique des Solides
16:20 - 16:40	<a href="#">Graphene high frequency devices for flexible application</a> - <b>Emiliano Pallecchi</b> , Institut d'électronique, de microélectronique et de nanotechnologie
16:40 - 17:00	<a href="#">Ultralow 1/f Noise in Superconducting Cobalt Dicilicide Thin Films on Silicon</a> - <b>Shao-pin Chiu</b> , Institute of Physics, National Chiao Tung University
15:20 - 16:40	<b>Topological Metals/Insulators/Superconductors, Weyl/Dirac/Majorana Fermions - F. von Oppen</b>
15:20 - 15:40	<a href="#">The complete topological classification of gapped states of matter in the presence of reflection symmetry</a> - <b>Luka Trifunovic</b> , Freie University Berlin
15:40 - 16:00	<a href="#">Train of Majorana bound states in a topological Josephson junction under a magnetic field</a> - <b>Sang-Jun Choi</b> , Korea Advanced Institute of Science and Technology
16:00 - 16:20	<a href="#">Deep learning the quantum phase transitions of disordered topological matters</a> - <b>Tomi Ohtsuki</b> , Physics Division, Sophia University
16:20 - 16:40	<a href="#">Effective Hamiltonian for protected edge states in graphene</a> - <b>Roland Winkler</b> , Northern Illinois University, Material Science Division [ANL]
15:20 - 16:20	<b>Electron Quantum Optics / Quantum Hall effect - X. Waintal</b>
15:20 - 15:40	<a href="#">Decoherence control in quantum Hall edge channels</a> - <b>Clément Cabart</b> , Laboratoire de Physique de l'ENS Lyon
15:40 - 16:00	<a href="#">Reconfiguration of electronic states in PT-symmetric quasi-one-dimensional lattices</a> - <b>Hee Chul Park</b> , Institute for Basic Science, Center for Theoretical Physics of Complex Systems
16:00 - 16:20	<a href="#">The Interacting Mesoscopic Capacitor Out of Equilibrium</a> - <b>Michele Filippone</b> , Département de Physique de la Matière Condensée
15:20 - 17:00	<b>Nanodevices, Nanoelectronics, Nanospintronics, Nanoelectromechanics - A. Bachtold</b>
15:20 - 15:40	<a href="#">Superconductivity in two dimensions in the AlOx/SrTiO<sub>3</sub> heterostructure</a> - <b>Shamashis Sengupta</b> , Centre de Sciences Nucléaires et de Sciences de la Matière
15:40 - 16:00	<a href="#">Spin Orbit interactions, time reversal symmetry and spin filtering</a> - <b>Amnon Aharony</b> , Ben Gurion University, Tel Aviv University

16:00 - 16:20	<u>Ultra-smooth SiC and oxide surfaces planarized using catalyst-referred etching</u> - <b>Pho Bui</b> , Osaka University
16:20 - 16:40	<u>Quench dynamics in superconducting nanojunctions: metastability and dynamical Yang-Lee zeros</u> - <b>Rubén Seoane Souto</b> , Universidad Autonoma de Madrid, Condensed Matter Physics Cente, Instituto Nicol�s Cabrera
16:40 - 17:00	<u>Critical properties of the Anderson transition through the looking-glass of the CBS and CFS peaks</u> - <b>Sanjib Ghosh</b> , UMI 3654 MajuLab, CNRS-UNS-NUS-NTU International Joint Research Unit
16:20 - 17:00	<b>High frequency Transport and Noise - X. Waintal</b>
16:20 - 16:40	<u>High frequency emission of a carbon nanotube in the Kondo regime: quantum noise and AC Josephson effect</u> - <b>Rapha�lle Delagr�ge</b> , University of Basel Department of Physics, Laboratoire de Physique des Solides
16:40 - 17:00	<u>"0.7 anomaly" in the confined quantum coherent conductor controlled by high frequency oscillation voltage</u> - <b>Hua Zhong Guo</b> , College of Physical Science and Technology, Sichuan University, 610064 Chengdu, China
16:40 - 17:00	<b>Quantum Dots and Nanowires - F. von Oppen</b>
16:40 - 17:00	<u>Shot noise of a superconductor/nanotube junction in the SU(2) and SU(4) Kondo regime</u> - <b>Tokuro Hata</b> , Osaka University

## Thursday, August 3, 2017

TIME	EVENT
08:30 - 10:00	<b>Graphene and 2D materials - N. Wang</b>
08:30 - 09:00	<u>Transport properties of electron-hole bilayer/superconductor hybrid junction</u> - <b>Dario Bercioux</b> , Donostia International Physics Center - DIPC (SPAIN)
09:00 - 09:30	<u>Quantum Transport along PN-Junctions in Ballistic Graphene</u> - <b>Christian Sch�nenberger</b> , UBAS, Dept. of Physics, University of Basel
09:30 - 10:00	<u>Unconventional superconductivity from magnetism in transition metal dichalcogenides</u> - <b>Michele Governale</b> , Victoria University of Wellington
10:00 - 10:30	<b>Coffee break</b>
10:30 - 11:30	<b>Graphene and 2D materials - N. Wang</b>
10:30 - 11:00	<u>Upper critical field in superconducting transition metal dichalcogenide monolayers</u> - <b>Julia Meyer</b> , INAC/PHELIQS
11:00 - 11:30	<u>Fabrication of atomically flat silicon carbide surface using catalyst-referred etching (CARE)</u> - <b>Yasuhisa Sano</b> , Graduate School of Engineering, Osaka University
11:30 - 12:30	<b>High frequency Transport and Noise - C. Schoenenberger</b>
11:30 - 12:00	<u>Shot Noise Induced by Nonequilibrium Spin Accumulation</u> - <b>Kensuke Kobayashi</b> , Osaka University
12:00 - 12:30	<u>Charge- and energy noise in ac-driven conductors and their detection from frequency-resolved potential- and temperature fluctuations</u> - <b>Janine Splettstoesser</b> , Chalmers University of Technology, Department for Microtechnology and Nanoscience
12:30 - 13:30	<b>Lunch</b>

13:30 - 14:30	<b>High frequency Transport and Noise - C. Schoenenberger</b>
13:30 - 14:00	<u>Full Counting Statistics of Electron Tunneling in Coulomb-Blockade Devices</u> - <b>Jürgen König</b> , University of Duisburg-Essen
14:00 - 14:30	<u>Quantum conductors as non-classical light emitters</u> - <b>Christophe Mora</b> , Laboratoire Pierre Aigrain
14:30 - 15:00	<b>Electron Quantum Optics - C. Schoenenberger</b>
14:30 - 15:00	<u>Supercurrent in the quantum Hall regime</u> - <b>Gleb Finkelstein</b> , Duke university [Durham]
15:00 - 17:00	<b>Poster</b>
15:00 - 17:00	<u>Chiral Magnetic Effect in Weyl semimetals: the interplay of the bulk and the boundary</u> - <b>Artem Ivashko</b> , Lorentz Institute
15:00 - 17:00	<u>Coherent dynamics and mesoscopic capacitance oscillations in quantum coherent capacitors</u> - <b>Jianhong He</b> , College of Physical Science and Technology, Sichuan University
15:00 - 17:00	<u>Damage-free dry etching processing of SiC substrates by using high-pressure plasma</u> - <b>Risa Mukai</b> , Yamauchi.Lab in Osaka.Univ
15:00 - 17:00	<u>Dynamics of Pure Spin Current in High-frequency Quantum Regime</u> - <b>Iwakiri Shuichi</b> , Department of Physics, Graduate School of Science, Osaka University
15:00 - 17:00	<u>Entanglement negativity of a single-channel Kondo system</u> - <b>JeongMin Shim</b> , Department of Physics, Korea Advanced Institute of Science and Technology
15:00 - 17:00	<u>Experimental mapping of the quantum phase diagram for the two-impurity Kondo effect</u> - <b>Ruey-Tay Wang</b> , Institute of Physics, National Chiao Tung University
15:00 - 17:00	<u>Fermi-edge singularity and related interaction induced phenomena in multilevel quantum dots.</u> - <b>Anna Goremykina</b> , Université de Genève
15:00 - 17:00	<u>Formalism of temperature-driven adiabatic charge pumping via a single level quantum dot in coherent transport region</u> - <b>Masahiro Hasegawa</b> , Institute for Solid State Physics, The University of Tokyo
15:00 - 17:00	<u>Magnetocapacitance oscillations in a mesoscopic RC circuit</u> - <b>Wei Liu</b> , College of Physical Science and Technology, Sichuan University
15:00 - 17:00	<u>Manifestation of fermi edge singularity in co-tunnelling regime</u> - <b>Artem Borin</b> , University of Genoa
15:00 - 17:00	<u>Modeling Electrical Conductivity and Transfer Characteristics of n- and p-Type Graphene/MoS2 Hetero-structures</u> - <b>Khoe Nguyen</b> , Molecular Science and Technology Program, Taiwan International Graduate Program, Academia Sinica, Department of Physics, National Central University, Research Center for Applied Sciences, Academia Sinica
15:00 - 17:00	<u>Nanoprecision process for improving thickness uniformity of top silicon layer of silicon-on-insulator wafer by using a multi-electrode plasma generator</u> - <b>Shinya Okayama</b> , Osaka Univ.
15:00 - 17:00	<u>Non-Hermitian Floquet Topological Phase</u> - <b>Cem Yuce</b> , Anadolu University
15:00 - 17:00	<u>Overview of melting graphene nanoribbon</u> - <b>Hang Nguyen</b> , Ho Chi Minh city University of Technology, VNU - HCM, Vietnam.
15:00 - 17:00	<u>Preparation and Characterization of Chitosan Coated Magnetic Nanoparticles</u> - <b>Qudsia Asad</b> , UET Taxila

15:00 - 17:00	<a href="#">Strain induced superconductivity of Li intercalated bilayer Boron Phosphide by first principles study</a> - <b>Duc-Long Nguyen</b> , Department of Physics, National Central University, Institute of Atomic and Molecular Sciences, Academia Sinica
15:00 - 17:00	<a href="#">The gigahertz complex admittance of a quantum R-L circuit in chiral edge channels</a> - <b>Shuwei Chen</b> , Laboratory of Mesoscopic and Low Dimensional Physics, College of Physical Science and Technology, Sichuan University
19:30 - 23:00	<b>Conference Dinner</b>

## Friday, August 4, 2017

TIME	EVENT
08:30 - 10:00	<b>Topological Metals/Insulators/Superconductors, Weyl/Dirac/Majorana Fermions - L. Molenkamp</b>
08:30 - 09:00	<a href="#">Color code quantum computation with Majorana bound states</a> - <b>Felix von Oppen</b> , Freie University Berlin
09:00 - 09:30	<a href="#">The origin of bias independent conductance plateaus and zero bias conductance peaks in Bi<sub>2</sub>Se<sub>3</sub>/NbSe<sub>2</sub> hybrid structures</a> - <b>Jiannong Wang</b> , Hong Kong University of Science and Technology
09:30 - 10:00	<a href="#">Anomalous Hall effect and topological phase transitions</a> - <b>Pavel Streda</b> , Institute of Physics ASCR
10:00 - 10:30	<b>Coffee break</b>
10:30 - 12:30	<b>Topological Metals/Insulators/Superconductors, Weyl/Dirac/Majorana Fermions - L. Molenkamp</b>
10:30 - 11:00	<a href="#">Quantum capacitance and spin susceptibility of HgTe quantum wells</a> - <b>Ulrich Zülicke</b> , Victoria University of Wellington
11:00 - 11:30	<a href="#">Topological superconductivity and Majorana fermions in a superconducting-ferromagnetic hybrid system</a> - <b>Tristan Cren</b> , Institut des NanoSciences de Paris
11:30 - 12:00	<a href="#">Robustness of symmetry-protected topological states against time-periodic perturbations</a> - <b>Henrik Johannesson</b> , University of Gothenburg
12:00 - 12:30	<b>Quantum Dots and Nanowires - L. Molenkamp</b>
12:00 - 12:30	<a href="#">Are odd-parity states in Andreev Quantum Dots always a nuisance?</a> - <b>Marcelo Goffman</b> , Qnantronics Group
12:30 - 13:30	<b>Lunch</b>
13:30 - 15:30	<b>Quantum Dots and Nanowires - K. Kobayashi</b>
13:30 - 14:00	<a href="#">Strong Correlation Effects in Nanostructure: Theory and Experiment</a> - <b>Mahn-Soo Choi</b> , Department of Physics, Korea University
14:00 - 14:30	<a href="#">Not just an electron waveguide or quantum box - uncovering the structure of carbon nanotubes in transport</a> - <b>Andreas Hüttel</b> , Universität Regensburg
14:30 - 15:00	<a href="#">Non-equilibrium Noise and Symmetry of the Kondo effect</a> - <b>Meydi Ferrier</b> , Laboratoire de Physique des Solides
15:00 - 15:30	<a href="#">Experimental mapping of the quantum phase diagram for the two-impurity Kondo effect</a> - <b>Juhn-Jong Lin</b> , Institute of Physics, National Chiao Tung University, Department of Electrophysics, National Chiao Tung University

15:30 - 16:00	<b>Coffee break</b>
16:00 - 17:00	<b>Quantum Dots and Nanowires - K. Kobayashi</b>
16:00 - 16:30	<u>Tunable Quantum Criticality and Super-ballistic Transport in a 'Charge' Kondo Circuit</u> - <b>Frédéric Pierre</b> , Centre de Nanosciences et de Nanotechnologies
16:30 - 17:00	<u>Multiscale modeling of optical and transport properties of nanostructures and low-dimensional materials</u> - <b>Yia-Chung Chang</b> , Research Center for Applied Sciences, Academia Sinica

## Saturday, August 5, 2017

TIME	EVENT
08:30 - 10:00	<b>Electron Quantum Optics - J. Splettstoesser</b>
08:30 - 09:00	<u>Two-particle interferometry for signal processing of a quantum electrical current</u> - <b>Gwendal Feve</b> , Laboratoire Pierre Aigrain
09:00 - 09:30	<u>Quantum tomography of an electron</u> - <b>Preden Roulleau</b> , Service de Physique de l'Etat Condensé
09:30 - 10:00	<u>From surface plasmons to fractional levitons: electron-electron interactions and ultrafast electronic interferometry</u> - <b>Xavier Waintal</b> , Université Grenoble Alpes, Commissariat à l'Energie Atomique, PHELIQS/INAC
10:00 - 10:30	<b>Concluding remarks</b>

# Abstracts

## 1 Topological Metals - Insulators - Superconductors, Weyl - Dirac - Majorana Fermions

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### Engineering Majoranas

Akhmerov Anton

Akhmerov Anton <sup>(1)</sup>, Sticlet Doru, Nijholt Bas, Vuik Adriaan, Rosdahl Tómas

1 - *Kavli Institute of Nanosciences (Netherlands)*

The goal of making Majorana states in the lab requires bringing together very different and sometimes incompatible physical phenomena: superconductivity, magnetic field, and one-dimensional systems. The reward is high?creating and controlling the first non-Abelian anyons, exotic particles, but so is the challenge. I will show how different physical phenomena impact the creation of Majoranas. I will show how the coupling strength to the superconductor impacts the properties of Majoranas and how the orbital effect of magnetic field influences the spin-orbit physics. Looking ahead, I will show how to detect these physical phenomena using the nonlocal conductance as a bulk probe of induced superconductivity.

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### Negative longitudinal magnetoresistance in the topological regime of $\text{Pb}_{1-x}\text{Sn}_x\text{Se}$

Assaf Badih

Assaf Badih <sup>(1)</sup>, Phuphachong Thanyanan <sup>(2)</sup>, Kampert Erik <sup>(3)</sup>, Volobuev Valentine <sup>(4)</sup>, Bauer Guenther <sup>(4)</sup>, Springholz Gunther <sup>(4)</sup>, De Vaultier Louis-Anne <sup>(2)</sup>, Guldner Yves <sup>(2)</sup>

1 - *Fédération de recherche du département de physique de l'Ecole Normale Supérieure (France)*, 2 - *Laboratoire Pierre Aigrain (France)*, 3 - *Helmholtz-Zentrum Dresden Rossendorf [Allemagne] (Germany)*, 4 - *Institut für Halbleiter und Festkörperphysik, Johannes Kepler Universität (Austria)*

$\text{Pb}_{1-x}\text{Sn}_x\text{Se}$  is a highly tunable material where a topological phase transition from a normal insulator to a topological insulator can be induced by increasing Sn content above a critical composition  $x=0.16$ . [1] We thus study magnetotransport at pulsed magnetic fields in  $\text{Pb}_{1-x}\text{Sn}_x\text{Se}$  for  $x$  varying between 0.1 and 0.3 across the topological phase transition. We report the observation of a negative longitudinal magnetoresistance (NLMR) only in samples that are in the topological regime ( $x > 0.16$ ). This NLMR is only observed when the samples reach the quantum limit. In trivial control samples ( $x < 0.16$ ), the MR is robustly positive up to 60T, suggesting that the NLMR may be a hallmark of the topological insulating state. We argue that this effect can be due to the anomalous behavior of the  $N=0$  Landau levels, predicted to converge and cross, leading to a magnetic field induced closure of the energy gap in topological materials. [2] We thus tie the occurrence of the NLMR to the non-trivial topological character of  $\text{Pb}_{1-x}\text{Sn}_x\text{Se}$ . [3] [1] B. A. Assaf, T. Phuphachong, V. V. Volobuev, G. Bauer, G. Springholz, L.-A. De Vaultier, and Y. Guldner, Arxiv 1608.08912. [2] B. A. Bernevig and T. L. Hughes, Topological Insulator and Topological Superconductors (Princeton University Press, 2013). [3] B.A. Assaf, T. Phuphachong, E. Kampert, V.V. Volobuev, G. Bauer, G. Springholz, L.A. de Vaultier, and Y. Guldner. Arxiv 1704.02021

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### Visualizing Fermi arcs and coexisting surface states of weak and crystalline topological insulator

Avraham Nuri

Avraham Nuri <sup>(1)</sup>, Batabyal Rajib <sup>(1)</sup>, Morali Noam <sup>(1)</sup>, Sun Yan <sup>(2)</sup>, Schmidt Marcus <sup>(2)</sup>, Pan Lin <sup>(2)</sup>, Shu-Chun Wu <sup>(2)</sup>, Norris Andrew <sup>(3)</sup>, Stern Ady <sup>(1)</sup>, Felser Claudia <sup>(2)</sup>, Yan Binghai <sup>(1)</sup>, Beidenkopf Haim <sup>(1)</sup>

1 - *The Weizmann Institute of science (Israel)*, 2 - *Max Planck Institute for Chemical Physics of Solids, Dresden (Germany)*, 3 - *Institute IMDEA Nanoscience, Madrid (Spain)*

In my talk I will present our recent findings on two topological materials: the Weyl semimetal TaAs and the weak and crystalline topological insulator  $\text{Bi}_2\text{TeI}$ . The correspondence between surface ?Fermi-arcs? and bulk Weyl cones

in a Weyl semimetal uniquely allows to study the notion of bulk surface correspondence. The surface of tantalum arsenide, similar to that of other members of the Weyl semimetal class, hosts non-topological states that obscure the exploration of the Fermi arc states. We use the spatial structure of the surface states' wave function visualized by scanning tunneling microscopy (STM) to distinguish the surface Fermi arcs and to observe their unique properties and their correspondence with the bulk states [1]. While the non-topological states show strong coupling to the lattice structure, we find that the Fermi arcs are only weakly bound to it. We find that the arcs' energy dispersion shows clear correspondence with the Weyl nodes. We obtain these results using an analysis technique based on the role of the Bloch wave function in shaping quantum electronic interference patterns. Bi<sub>2</sub>TeI is a layered material predicted theoretically to be both a weak and a crystalline topological insulator (TI). It's layered structure enables us to study both types of topological surface states on the same material facet. We observe robust 2D gapless states on the top facet, perpendicular to the material mirror planes. These states are observed for all surface terminations and show excellent agreement with theoretical calculations of the mirror protected surface states. On step edges that occur naturally on this surface, we visualize 1D conducting channels which remain decoupled from the mirror protected 2D states. These 1D channels appear only at the edges of 'topological terraces' which contain Bi bilayer, and are absent at the edges of 'trivial terraces'. This indicates their relation with the weak TI states residing on the side surfaces (parallel to the stacking direction). [1] <http://advances.sciencemag.org/content/2/8/e1600709>

## Train of Majorana bound states in a topological Josephson junction under a magnetic field

Choi Sang-Jun

Choi Sang-Jun <sup>(1)</sup>, Sim H.-S. <sup>(1)</sup>

*1 - Korea Advanced Institute of Science and Technology (South Korea)*

We theoretically study a Josephson junction, which is formed by two finite-size superconductors on a topological insulator under a magnetic field where the integer number of flux quanta is piercing inside of the junction. A train of Majorana bound states, spatially well separated from each other, can emerge along the junction, in addition to a chiral Majorana mode surrounding the two superconductors. We find that the state composed of the Majorana bound states can be manipulated and controlled by a bias voltage across the superconductors, and that the non-Abelian braiding statistics of the Majorana bound states can be detected by measuring the Josephson current.

## Topological superconductivity and Majorana fermions in a superconducting-ferromagnetic hybrid system

Cren Tristan

Cren Tristan <sup>(1)</sup>, Ménard Gerbold <sup>(1)</sup>, Guissart Sébastien <sup>(2)</sup>, Brun Christophe <sup>(1)</sup>, Leriche Raphaël <sup>(1)</sup>, Debontridder François <sup>(1)</sup>, Triff Mircea <sup>(2)</sup>, Roditchev Dimitri <sup>(3)</sup>, Simon Pascal <sup>(2)</sup>

*1 - Institut des NanoSciences de Paris (France), 2 - Laboratoire de Physique des Solides (France), 3 - LPEM (France)*

Majorana fermions are very peculiar quasiparticles that are their own antiparticle. They obey non-abelian statistics: upon exchange, they behave differently from fermions (antisymmetric) and bosons (symmetric). Their unique properties could be used to develop new kind of quantum computing schemes. Majorana states are predicted to appear as edge states of topological superconductors, in a similar way as Dirac surface states appears at the edge of topological insulators. Spectroscopic signatures of Majorana bound states were first observed in one-dimensional (1D) InAs nanowires proximity-coupled to a bulk superconductor. Then Nadj-Perge et al. [1] have realized a chain of Fe adatoms on a Pb(110) that induce locally a 1D topological p-wave superconductivity as demonstrated by the appearance of Majorana bound states at the extremity of the Fe chain. The Majorana states are strongly localized; they appear only on a few atoms at the end of the magnetic chains which inhibits their manipulation. A different strategy, using sizeable magnetic disks made of Cobalt buried under a superconducting monolayer of Pb/Si(111), allows to generate topological superconductivity in 2D. In this case dispersive edge states crossing the gap appears around the magnetic domains [2]. These spectroscopic features are the signature of a locally induced topological superconductivity in 2D Pb/Co/Si(111). This is at odds with the Fe chains whose edge states are intrinsically 0D and are thus characterized by non-propagative bound states. Indeed, in 2D systems one expects to get some propagative Majorana edge states around the topological domains since the edges have a 1D character. The edge states in 2D topological superconductors are analogous to the edge states in Quantum Spin Hall systems. However, there is a very fundamental difference here as the superconducting topological edge states have the specificity of being Majorana excitations. We will show that

superconducting vortices can be generated in topological domains; they support localized Majorana bound states in their core. Such Majorana vortex states have been the focus of numerous theoretical proposals for quantum computing schemes due to their non-Abelian anyonic nature. The manipulation of vortices in such 2D architecture may thus be an efficient way to do braiding experiments with Majorana bound states. [1] S. Nadj-Perge, I. K. Drozdov, J. Li, H. Chen, S. Jeon, J. Seo, A. H. MacDonald, B. A. Bernevig, and A. Yazdani, *Science* 346, 602 (2014) [2] G. C. Ménard, S. Guissart, C. Brun, M. Trif, F. Debontridder, R. T. Leriche, D. Demaille, D. Roditchev, P. Simon, T. Cren, arXiv:1607.06353 (2016)

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## Transport properties of spin-helical Dirac fermions in disordered quantum confined systems

Dufouleur Joseph

Dufouleur Joseph <sup>(1)</sup>, Funke Hannes <sup>(1)</sup>, Veyrat Louis, Dassonneville Bastien, Xypakis Emmanouil, Nowka Christian <sup>(1)</sup>, Hampel Silke <sup>(1)</sup>, Büchner Bernd <sup>(1)</sup>, Bardarson Jens <sup>(2)</sup>, Giraud Romain <sup>(1) (3)</sup>

1 - *Leibniz Institute for Solid State and Materials Research - IFW Dresden (Dresden, Germany) (Germany)*, 2 - *Max Planck Institute for the Physics of Complex Systems (Germany)*, 3 - *INAC-SPINTEC, Univ. Grenoble Alpes/CNRS/CEA (France)*

Quantum wires of 3D topological insulators offer a serious way to unveil the topological properties of the band structure and are promising systems for the search of robust signatures of topological conductivity and superconductivity in condensed matter [1]. Due to the strong degree of disorder typical for such materials, disorder remains a key limitation for such systems and prevents the emergence of transport properties specific for spin-helical Dirac fermions. Here, we reveal that the interaction between the static disorder and the quasi-particles of the 3D topological insulator surface states is considerably reduced due to the spin texture of the band structure by investigating the transconductance properties of a Bi<sub>2</sub>Se<sub>3</sub> nanoribbon [2]. This result suggests that the ballistic or quasi-ballistic regime could be achieved in narrow structures of 3D topological insulator like nanowires [3]. Furthermore, the typical surface states transport length measured in our nanostructures corresponds to an energy broadening (?) that is of the same order of magnitude or even smaller than the level spacing (?) in nanowires of Bi<sub>2</sub>Se<sub>3</sub> or Bi<sub>2</sub>Te<sub>3</sub>, an unusual result for highly-disordered mesoscopic nanostructures[3,4]. As a result, contrary to the expected diffusive case corresponding to ? ?, the conductance fluctuation are found to be non-universal. Theory shows that such a unique behavior is specific to spin-helical Dirac fermions with strong quantum confinement, which retain ballistic properties over an unusually large energy scale due to their spin texture. Following our experimental work, we also present the results of a theoretical investigation of the transport properties quantum wires of topological insulators, in the high energy regime usually considered experimentally and we show that the spin-helicity and the linear dispersion of the band structures leads to specific conductance and shot noise properties as well as Aharonov-Bohm oscillations. [1] J. Bardarson 2010 [2] J. Dufouleur et al., *Nano Letters* 16, 6733-6737 (2016) [3] J. Dufouleur et al., *Physical Review Letters* 110, 186806 (2013) [4] J. Dufouleur et al., accepted for publication in *Scientific report* (2017)

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## Robustness of symmetry-protected topological states against time-periodic perturbations

Johannesson Henrik

Johannesson Henrik <sup>(1)</sup>

1 - *University of Gothenburg (Sweden)*

The existence of gapless boundary states is a key attribute of any topological band insulator. Conventional band theory predicts that these states are robust against static perturbations that preserve the relevant symmetries. In this talk I will discuss how the symmetry-protection may extend also to states subject to time-periodic boundary perturbations ? in Floquet topological insulators as well as in ordinary time-independent topological insulators. Notably, boundary states in a time-independent topological insulator are found to exhibit an enhanced robustness against time-periodic perturbations, beyond that for static perturbations. Implications for experiments and applications to future quantum devices will be discussed.

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## Topological Physics in HgTe-based Quantum Devices

Molenkamp Laurens

Molenkamp Laurens <sup>(1)</sup>

1 - *Physikalisches Institut (EP3) Universität Würzburg (Germany)*

Suitably structured HgTe is a topological insulator in both 2- (a quantum well wider than some 6.3 nm) and 3 (an epilayer grown under tensile strain) dimensions. The material has favorable properties for quantum transport studies, i.e. a good mobility and a complete absence of bulk carriers, which allowed us to demonstrate variety of novel transport effects. One aspect of these studies is topological superconductivity, which can be achieved by inducing superconductivity in the topological surface states of these materials. Special emphasis will be given to recent results on the ac Josephson effect. We will present data on Shapiro step behavior that is a very strong indication for the presence of a gapless Andreev mode in our Josephson junctions, both in 2- and in 3-dimensional structure. An additional and very direct evidence for the presence of a zero mode is our observation of Josephson radiation at an energy equal to half the superconducting gap. Controlling the strain of the HgTe layers strain opens up yet another line a research. We have recently optimized MBE growth of so-called virtual substrates ((Cd,Zn)Te superlattices as a buffer on a GaAs substrate), that allow us to vary the strain from 0.4% tensile to 1.5% compressive. While tensile strain turns 3-dimensional HgTe into a narrow gap insulator, compressive strain turns the material into a topological (Weyl) semimetal, exhibiting clear signs of the Adler-Bell-Jackiw anomaly in its magnetoresistance. In quantum wells, compressive strain allows inverted energy gaps up to 60 meV.

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## Deep learning the quantum phase transitions of disordered topological matters

Ohtsuki Tomi

Ohtsuki Tomi <sup>(1)</sup>, Ohtsuki Tomoki

1 - *Physics Division, Sophia University (Japan)*

Three-dimensional random electron systems undergo quantum phase transitions and show rich phase diagrams. Examples of the phases are the band gap insulator, Anderson insulator, strong and weak topological insulators, Weyl semimetal, and diffusive metal. We use an image recognition algorithm based on a multilayered convolutional neural network to identify which phase the eigenfunction belongs to. The Wilson-Dirac model for topological insulators, and the layered Chern insulator model for Weyl semimetal are studied. The situation where the standard transfer matrix approach is not applicable is also treated by this method.

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## Topological confined massive surface states in strained bulk HgTe probed by RF compressibility

Plaças Bernard

Inhofer Andreas <sup>(1)</sup>, Tchoumakov Sergueï <sup>(2)</sup>, Assaf Badih <sup>(3)</sup>, Fève Gwendal <sup>(1)</sup>, Berroir Jean-Marc <sup>(1)</sup>, Jouffrey Victor <sup>(4)</sup>, Carpentier David <sup>(4)</sup>, Goerbig Mark Oliver <sup>(2)</sup>, Plaças Bernard <sup>(1)</sup>, Bendias Kalle <sup>(5)</sup>, Mahler David <sup>(5)</sup>, Bocquillon Erwann <sup>(5)</sup> <sup>(1)</sup>, Schlereth R. <sup>(5)</sup>, Brüne C. <sup>(5)</sup>, Buhmann Hartmut <sup>(5)</sup>, Molenkamp Laurens <sup>(5)</sup>

1 - *Laboratoire Pierre Aigrain (France)*, 2 - *Laboratoire de Physique des Solides (France)*, 3 - *Département de Physique de l'ENS Paris (France)*, 4 - *Laboratoire de Physique de l'ENS Lyon (France)*, 5 - *Physikalisches Institut (EP3) Universität Würzburg (Germany)*

It is well established that topological insulators sustain Dirac fermion surface states as a consequence of band inversion in the bulk. These states have a helical spin polarization and a linear dispersion with large Fermi velocity. In this talk we will report on a set of experimental observations indicating the existence of massive surface states. These states are confined at the interface and dominate equilibrium and transport properties at high energy and/or high electric field. By monitoring the AC admittance of HgTe topological insulator field-effect capacitors, we access the compressibility and conductivity of surface states in a broad range of energy and electric fields. The Dirac surface states are characterized by a compressibility minimum, a linear energy dependence and a high mobility persisting up to energies much larger than the transport bandgap of the bulk. New features are revealed at high energies with signatures such as conductance peaks, compressibility bumps, a strong charge metastability and a Hall resistance anomaly. These features point to the existence of excited massive surface states, responsible for a strong intersubband scattering with the Dirac states and the nucleation of metastable bulk carriers. The spectrum of excited states agrees with predictions of a phenomenological model of the topological-trivial semiconductor interface. The model accounts for the finite interface depth and the effect of electric fields. The existence of excited topological states is essential for the understanding of topological phases and opens a route for engineering and exploiting topological resources in quantum technology.

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## Topological superconductivity between one and two dimensions

Stern Ady

Stern Ady <sup>(1)</sup>

1 - Weizmann Institute of Science (Israel)

In this talk I will describe the way that two dimensional Josephson junctions may be employed to create one dimensional topological superconductors and describe the unique properties of the resulting system. These properties include robust topological superconductivity and self-tuning of the system to the topological regime. I will discuss the interplay of topological superconductivity in these junctions with disorder and with screening currents, and possible relations to existing experiments. My collaborators in this work are Anna Keselman, Falko Pientka, Arbel Haim, Erez Berg, Bert Haleprin and Amir Yacoby (Weizmann, Harvard, U. Chicago, Microsoft's Station Q).

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## Anomalous Hall effect and topological phase transitions

Streda Pavel

Streda Pavel <sup>(1)</sup>

1 - Institute of Physics ASCR (Czech Republic)

To illustrate the close relation of the anomalous Hall conductivity and the orbital momentum, the response to the chemical potential gradient will be described in detail. The obtained result will be compared with that obtained by means of the Kubo formula representing the response to the electric field. The general expressions will be applied to a simple two-dimensional network model so that the physical origin of the anomalous Hall effect and the topological phase transitions between insulators of different Chern numbers can be clarified. It will be shown that such transitions are accompanied by the space redistribution of local currents.

Finally, the effect of the boundary conditions to the appearance of chiral edge states will be analyzed. It will be argued that changing the boundary conditions the current-carrying edge-state branches can be induced or destroyed, at the particular sample edge. It suggests that, at least in principle, new types of spintronic devices like quasi-one dimensional spin filters and diodes can be prepared.

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## Massive surface states of topological materials

Tchoumakov Sergueï

Tchoumakov Sergueï <sup>(1)</sup>, Inhofer Andreas <sup>(2)</sup>, Jouffrey Victor <sup>(3)</sup>, Bocquillon Erwann <sup>(4)</sup> <sup>(2)</sup>, Plaçais Bernard <sup>(2)</sup>, Carpentier David <sup>(3)</sup>, Civelli Marcello <sup>(5)</sup>, Goerbig Mark <sup>(6)</sup>

1 - Laboratoire de Physique des Solides (France), 2 - Laboratoire Pierre Aigrain (France), 3 - Laboratoire de Physique de l'ENS Lyon (France), 4 - Physikalisches Institut (EP3) Universität Würzburg (Germany), 5 - Laboratoire de Physique des Solides (France), 6 - laboratoire de physique des solides (France)

The condensed matter realizations of gaped and gapless materials where the low-energy physics reproduce the Dirac equation show surprising surface states when inverted and normal gaps are in contact. These surface states are spin-momentum locked, are usually more metallic than the bulk states and are topologically protected. Such topological surface states (TSS) have been identified by angle resolved photoemission spectroscopy (ARPES), scanning tunneling spectroscopy (STM) and transport.

Along with these TSS the same experiments indicate the existence of massive surface states (MSS) attached to both the valence and conduction bands and that are influenced by band bending. One explanation for this effect is that one observes the quantum-well states associated to the lower (resp. higher) part of the conduction and valence bands due to downward (resp. upward) band-bending. In this description the gaped surface states are a consequence of band bending.

In this talk we will discuss another origin of these massive surface states, as a consequence of a finite-sized interface between the inverted- and normal-gaped materials. The role of band bending is to delocalize and reduce the energy of these states which allows for their manipulation.

# The complete topological classification of gapped states of matter in the presence of reflection symmetry

Trifunovic Luka

Trifunovic Luka <sup>(1)</sup>, Brouwer Piet <sup>(1)</sup>

1 - Freie University Berlin (Germany)

We obtain the complete classification of the reflection symmetric topological insulators and superconductors using relative homotopy groups and exact sequences. The definition of topological indices and corresponding generators are provided. Additionally, we address the issue of 'subtle instability' of the second descendant  $\mathbb{Z}_2$  phase the presence of disorder.

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## Color code quantum computation with Majorana bound states

Von Oppen Felix

Litinski Daniel <sup>(1)</sup>, Kesselring Markus <sup>(2)</sup>, Eisert Jens <sup>(2)</sup>, Von Oppen Felix <sup>(1)</sup>

1 - Freie University Berlin (Germany), 2 - Dahlem Center for Complex Quantum Systems, Freie Universität Berlin (Germany)

We establish color codes as providing a natural setting in which advantages offered by topological hardware can be combined with those arising from topological error-correcting software for full-fledged fault-tolerant quantum computing. Most importantly, color codes have a set of transversal gates which coincides with the set of topologically protected gates in Majorana-based systems, namely the Clifford gates. We illustrate our scheme by providing a complete description of a possible architecture based on topological superconductor networks. D. Litinski, M. S. Kesselring, J. Eisert, F. von Oppen, Combining Topological Hardware and Topological Software: Color Code Quantum Computing with Topological Superconductor Networks, arXiv:1704.01589 (2017)

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## The origin of bias independent conductance plateaus and zero bias conductance peaks in Bi<sub>2</sub>Se<sub>3</sub>/NbSe<sub>2</sub> hybrid structures

Wang Jiannong

Wang Jiannong <sup>(1)</sup>

1 - Department of Physics and the Center for Quantum Materials, the Hong Kong University of Science and Technology (Hong Kong SAR China)

Superconducting proximity effect in topological insulator and superconductor hybrid structure has attracted intense attention in recent years in an effort to search for mysterious Majorana fermions in condensed matter systems. Here we report on the superconducting proximity effect in a Bi<sub>2</sub>Se<sub>3</sub>/NbSe<sub>2</sub> junction fabricated with an all-dry transfer method. Resulting from the highly transparent interface, two sharp resistance drops are observed at 7 K and 2 K, respectively, corresponding to the superconducting transition of NbSe<sub>2</sub> flake and the superconducting proximity effect induced superconductivity in Bi<sub>2</sub>Se<sub>3</sub> flake. Experimentally measured differential conductance spectra exhibit a bias-independent conductance plateau in the vicinity of zero bias below 7 K. As temperatures further decrease a zero bias conductance peak emerges from the plateau and becomes more enhanced and sharpened at lower temperatures. Our numerically simulated differential conductance spectra reproduce the observed bias-independent conductance plateau and zero bias conductance peak and show that the superconducting proximity effect in topological surface states is much stronger than that in the bulk states of Bi<sub>2</sub>Se<sub>3</sub>. The Superconducting proximity effect induced superconducting gap for the topological surface states of Bi<sub>2</sub>Se<sub>3</sub> is comparable to that of NbSe<sub>2</sub> and gives rise to the observed bias-independent conductance plateau below 7 K. In contrast, the superconducting proximity effect induced superconducting gap for the bulk states of Bi<sub>2</sub>Se<sub>3</sub> is an order of magnitude smaller than that of NbSe<sub>2</sub> and superconducting topological surface states. These weakly paired bulk states in Bi<sub>2</sub>Se<sub>3</sub> give rise to the zero bias conductance peak below 2 K. Our study has clearly unveiled the different roles of topological surface states and bulk states in the superconducting proximity effect, clarified the physical origin of the induced features, and shined light on further investigation of superconducting proximity effect and Majorana fermion in topological insulator and superconductor hybrid structures.

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# Effective Hamiltonian for protected edge states in graphene

Winkler Roland

Deshpande Harsh <sup>(1)</sup>, Winkler Roland <sup>(1)</sup> <sup>(2)</sup>

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Edge states in topological insulators (TIs) disperse symmetrically about one of the time-reversal invariant momenta  $\Lambda$  in the Brillouin zone (BZ) with protected degeneracies at  $\Lambda$ . Commonly TIs are distinguished from trivial insulators by the values of one or multiple topological invariants that require an analysis of the bulk band structure across the BZ. We propose an effective two-band Hamiltonian for the electronic states in graphene based on a Taylor expansion of the tight-binding Hamiltonian about the time-reversal invariant M point at the edge of the BZ. This Hamiltonian provides a faithful description of the protected edge states for both zigzag and armchair ribbons though the concept of a BZ is not part of such an effective model. We show that the edge states are determined by a band inversion in both reciprocal and real space, which allows one to select  $\Lambda$  for the edge states without affecting the bulk spectrum.

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# Quantum capacitance and spin susceptibility of HgTe quantum wells

Zülicke Ulrich

Kernreiter Thomas <sup>(1)</sup>, Governale Michele <sup>(1)</sup>, Zülicke Ulrich <sup>(1)</sup>

1 - Victoria University of Wellington (New Zealand)

Our theoretical study of quantum capacitance [1] and spin response [2] for electrons in HgTe quantum wells reveals unconventional properties that distinguish this paradigmatic topological-insulator material from all other currently known 2D electronic systems. It also provides alternative means for experimental identification of the topological regime and extends current knowledge about the fundamentals of many-particle collective behaviour in solids. [1] T. Kernreiter, M. Governale, U. Zülicke, Phys. Rev. B 93, 241304(R) (2016). [2] T. Kernreiter, M. Governale, U. Zülicke, E.M. Hankiewicz, Phys. Rev. X 6, 021010 (2016)

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## 2 Nanodevices, Nanoelectronics, Nanospintronics, Nanoelectromechanics

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# Spin Orbit interactions, time reversal symmetry and spin filtering

Aharony Amnon

Aharony Amnon <sup>(1)</sup> <sup>(2)</sup>

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Quantum computing requires the ability to write and read quantum information on the spinors of electrons. Here we discuss writing information on mobile electrons, which move through mesoscopic (or molecular) quantum wire networks. When such a network is connected to one source and one drain then time-reversal symmetry and unitarity imply no spin polarization. Tunable spin filtering can be achieved by adding a magnetic field, which breaks time-reversal symmetry, or by leakage, which breaks unitarity. Alternatively, filtering is also achieved with more than one drain. Specific examples include transport through a mesoscopic Aharonov-Bohm interferometer and through a helical molecule. Filtering can also be achieved for a single one-dimensional wire which has spin-orbit interactions, when the chain vibrates in the transverse direction. Such a single wire can also change the Josephson current between two superconductors.

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# Size dependent effects in ordered ultrathin ferroic films

Bach Thanh Cong

Bach Thanh Cong <sup>(1)</sup>  
1 - VNU University of science (Vietnam)

Ultrathin ferroic (magnetic or ferroelectric) films (UFF) as quasi-2D system now are widely applied as important materials for modern electronic devices. In this research, size dependence of the order parameters (magnetization or polarization) phase transition temperature, specific heat of UFF is investigated theoretically using Ising model in transversal and longitudinal fields. Calculation within mean field and correction from Gaussian fluctuation theory shows enhancement of the size dependence effects due to fluctuation of the order parameter. Density functional theory calculation for some ferroelectric titanate perovskite ultrathin films is also carried out for comparison with analytical and experimental results.

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## Electro-mechanical resonators based on graphene

Bachtold Adrian

Bachtold Adrian <sup>(1)</sup>  
1 - The Institute of Photonic Sciences (Spain)

When a graphene layer is suspended over a circular hole, the graphene vibrates as a music drum. However, such a graphene drum has an extremely small mass. Another difference is the quality factor  $Q$ , which becomes extremely large in graphene resonators at cryogenic temperature ( $Q$  above 1 million). Because of this combination of low mass and high quality factor, the motion is enormously sensitive to external forces. Here, we couple the graphene resonator to a superconducting cavity via the radiation pressure interaction. The superconducting cavity allows us to transduce the graphene motion with unprecedented sensitivity. We sideband cool the graphene motion to an average phonon occupation that approaches the quantum ground-state. We show that the graphene resonator is a fantastic force sensor with a sensitivity approaching the fundamental limit imposed by thermo-mechanical noise. We find that energy decays in a way that has thus far never been observed nor predicted. As the energy of a vibrational mode freely decays, the rate of energy decay switches abruptly to lower values, in stark contrast to what happens in the paradigm of a system directly coupled to an environmental bath. Our finding is related to the hybridization of the measured mode with other modes of the resonator. Our work opens up new possibilities to manipulate vibrational states, engineer hybrid states with mechanical modes at completely different frequencies, and to study the collective motion of this highly tunable system.

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## Ground-state cooling a mechanical oscillator by spin-dependent transport and Andreev reflection

Belzig Wolfgang

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1 - University of Konstanz (Germany)

We study the ground-state cooling of a mechanical oscillator coupled to the charge or the spin of a quantum dot inserted between spin-polarized or a normal metal and a superconducting contact. Such a system can be realized e.g. by a suspended carbon nanotube quantum dot with a suitable coupling between a vibrational mode and the charge or spin. We show that ground-state cooling of the mechanical oscillator can be achieved for many oscillator modes simultaneously [3] as well as selectively for single modes [1]. We discuss different modes of operation which also include single mode cooling by resonance, which is tunable by a magnetic field [1,2]. We finally discuss how the oscillator's state can be detected in the current-voltage characteristic [2,3] and how quasiparticles can be used as alternative cooling mechanism [4]. [1] P. Stadler, W. Belzig, and G. Rastelli, Phys. Rev. Lett. 113, 047201 (2014). [2] P. Stadler, W. Belzig, and G. Rastelli, Phys. Rev. B 91, 085432 (2015) [3] P. Stadler, W. Belzig, and G. Rastelli, Phys. Rev. Lett. 117, 197202 (2016) [4] P. Stadler, W. Belzig, and G. Rastelli, arxiv: 1703.05274

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## Brillouin light scattering in optomagnonics

Blanter Yaroslav

Blanter Yaroslav <sup>(1)</sup>

Brillouin light scattering is an established technique to study magnons, the elementary excitations of a magnet. Its efficiency can potentially be enhanced by cavity effects that concentrate the light power in the magnet. Here, we study inelastic scattering of photons by a magnetic sphere that supports optical whispering gallery modes, in a configuration of light traveling perpendicular to the magnetization. We find light scattering in two regimes. For low angular momentum magnons, the light is scattered in the forward direction with a pronounced asymmetry in the Stokes and the anti-Stokes scattering probability, consistent with recent experiments. High angular momentum magnons back-scatter light into either the Stokes or anti-Stokes peaks. We further show that the light scattering in the latter regime permits mapping of the high angular momentum magnon dispersion.

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## Spin-orbit induced triplet correlations and magnetoelectrics in superconducting heterostructures

Bobkova Irina

Bobkova Irina <sup>(1)</sup>, Bobkov Alexander <sup>(1)</sup>, Zyuzin Alexander <sup>(2) (3)</sup>, Alidoust Mohammad <sup>(4)</sup>

1 - Institute of Solid State Physics RAS (Russia), 2 - A.F. Ioffe Physical - Technical Institute (Russia), 3 - Department of Physics, KTH-Royal Institute of Technology (Sweden), 4 - K.N. Toosi University of Technology (Iran)

The systems with full spin-momentum locking of the conducting states, such as the surface states of 3D topological insulator, are a platform for realization and investigation of interplay between superconductivity and the strongest spin-orbit coupling. We study the effective superconducting order parameter and the condensate wave function, induced in surface states of 3D topological insulator (TI) by proximity to an s-wave superconductor (S) in the presence of an external magnetic field or an applied supercurrent. We perform a symmetry analysis of the induced superconductivity and find that all possible pairings, allowed by the Pauli principle, are present due to the full spin-momentum locking of the underlying conducting surface state of the TI. We unveil the connection between the odd-frequency pairing in S/3D TI heterostructures and magnetoelectrical effects. It is shown that in the presence of the magnetic field or the supercurrent the helical nature of the surface states manifests itself not only in the condensate wave function, as it was known previously [1-5], but also in the structure of the effective order parameter, which acquires an odd-frequency component. Due to the full spin-momentum locking of the surface states of the TI the magnetoelectric effects are extremely strong there. We consider possible experimental manifestations of the magnetoelectrical effects in S/3D TI heterostructures and their potential applications. In particular, we discuss a proposal to use such heterostructures as electrically controllable sources of highly spin-polarized current for spintronics applications. [1] J. Linder et.al, Phys. Rev. B 81, 184525 (2010). [2] M. Snelder et.al, J. Phys.: Condens. Matter 27, 315701 (2015). [3] M. Snelder et.al, Phys. Rev. B 87, 104507 (2013). [4] P. Burset et.al, Phys. Rev. B 92, 205424 (2015). [5] A.S. Vasenko et.al, arXiv:1606.00905.

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## Thermospin effects in superconducting heterostructures

Bobkov Alexander

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Recently the thermally created pure spin currents were predicted for Zeeman-split superconductor/normal metal heterostructures. Here it is shown that this "thermospin" current can lead to an accumulation of a pure spin imbalance in a system. The thermally induced spin imbalance can reach the value of Zeeman splitting of the superconducting DOS and strongly influences superconductivity in the heterostructure. Depending on the temperature difference between the superconductor and the normal reservoir it can enhance the critical temperature of the superconductor or additionally suppress the zero-temperature superconducting state. The last possibility gives rise to an unusual superconducting state, which starts to develop at finite temperature.

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## Ultra-smooth SiC and oxide surfaces planarized using catalyst-referred etching

Bui Pho

Bui Pho <sup>(1)</sup>, Toh Daisetsu <sup>(1)</sup>, Isohashi Ai <sup>(1)</sup>, Sano Yasuhisa <sup>(1)</sup>, Yamauchi Kazuto <sup>(1)</sup>  
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Catalyst-referred etching (CARE) has been invented and developed over several years by our group to accomplish atomic level smoothness, no micro-scratches, local and global uniformity of SiC and oxides surfaces. The method utilizes a deposited Pt layer on a rubber pad as a catalyst pad and water as an etchant. Chemical etching occurs when the topmost wafer surface comes into contact with the catalyst plate in the etchant. Based on this concept, CARE can produce crystallographically nondamaged and smooth SiC and oxides surfaces with a root-mean-square roughness of less than 0.1 nm over a whole wafer.

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## Superconductivity, Magnetism, Anisotropy and Memory: The Remarkable Properties of the Conducting Gas at the (111) LaAlO<sub>3</sub>/SrTiO<sub>3</sub> Interface

Chandrasekhar Venkat

Chandrasekhar Venkat <sup>(1)</sup>, Davis Samuel <sup>(1)</sup>, Huang Zhen <sup>(2)</sup>, Han Kun <sup>(2)</sup>, Ariando A <sup>(2)</sup>, Venkatesan Thirumalai <sup>(2)</sup>

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The 2D conducting gas that forms at the interface between the two insulators LaAlO<sub>3</sub> (LAO) and SrTiO<sub>3</sub> (STO) has garnered a lot of attention due to wide variety of physical phenomena that it exhibits, including strong spin-orbit coupling, superconductivity, magnetism, and localization effects, among others. Most of the experimental and theoretical work so far has been on LAO/STO interfaces grown in the (001) crystal orientation, in which the system has rectangular symmetry at the interface. More recently, interest has focused on LAO/STO interface grown in the (111) crystal orientation, in which the interface has hexagonal symmetry, similar to graphene and transition-metal-dichalcogenides, raising the possibility of topological effects. As with the (001) interface structures, we find that the system exhibits both superconductivity and magnetism coexisting at the same interface. Unlike the (001) interface, the (111) interface is highly anisotropic, showing different characteristics along different crystal directions in all its properties, including longitudinal resistivity, Hall effect, quantum capacitance, superconductivity and magnetism. In addition, we observe an unusual memory effect in the superconducting state: the system remembers the gate voltage at which it is cooled through the superconducting transition.

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## Enhanced performance of three-terminal thermoelectric devices

Entin-Wohlman Ora

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A three-terminal device, comprising two electronic terminals and a thermal one (e.g., a boson bath, Fig. 1), is discussed. In the first part, we investigate the coefficient of performance for the joint operation of cooling one of the electronic terminals and producing electric power. Surprisingly enough, the coefficient of performance can be enhanced as compared to the case where that electronic terminal is cooled by investing thermal power (from the thermal bath) and electric power (from voltage applied across the electronic junction). We next examine the efficiency of an effective two-terminal thermoelectric device under a broken time-reversal symmetry which is derived from the three-terminal thermoelectric device. We find that breaking time-reversal symmetry can enhance the figure of merit for delivering electric power by supplying heat from a phonon bath beyond the one for producing the electric power by investing thermal power from the electronic baths. We also show that such a device cannot reach the Carnot efficiency, contrary to a recent claim. [1] O. Entin-Wohlman and A. Aharony, Three-terminal thermoelectric transport under broken time-reversal symmetry, Phys. Rev. B 85, 085401 (2012). [2] O. Entin-Wohlman, Y. Imry, and A. Aharony, Enhanced performance of joint cooling and energy production, Phys. Rev. B 91, 054302 (2015). [3] Kaoru Yamamoto, Ora Entin-Wohlman, Amnon Aharony, and Naomichi Hatano, Efficiency bounds on thermoelectric transport in magnetic fields: the role of inelastic processes, Phys. Rev. B 94, 121402(R) (2016). FIG.

# Top-gating control of the 2-DEG at the LAO/STO interface

Feuillet-Palma Cheryl

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1 - Laboratoire de Physique et d'Etude des Matériaux (France)

Transition metal oxides display a great variety of quantum electronic behaviors where correlations often play an important role. The achievement of high quality epitaxial interfaces involving such materials gives a unique opportunity to engineer artificial materials where new electronic orders take place. The recent discovery [1-3] of a superconducting two-dimensional electron gas (2DEG) at the interface of insulating oxides such as SrTiO<sub>3</sub>/LaAlO<sub>3</sub> or LaTiO<sub>3</sub>/SrTiO<sub>3</sub> provide a unique system in which superconducting to insulating transition can be continuously controlled using a back gate. In addition, those 2DEG present a field-effect-tunable strong Rashba spin-orbit coupling. Thus they naturally combine all the ingredients to host topological states. In this presentation, we report the local control of superconducting properties and Rashba spin-orbit coupling with top gated [4,5], in device based on LaAlO<sub>3</sub>/SrTiO<sub>3</sub> oxides interfaces. Finally, we will discuss the recent results on local control of the metallic 2DEG at even shorter scales with top gates in a quantum point contact geometry. This study paves the way for an accurate control of the 2DEG at oxides interfaces at mesoscopic scales. [1] N. Reyren, S. Thiel, A. D. Caviglia, L. F. Kourkoutis, G. Hammerl, C. Richter, C. W. Schneider, T. Kopp, A. S. Ruetschi, D. Jaccard, M. Gabay, D. A. Muller, J. M. Triscone, and J. Mannhart, *Science* 317, 1196 (2007). [2] J. Biscaras, N. Bergeal, A. Kushwaha, T. Wolf, A. Rastogi, R. C. Budhani, and J. Lesueur, *Nature Communications* 1, 1 (2010). [3] J. Biscaras, N. Bergeal, S. Hurand, C. Grossette, A. Rastogi, R. C. Budhani, D. LeBoeuf, C. Proust, and J. Lesueur, *Physical Review Letters* 108, 247004 (2012). [4] S. Hurand, A. Jouan, C. Feuillet-Palma, G. Singh, E. Lesne, N. Reyren, A. Barthélémy, M. Bibes, J. E. Villegas, C. Ulysse, M. Pannetier-Lecoeur, M. Malnou, J. Lesueur, and N. Bergeal, *Appl. Phys. Lett.* 108, 052602 (2016). [5] S. Hurand, A. Jouan, C. Feuillet-Palma, G. Singh, J. Biscaras, E. Lesne, N. Reyren, A. Barthélémy, M. Bibes, J. E. Villegas, C. Ulysse, X. Lafosse, M. Pannetier-Lecoeur, S. Caprara, M. Grilli, J. Lesueur, and N. Bergeal, *Sci. Rep.* 1 (2015).

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# Critical properties of the Anderson transition through the looking-glass of the CBS and CFS peaks

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In disordered media, the absence of diffusion arising from the spatial localization of single-particle states is known as Anderson localisation (AL). In three dimensions, AL manifests itself as a phase transition which occurs at a critical energy or at a critical disorder strength (the mobility edge) separating a metallic phase where states are spatially extended, from an insulating one where states are localized. Theoretically, much efforts have been devoted to the study of the critical properties of the Anderson transition (AT), such as wave-function multifractality or critical exponents. In practice however, only a handful of experiments have found evidence for the 3D Anderson transition, among them cold atoms, and even fewer have investigated its critical features (mostly in the context of quantum-chaotic dynamical localization). In addition to the intrinsic difficulty of achieving wave localization in three dimensions, one reason for the rareness of experimental characterizations of the Anderson transition is the lack of easily measurable observables displaying criticality. In this talk, I will show that the critical properties of the AT are encoded in two emblematic interference effects observed in momentum space: the coherent backscattering (CBS) and the coherent forward scattering (CFS) peaks, the latter being a critical parameter of the transition. By a finite time scaling analysis of the CBS width and of the CFS contrast temporal dynamics, one can extract accurate values of the mobility edge and critical exponents of the transition in agreement with their best known values to this date.

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# Coherent caloritronics with superconducting hybrid circuits: from heat interferometers to 0- $\pi$ controllable thermal Josephson junctions

Giazotto Francesco

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1 - NEST Istituto Nanoscienze-CNR and Scuola Normale Superiore (Italy)

The Josephson effect [1] represents perhaps the prototype of macroscopic phase coherence and is at the basis of the most widespread interferometer, i.e., the superconducting quantum interference device (SQUID). Yet, in analogy to

electric interference, Maki and Griffin [2] predicted in 1965 that thermal current flowing through a temperature-biased Josephson tunnel junction is a stationary periodic function of the quantum phase difference between the superconductors. In this scenario, a temperature-biased SQUID would allow heat currents to interfere thus implementing the thermal version of the electric Josephson interferometer. In this talk I will initially report the first experimental realization of such a heat interferometer [3]. We investigate heat exchange between two normal metal electrodes kept at different temperatures and tunnel-coupled to each other through a thermal device in the form of a DC-SQUID. Heat transport in the system is found to be phase dependent, in agreement with the original prediction. After this initial demonstration, we have extended the concept of heat interferometry to various other devices, implementing the first quantum ‘diffractor’ for thermal flux [4, 5], realizing the first balanced Josephson heat modulator [6], and an ultra-efficient low-temperature hybrid ‘heat current rectifier’ [7, 8], thermal counterpart of the well-known electric diode [9]. The latter structure offers a remarkable heat rectification ratio up to about 140 which allows its implementation in solid-state thermal nanocircuits and general-purpose electronic applications requiring energy harvesting and isolation at the nanoscale. Finally, I will conclude by showing the realization of a fully superconducting heat modulator based on the first tunable  $\pi$ -junction thermal Josephson junction [10].

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## Heat transport via a local two-state system

Kato Takeo

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The recent progress of micro-fabrication technology has enabled us to study quantum transport phenomena of phonons and photons experimentally. It is remarkable that there are several similarities between heat transport and electron transport. For example, quantization of heat conductance, which is an analogue of quantization of conductance in electron transport, has been observed experimentally. Recently, it has been shown that a phenomenon similar to the Kondo effect occurs in heat transport via a local two-state system[1]. In this study, the heat conductance has been calculated based on the spin-Boson model with the spectral function for the ohmic case. However, the sub-ohmic case and the super-ohmic case have not been studied in detail. In this study [2], we study heat transport via a local two-state system coupled to non-ohmic heat baths by using a quantum Monte Carlo method. We show that the heat conductance is proportional to  $T^{(2s+1)}$  at low temperatures whenever the system has a delocalized(singlet) ground state. This result is consistent with the general Shiba’s relation. For the sub-ohmic case, if the coupling strength was larger than a critical value, the behavior of heat conductance at low temperatures changes drastically, because of a quantum phase transition. References [1] K. Saito and T. Kato, Phys. Rev. Lett. 111, 214301 (2013) [2] M. Kato, T. Kato, and K. Saito, in preparation.

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## Thermoelectric transport through quantum dot-quantum point contact systems

Nguyen Thanh

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We show that thermo-electric transport through some Quantum Dot - single-mode Quantum Point Contact systems depends on the backscattering amplitude difference of the two  $\pi$ -charge Kondo channels. The appearance of new energy scales depending on this (these) difference(s) controls the crossover from Non-Fermi-liquid two-channel Kondo regime to Fermi-liquid single-channel Kondo one. We discuss windows of parameters for observation of NFL effects.

# Superconductivity in two dimensions in the AlOx/SrTiO3 heterostructure

Sengupta Shamashis

Sengupta Shamashis <sup>(1)</sup>, Monteverde Miguel <sup>(2)</sup>, Rodel Tobias, Tisserond Emilie <sup>(3)</sup>, Linez Florence, Murani Anil <sup>(4)</sup>, Deblock Richard <sup>(5)</sup>, Gueron Sophie, Bouchiat Helene <sup>(4)</sup>, Lecoeur Philippe <sup>(6)</sup>, Maroutian Thomas, Marrache-Kikuchi Claire, Santander-Syro Andrés <sup>(7)</sup>, Fortuna Franck

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The realization of two-dimensional electronic gases (2DEGs) in oxide-based heterostructures has led to important discoveries [1,2] about superconductivity in low dimensions, such as the observation of pairing interactions without superconductivity [3] and density-of-states features resembling the pseudogap in cuprates [4]. Consequently, this 2DEG has emerged as a model system to study the physics of Cooper pair formation in two dimensions and to gain useful insights about complex problems, e.g., the phase diagram of high temperature superconductors. In this talk, we will focus on: i) the facile realization of a 2DEG in AlOx/SrTiO3 using a method devised in our group that is more accessible to researchers than conventional hetero-epitaxial techniques, and ii) the phenomenon of gate-tunable superconductivity in two dimensions. A conducting 2DEG can be realized on the bare surface of SrTiO3 by the creation of oxygen vacancies [5]. The electrons populate the bands arising from Ti 3d orbitals. In a recent work (Rodel et al., Advanced Materials, 28:1976?1980, 2016), we have shown that the deposition in ultra-high vacuum of a thin layer of metallic Al on SrTiO3 leads to the creation of the same 2DEG due to the withdrawal of oxygen atoms from the surface by the reducing agent Al (which turns into insulating AlOx). The resulting heterostructure, AlOx/SrTiO3, is suitable for transport experiments because the layer of AlOx protects the 2DEG in ambient conditions against the percolation of oxygen from air. From transport experiments, we have determined that the 2DEG is superconducting with a critical temperature of 320 mK. The critical parameters (temperature and field) are tunable with the gate voltage, leading to a 'superconducting dome' in the phase diagram. Phase fluctuations of the order parameter play a dominant role in the phenomenon of superconductivity in two dimensions. By continuously varying the carrier density, we have been able to tune the 2DEG across different regimes of electronic interactions that influence the phenomenon of Cooper pair condensation. We will present our results on this topic. References: [1] Reyren et al., Science 317, 1196 (2007) [2] Caviglia et al., Nature 456, 624 (2008) [3] Cheng et al., Nature 521, 196 (2015) [4] Richter et al., Nature 502, 528 (2013) [5] Santander-Syro et al., Nature 469, 189 (2011)

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# Quench dynamics in superconducting nanojunctions: metastability and dynamical Yang-Lee zeros

Seoane Souto Rubén

Seoane Souto Rubén <sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup>, Martn-Rodero Ivaro <sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup>, Levy Yeyati Alfredo <sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup>

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The shot noise and the higher order cumulants contain valuable information about interactions and quantum correlations between electrons in nanodevices. While these studies have traditionally been restricted to the stationary case, recent technological advances in the direction of the single electron detection have attracted an increasing interest in the time resolved full counting statistics. On the other hand, superconducting nanodevices are of central interest as building blocks in quantum technologies. In this kind of devices, an unexplained excess of quasiparticles has been observed, which set the limit for possible applications. In superconducting atomic junctions these quasiparticles can decay to the Andreev bound states, giving rise to long lived odd parity states [1]. In this presentation I will focus in the dynamics of the charge transfer through nanojunctions coupled to superconducting electrodes. Under rather general conditions, the system gets trapped in a metastable state, characterized by a non-equilibrium population of the Andreev bound states. Although the trapped quasiparticles lead to a peculiar time dynamics, the quantum state of the system cannot be inferred from the evolution of the single particle observables. Instead, the information provided by the full counting statistics (FCS) is needed to fully characterize the state [2,3]. Finally, I will also demonstrate that the evolution of the roots of the FCS generating function, recently measured experimentally for the first time in a superconducting nanojunction [4], contain all the information about the system transport properties. Their evolution also allows to identify dynamical quantum phase transitions, much in the same way as the Lee Yang zeros of the partition function are connected to phase transitions in the equilibrium mechanics [5]. I will also discuss when a simplified description of the system dynamics based on the ?dominant? zeros is possible. [1] M. Zgirski, L. Bretheau,

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### 3 Electron Quantum Optics / Quantum Hall effect

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#### Decoherence control in quantum Hall edge channels

Cabart Clément

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The recent developments of electron quantum optics and, in particular, of single electron quantum tomography protocols based on two particle interferences has given us a new way to quantitatively probe the effect of interactions in ballistic chiral conductors down to the level of single electron excitations. In the quantum Hall edge system at filling fraction two, strong Coulomb interactions between the two channels lead to strong electronic decoherence effects. In this talk, we discuss electronic decoherence through electron/hole pair creations in a single quantum Hall edge channel and show that a careful sample design can lead to decoherence control in the quantum Hall edge channel system at filling fraction two.

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#### Two-particle interferometry for signal processing of a quantum electrical current

Feve Gwendal

Marguerite Arthur, Roussel Benjamin, Bisognin Rémi, Cabart Clément, Berroir Jean-Marc <sup>(1)</sup>, Bocquillon Erwann <sup>(1)</sup>, Plaças Bernard <sup>(1)</sup>, Cavanna Antonella <sup>(2)</sup>, Jin Yong <sup>(2)</sup>, Degiovanni Pascal <sup>(3)</sup>, Feve Gwendal <sup>(1)</sup>

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Quantum nanoelectronics has entered an era where quantum electrical currents built from single to few elementary excitations generated on demand. However, very limited tools have been implemented so far to characterize the emitted states. In this work, we present a two stage quantum analyzer able to extract single electron and hole excitations as well as their quantum coherences from a quantum electrical current. The first on-chip and quantum stage reconstructs, from two electron interferences, the Wigner distribution of an unknown electronic state without a priori knowledge. Using simple a.c. drives for demonstration, we reconstruct their Wigner distributions and can distinguish between quasi-classical and quantum drives. In the latter case, a second stage extracts through a signal procedure the relevant single electron and hole excitations localized within each emission period from the reconstructed Wigner distribution. This analysis is instrumental for characterizing and controlling single to few quantum excitations of the electronic fluid and for investigating electron/hole entanglement.

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#### The Interacting Mesoscopic Capacitor Out of Equilibrium

Filippone Michele

Litinski Daniel <sup>(1)</sup>, Brouwer Piet <sup>(1)</sup>, Filippone Michele <sup>(2)</sup>

*1 - Freie Universität Berlin (Germany), 2 - Département de Physique de la Matière Condensée (Switzerland)*

We consider the full non-equilibrium response of a mesoscopic capacitor in the large transparency limit, exactly solving a model with electron-electron interactions appropriate for a cavity in the quantum Hall regime. For a cavity

coupled to the electron reservoir via an ideal point contact, we show that the response to any time-dependent gate voltage  $V_g(t)$  is strictly linear in  $V_g$ . We analyze the charge and current response to a sudden gate voltage shift, and find that this response is not captured by a simple circuit analogy. In particular, in the limit of strong interactions a sudden change in the gate voltage leads to the emission of a sequence of multiple charge pulses, the width and separation of which are controlled by the charge-relaxation time  $\tau_c = hC_g/e^2$  and the time of flight  $\tau_f$ . We also consider the effect of a finite reflection amplitude in the point contact, which leads to non-linear-in-gate-voltage corrections to the charge and current response.

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## Supercurrent in the quantum Hall regime

Finkelstein Gleb

Finkelstein Gleb <sup>(1)</sup>

1 - Duke university [Durham] (United States)

One of the promising routes towards creating novel topological states and excitations is to combine superconductivity and quantum Hall (QH) effect. It has been predicted that QH chiral edge states can carry supercurrent. However, signatures of superconductivity in the QH regime remain scarce, and a superconducting current through a QH weak link has so far eluded experimental observation. By utilizing high mobility graphene/boron nitride heterostructures we demonstrate the existence of a novel type of supercurrent-carrying states in a QH regime at magnetic fields as high as 2 Tesla. At low magnetic fields, devices demonstrate the Fraunhofer pattern and Fabry-Perot oscillations, confirming their uniformity and ballisticity. In the QH regime, when Landau quantization is fully developed, regions of superconductivity can be observed on top of the conventional QH fan diagram. The measured supercurrent is very small, on a few nA scale, and periodic in magnetic field. We discuss possible mechanisms that could mediate supercurrent along the QH edge states.

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## Spin Phase Transition at the Edge of a QH System

Gefen Yuval

Gefen Yuval <sup>(1)</sup>, Khanna Udit <sup>(2)</sup>, Murthy Ganpathy <sup>(3)</sup>, Rao Sumathi <sup>(2)</sup>

1 - Weizmann Institute of Science (Israel), 2 - HRI (India), 3 - University of Kentucky (United States)

Quantum Hall states can be characterized by their chiral edge modes. Upon softening the edge potential, the edge has long been known to undergo spontaneous reconstruction driven by charging effects. I will discuss [1] a new type of quantum phase transitions at the edge, which are qualitatively distinct from charge-driven transitions. The spin-switching phase transition is driven by exchange effects, and is manifest by an abrupt change in the ordering of the chiral modes at the edge. I will specifically discuss the  $\nu = 3$  scenario. The transition occurs as the edge potential is made softer, while the ordering in the bulk remains intact. This phenomenon is robust, and has many variable experimental signatures in transport. 1. U. Khanna, G. Murthy, S. Rao, Y. Gefen, submitted.

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## Fractional quantum Hall effect and Wigner crystallization in suspended Corbino graphene disk

Hakonen Pertti

Hakonen Pertti <sup>(1)</sup>, Kumar Manohar <sup>(1)</sup>, Laitinen Antti <sup>(1)</sup>

1 - Aalto University School of Science (Finland)

Competition between kinetic and Coulomb energy in two-dimensional electron system leads to a multitude of different ordered phases. At high magnetic fields, kinetic energy of electrons is suppressed, which favors crystallization of electrons i.e. Wigner crystal. However, electrons commonly favor an incompressible liquid state, the fractional quantum Hall (FQH) liquid, instead of the Wigner crystal solid phase.

We have investigated competing Wigner crystal and FQH liquid phases in monolayer suspended graphene devices in Corbino geometry [1]. Magneto- and transconductance measurements along with IV characteristics and mechanical resonances all indicate unconventional sequence of FQH phases with lowering electron density  $n$ , where the conventional sequence of FQH states is interrupted by Wigner crystal order. At small  $n$ , with the filling factor  $\nu \approx 0.15 - 0.16$ , the

electron crystallizes into ordered Wigner solid, while incompressible liquid state is reemerged with lowering density down to  $\sim 1/7$ . The Wigner crystal state was experimentally confirmed by a microwave absorption resonance near 3 GHz which agrees with pinned, submicron-sized crystallites. The interaction of Wigner crystal and FQH states with mechanical vibrations has also been investigated. [1] M. Kumar, A. Laitinen, and P. J. Hakonen, Fractional quantum Hall effect and Wigner crystallization in suspended Corbino graphene disk, arXiv:1611.02742.

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## Topological vacuum bubbles in a non-Abelian anyon interferometer

Han Cheolhee

Han Cheolhee <sup>(1)</sup>, Sim Heung-Sun <sup>(1)</sup>

1 - Korea Advanced Institute of Science and Technology (South Korea)

In fermionic and bosonic many-body physics, vacuum bubbles do not contribute to physical observables, known as the linked cluster theorem [1]. However, it is shown [2] that certain vacuum bubbles of Abelian anyons affect physical observables, disobeying the linked cluster theorem. These vacuum bubbles, named as topological vacuum bubbles, represent a virtual anyonic excitation which braids real anyonic excitations. We generalize the concept of the topological vacuum bubble to the case of non-Abelian anyons. Because of non-Abelian braiding statistics, the topological vacuum bubbles affect physical observables in a different way from the Abelian case. We propose how to detect a non-Abelian topological vacuum bubble, hence the non-Abelian fractional statistics, in a fractional quantum Hall interferometer at filling factor  $5/2$ . [1] A. L. Fetter and J. D. Walecka, Quantum Theory of Many-Particle Systems (McGraw-Hill, New York, 1971). [2] C. Han et al., Nat. Commun. 7: 11131 (2016).

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## Fractional quasiparticles in the breakdown regime of a microscopic integer quantum Hall system

Hashisaka Masayuki

Hashisaka Masayuki <sup>(1)</sup>, Muraki Koji <sup>(1)</sup>, Fujisawa Toshimasa <sup>(2)</sup>

1 - NTT Basic Research Laboratories (Japan), 2 - Tokyo Institute of Technology (Japan)

Integer quantum Hall (QH) effect breaks down in a high electric field. Although the mechanism of the breakdown has been intensively investigated, the state prepared by the breakdown might not have attracted much attention. Here we demonstrate that fractional quasiparticles emerge in the breakdown regime of a microscopic integer-QH system. First, we prepare a local QH region at  $\nu_{\text{local}} = 1$  in a point-like constriction in a macroscopic QH system at  $\nu_{\text{bulk}} = 2$ , which is confirmed in the quantized conductance  $G_0 = e^2/h$ , the absence of shot noise, and a full Knight shift (full electron-spin polarization) of the resistively-detected nuclear magnetic resonance (NMR). When a large bias is applied, the conductance plateau breaks down. From the onset of the nonlinear behavior of the conductance, the shot noise starts to develop at a rate corresponding to the effective charge  $e^* = e/3$ . This fractional-charge tunneling is observed over a wide parameter space (the bias voltage  $\sim 500$  V and the differential conductance from  $0.7e^2/h$  to  $1.1e^2/h$  at various split-gate voltages). From the Knight shift of NMR, we find that the fractional-charge tunneling develops concomitant with the decrease in the spin polarization in the local region. These observations suggest the formation of a partially-polarized fractional QH liquid involving both spin-up and -down electrons in the non-equilibrium microscopic system. This work was supported by KAKENHI JP15H05854, JP26247051, JP16H06009, and Nanotechnology Platform Program (Tokyo Tech.).

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## Reconfiguration of electronic states in PT-symmetric quasi-one-dimensional lattices

Park Hee Chul

Jung-Wan Ryu, Nojoon Myoung, Park Hee Chul <sup>(1)</sup>

1 - Institute for Basic Science, Center for Theoretical Physics of Complex Systems (South Korea)

We demonstrate mesoscopic transport through electronic states in quasi-1D lattices maintaining the combination of parity and time-reversal symmetries by controlling energy gain and loss. We investigate the phase diagram of the non-Hermitian systems where transitions take place between unbroken and broken PT-symmetric phases via exceptional

points. Electron transport in the lattice is measured only in the unbroken—but not broken—phase in the energy band. The broken phase allows for spontaneous symmetry broken states where the cross-stitch lattice is separated into two identical single lattices corresponding to conditionally degenerate eigenstates. These degeneracies show a lift-up in complex energy plane, caused by the non-Hermiticity with PT-symmetry.

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## Quantum transport in graphene p-n junctions in the quantum Hall regime

Parmentier François

Parmentier François <sup>(1)</sup>, Kumada Norio <sup>(2)</sup>, Hibino Hiroki <sup>(2)</sup>, Glattli Christian <sup>(1)</sup>, Roulleau Preden <sup>(1)</sup>

1 - Service de Physique de l'Etat Condensé (France), 2 - NTT Basic Research Laboratories (Japan)

Graphene offers a unique system to investigate transport of Dirac Fermions at p?n junctions. In a magnetic field, combination of quantum Hall physics and the characteristic transport across p?n junctions leads to a fractionally quantized conductance associated with the mixing of electron-like and hole-like modes and their subsequent partitioning. The mixing and partitioning suggest that a p?n junction could be used as an electronic beam splitter. Here we report the shot noise study of the mode-mixing process and demonstrate the crucial role of the p?n junction length. For short p?n junctions, the amplitude of the noise is consistent with an electronic beam-splitter behaviour, whereas, for longer p?n junctions, it is reduced by the energy relaxation. Remarkably, the relaxation length is much larger than typical size of mesoscopic devices, encouraging using graphene for electron quantum optics and quantum information processing. N. Kumada, F. D. Parmentier, H. Hibino, D. C. Glattli, and P. Roulleau, Nature Communications 6, 8068 (2015)

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## Quantum tomography of an electron

Roulleau Preden

Roulleau Preden <sup>(1)</sup>, Jullien Thibaut <sup>(2)</sup> <sup>(3)</sup>, Roche Benoit, Cavanna Antonella <sup>(4)</sup>, Jin Yong, Glattli Christian <sup>(5)</sup>

1 - Service de Physique de l'Etat Condensé (France), 2 - Service de physique de l'état condensé (France), 3 - Kavli Institute of Nanosciences (Netherlands), 4 - Laboratoire de photonique et de nanostructures (France), 5 - Service de Physique de l'Etat Condensé (France)

The complete knowledge of a quantum state allows the prediction of the probability of all possible measurement outcomes, a crucial step in quantum mechanics. It can be provided by tomographic methods which have been applied to atomic, molecular, spin and photonic states. For optical or microwave photons, standard tomography is obtained by mixing the unknown state with a large-amplitude coherent photon field. However, for fermions such as electrons in condensed matter, this approach is not applicable because fermionic fields are limited to small amplitudes (at most one particle per state), and so far no determination of an electron wavefunction has been made. Recent proposals involving quantum conductors suggest that the wavefunction can be obtained by measuring the time-dependent current of electronic wave interferometers or the current noise of electronic Hanbury-Brown/Twiss interferometers. Here we show that such measurements are possible despite the extreme noise sensitivity required, and present the reconstructed wavefunction quasiprobability, or Wigner distribution function, of single electrons injected into a ballistic conductor [1]. Many identical electrons are prepared in well-controlled quantum states called levitons by repeatedly applying Lorentzian voltage pulses to a contact on the conductor. After passing through an electron beam splitter, the levitons are mixed with a weak-amplitude fermionic field formed by a coherent superposition of electron?hole pairs generated by a small alternating current with a frequency that is a multiple of the voltage pulse frequency. Antibunching of the electrons and holes with the levitons at the beam splitter changes the leviton partition statistics, and the noise variations provide the energy density matrix elements of the levitons. This demonstration of quantum tomography makes the developing field of electron quantum optics with ballistic conductors a new test-bed for quantum information with fermions. These results may find direct application in probing the entanglement of electron flying quantum bits, electron decoherence and electron interactions. They could also be applied to cold fermionic atoms. [1] Quantum tomography of an electron, T. Jullien, P. Roulleau, B. Roche, A. Cavanna, Y. Jin and D.C. Glattli, Nature 514, 603-607 (October 2014)

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## Signal processing for electron quantum optics

Roussel Benjamin

Roussel Benjamin <sup>(1)</sup>, Cabart Clément <sup>(2)</sup>, Marguerite Arthur <sup>(3)</sup>, Fève Gwendal <sup>(3)</sup>, Degiovanni Pascal <sup>(4)</sup>

1 - Laboratoire de Physique de l'ENS Lyon (France), 2 - Laboratoire de Physique de l'ENS Lyon (France), 3 - Laboratoire Pierre Aigrain (France), 4 - Laboratoire de Physique de l'ENS Lyon (France)

Electron quantum optics is an emerging branch of electronic transport aiming at generating, manipulating and characterizing elementary excitations of the electronic fluid, similarly to what is done in photon quantum optics [Annalen der Physik 526, 1 (2014)].

The key question in electron quantum optics is to determine what single-electron and more generally many-electron wavefunctions are propagating within the conductor. This is encoded within the electronic coherences defined similarly to the Glauber correlation function of order  $n$  giving access to the result of every  $n$ -particle interferometry experiments. This raises the question of the best elementary signals describing the electronic coherences of a periodically driven electronic source [Physical Status Solidi (b), 1600621 (2017)].

In this work, we introduce the spectral decomposition of the electron and hole parts of the first-order coherence. From this we compute the best elementary signals describing a periodic source. Whenever interactions can be neglected, we can reconstruct the whole many-body state. We then define a many-body notion of entanglement spectrum giving a many-body criterion for pure electron or hole emission. This is in particular relevant when considering a driven Ohmic contact or the mesoscopic capacitor.

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## Topological vacuum bubbles of anyons

Sim Heung-Sun

Sim Heung-Sun <sup>(1)</sup>

1 - Department of Physics, Korea Advanced Institute of Science and Technology (South Korea)

According to the linked cluster theorem of fermionic and bosonic many-body physics, physical observables are not affected by vacuum bubbles, which represent virtual particles created from vacuum and self-annihilating without interacting with real particles. In this talk, we show that this conventional knowledge must be revised for anyons. We find that a certain class of vacuum bubbles of anyons, involving topological braiding of virtually excited anyons around real anyonic excitations, affects physical observables. We develop a theory of such topological vacuum bubbles for both of Abelian anyons [1] and non-Abelian anyons [2]. These topological vacuum bubbles can be detected in a fractional quantum Hall system accessible in current experiments, providing a tool for observation of elusive fractional Abelian/non-Abelian exchange statistics. [1] C. Han et al., Nat. Commun. 7: 11131 (2016). [2] C. Han and H.-S. Sim, preprint (2017).

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## Leviton in a Kondo quantum dot

Suzuki Takafumi

Suzuki Takafumi <sup>(1)</sup>

1 - Graduate School of Engineering, University of Tokyo (Japan)

We study coherent transport of levitons through a single-level quantum dot system driven by Lorentzian-shaped voltage pulses. We demonstrate the repeated emergence of the Kondo resonance in the dynamical regimes where the Fermi sea is driven by optimal pulses free of particle-hole excitations. The formation of the Kondo resonance significantly enhances the dc transport of levitons.

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## From surface plasmons to fractional levitons: electron-electron interactions and ultrafast electronic interferometry.

Waintal Xavier

Waintal Xavier <sup>(1)</sup>

1 - Université Grenoble Alpes, Commissariat à l'Energie Atomique, PHELIQS/INAC (France)

Recent experiments using high mobility two dimensional electron gas have shown that it is now possible to engineer fast voltage pulses that send exactly one electron flying through the system. The initial focus has been to show that a

judicious choice of the shape of the pulse allows one to minimize the quantum fluctuations of the number of electrons contained in the pulse [1].

This single electron source opens the path to being able to observe the quantum dynamics of pulse propagation experimentally. In this talk, I will discuss various practical proposals such as the propagation of voltage pulses through interferometers [2] or the dynamical modification of edge states in the quantum Hall regime [3]. I will discuss in particular the role of electron-electron interactions, i.e. how the non-interacting excitations get renormalized into surface plasmons [4].

[1] J. Dubois et al, Nature 502, 659 (2013) [2] B. Gaury et al, Nature Comm. 5, 3844 (2014) [3] B. Gaury et al, Phys. Rev. B 90, 161305(R) (2014) [4] Thomas Kloss et al, in preparation

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## Odd-integer quantum Hall states and giant spin susceptibility in p-type few-layer WSe<sub>2</sub>

Wang Ning

Wang Ning <sup>(1)</sup>

1 - Department of Physics and the Center for Quantum Materials, the Hong Kong University of Science and Technology (Hong Kong SAR China)

We observed quantum Hall effects (QHE) in p-type few-layer WSe<sub>2</sub> for the first time, and surprisingly these QHE's were predominated at odd-integer filling factors. This remarkable phenomenon arises from the super large effective mass and giant spin susceptibility of the hole carriers of few-layer WSe<sub>2</sub>. In two-dimensional electron gas (2DEG) systems, QHE's occur predominately at even-integer filling factors because the Zeeman energy is normally much smaller than the cyclotron energy. In addition, the quantum transport in atomically thin transition metal dichalcogenides had long been limited by the device fabrication and purification. In this talk, I demonstrate the fabrication of p-type WSe<sub>2</sub> field-effect transistors with mobility up to 12,000 cm<sup>2</sup>/V s, which facilitated the aforementioned unexpected observations. We further observed that the Zeeman energy, enhanced by electron-electron interactions, is about three times as large as the cyclotron energy. Our results directly suggest that few-layer WSe<sub>2</sub> offers a novel and unique platform for exploring strongly correlated physics.

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## 4 Quantum technologies, Quantum Information, Cavity QED

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### Hybrid quantum systems: Outsourcing superconducting qubits

Cleland Andrew

Cleland Andrew <sup>(1)</sup>

1 - University of Chicago (United States)

Superconducting qubits offer excellent prospects for manipulating quantum information, with good qubit lifetimes, high fidelity single- and two-qubit gates, and straightforward scalability (admittedly with multi-dimensional interconnect challenges). One interesting route for experimental development is the exploration of hybrid systems, i.e. coupling superconducting qubits to other systems. I will report on our group's efforts to develop approaches that will allow interfacing superconducting qubits in a quantum-coherent fashion to spin defects in solids, to optomechanical devices, and to resonant nanomechanical structures. The longer term goals of these efforts include transferring quantum states between different qubit systems; generating and receiving "flying" acoustic phonon-based as well as optical photon-based qubits; and ultimately developing systems that can be used for quantum memory, quantum computation and quantum communication, the last in both the microwave and fiber telecommunications bands. Work is supported by grants from AFOSR, ARO, DOE and NSF.

## From Majorana box qubits to topological Kondo physics

Egger Reinhold

Egger Reinhold <sup>(1)</sup>

1 - University of Duesseldorf (Germany)

Mesoscopic superconducting islands with Majorana bound states are proposed for the implementation of a topologically protected qubit, where the charging energy of the island plays a key role. In this talk, I will discuss this Majorana box qubit proposal in detail and outline its potential for topological quantum computation. In the presence of attached leads, the Majorana box acts as "quantum impurity spin" and undergoes Kondo screening. I will present recent theoretical progress on this problem.

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## Quantum microwaves in a strong coupling circuit QED regime

Esteve Daniel

Esteve Daniel <sup>(1)</sup>, Rolland Chloé, Westig Marc, Parlavacchio Olivier, Peugeot Ambroise, Hofheinz Max, Mukharsky Iouri, Altimiras Carles, Joyez Philippe, Vion Denis, Roche Patrice, Portier Fabien, Kubala Björn <sup>(2)</sup>, Ankerhold Joachim, Trif Mirca <sup>(3)</sup>, Simon Pascal

1 - Service de Physique de l'Etat Condensé, CEA Paris-Saclay, CNRS, Université Paris-Saclay (France), 2 - University of Ulm (Germany), 3 - laboratoire de Physique des Solides, CNRS, Université de Paris-Saclay (France)

Transport of elementary charge carriers across a circuit usually does not couple to the electromagnetic modes embedded in the circuit. We consider here a dc voltage biased Josephson junction in series with a microwave resonator. In this very simple quantum electrodynamics open system, the effective coupling constant that replaces the fine structure constant of QED is the ratio between the resonator characteristic impedance, which can be engineered, and the relevant resistance quantum  $R_Q = h/4e^2 \approx 6.5 \text{ k}\Omega$ . At large coupling constant, the transfer of a single Cooper pair across the Josephson junction strongly couples to the circuit mode. This regime corresponds to the dynamical Coulomb blockade of Cooper pair tunneling [1]. We show that, in the strong coupling regime, the transfer of a single Cooper pair only occurs when its energy  $2eV$  can be transformed in  $1, 2, \dots, n$  photonic excitations in the resonator. We also identify a recently predicted regime for which the presence of a single photon blocks the creation of a second one, which forces the resonator to emit a single photon in the external circuit before another Cooper pair can pass and re-excite it: Cooper pair transfer and photon emission are locked. Using a two-mode resonator circuit with different frequencies, we demonstrate a regime in which the transfer of a single Cooper pair simultaneously excites a single photonic excitation in each mode. We find that the quantum state of the resonator violates a Cauchy inequality, which demonstrates its non-classical character [2]. [1] Hofheinz et al., Phys. Rev. Lett. 106, 217005 (2011). [2] Westig et al., arXiv 1703.05009.

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## Landau - Zener interferometry in multi-level systems

Kiselev Mikhail

Kiselev Mikhail <sup>(1)</sup>

1 - The Abdus Salam International Centre for Theoretical Physics (Italy)

We propose a universal approach to the Landau-Zener (LZ) problem in a multilevel system. The problem is formulated in terms of generators of  $SU(N)$  algebra and maps the Hamiltonian onto the effective anisotropic pseudospin  $(N-1)/2$  model. The vector Bloch equation for the density matrix describing the temporal evolution of the multilevel crossing problem is derived and solved analytically for two generic cases: i) three-level crossing problem representing a minimal model for a LZ interferometer and ii) four-level crossing problem corresponding to a minimal model of coupled interferometers. It is shown that the analytic solution of the Bloch equation is in excellent quantitative agreement with the numerical solution of the Schroedinger equation for the 3- and 4- level crossing problems. The solution demonstrates oscillation patterns which radically differ from the standard patterns for the two-level Landau-Zener problem: "beats", when the dwell time in the interferometer is smaller compared to a tunnel time and "steps" in the opposite limit. The possibilities of the experimental realization of LZ interferometers in the system of coupled quantum dots, Josephson charge qubits and in two-well traps for cold gases are discussed.

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# From Majorana- to Parafermions in Single and Double Nanowires

Loss Daniel

Loss Daniel <sup>(1)</sup>

1 - University of Basel (Switzerland)

I will present some recent results on single and double nanowires with proximity gap hosting Majorana and Parafermions [1]. Typically, the topological phases are engineered by tuning the magnetic field to the topological threshold value of typically a few Teslas. However, the magnetic field has a detrimental effect on the host superconductor and so it is interesting to search for ways to achieve the topological phase without or with smaller B-fields. A particular way to achieve this goal is to exploit crossed Andreev pairing in a double nanowire setup [1,2,3] which destructively interferes with the direct pairing, and thereby lowers the threshold for the B-field substantially [3]. In re-examining the proximity effect in such finite-size geometries we discovered that the standard procedure of 'integrating out superconductivity' breaks down [2]. I will also present some recent results on hybrid platforms for quantum computing which combine spin qubits in quantum dots with topological qubits on a surface code architecture [4]. [1] J. Klinovaja and D. Loss, PRL 112, 246403 (2014); PRB 90, 045118 (2014). [2] C. Reeg, J. Klinovaja, and D. Loss, arXiv:1701.07107. [3] C. Schrade, M. Thakurathi, C. Reeg, S. Hoffman, J. Klinovaja, and D. Loss, arXiv:1705.09364. [4] S. Hoffman, C. Schrade, J. Klinovaja, and D. Loss. Phys. Rev. B 94, 045316 (2016).

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# Aharonov-Bohm and Aharonov-Casher effects of nonlocal and local Cooper pairs

Martinek Jan

Tomaszewski Damian <sup>(1)</sup>, Busz Piotr <sup>(1)</sup>, López Rosa <sup>(2)</sup>, Zitko Rok <sup>(3)</sup>, Lee Minchul <sup>(4)</sup>, Martinek Jan <sup>(1)</sup>

1 - Institute of Molecular Physics, Polish Academy of Sciences (Poland), 2 - Departament de Física, Universitat de les Illes Balears (Spain), 3 - Jozef Stefan Institute (Slovenia), 4 - Department of Physics, Kyung Hee University (South Korea)

In recent years, there is substantial progress in creation of specially separated spin entangled electrons in solid state using the splitting of Cooper pairs [1], which is necessary ingredient of quantum communication and computing. It is also possible to generate a Josephson supercurrent from split nonlocal Cooper pairs [2]. This new Josephson current requires further studies especially its interference properties, since these can provide quantum gates. While the behavior of single electrons under the influence of Aharonov-Bohm (AB) and Aharonov-Casher (AC) effects is well understood, it raises the question of the impact of these effects on nonlocal superconducting Cooper pairs that for s-wave superconductors are in spin singlet state. For electrons in solid-state, the AC effect can be caused by the Rashba spin-orbit interaction. We analyze two systems: (i) a normal ring, where a single electron interference is possible and (ii) two parallel nanowires connected to two superconducting electrodes, where a single-electron interference can be absent but a cross Andreev reflection is possible. At low transmission for both considered systems, we can link the AB effect only to local Cooper pairs and the AC effect to nonlocal Cooper pair transport [3]. This is a rather surprising effect since Cooper pairs in the singlet state have no magnetic moment that is necessary ingredient of the AC effect. We demonstrate that by inserting quantum dots in the two nanowires we can obtain different AC phases for the nonspin-flip and spin-flip transport processes that leads to a beating in the AC effect. [1] L. Hofstetter, S. Csonka, J. Nygrd, and C. Schönenberger, Nature 461, 960 (2009). [2] R. S. Deacon, A. Oiwa, J. Sailer, S. Baba, Y. Kanai, K. Shibata, K. Hirakawa, and S. Tarucha, Nature Communications 6, 7446 (2015). [3] D. Tomaszewski, P. Busz, R. Lopez, R. Zitko, M. Lee, and J. Martinek, Phys. Rev. Lett. (submitted).

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## 5 Graphene and 2D materials

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# Transport properties of electron-hole bilayer/superconductor hybrid junction

Bercioux Dario

Bercioux Dario <sup>(1)</sup>, Bergeret Sebastian <sup>(2)</sup>, Klapwijk Teunin <sup>(3)</sup>

1 - Donostia International Physics Center - DIPC (SPAIN) (Spain), 2 - Centro de Fisica de Materiales (San Sebastian, Spain) (Spain), 3 - Delft University of Echnology (Netherlands)

We investigate the transport properties of an electron-hole bilayer contacted with two normal and two superconducting leads. We assume that the electron-hole bilayer hosts an exciton condensate described by a BCS-like model with a gap in the quasiparticle density of states. The setup we propose differs from the standard Coulomb drag measurements for detecting the existence of the excitonic phase [1]. We show that the existence of the condensate via transport measurements revealed in the sub-gap regime. At this energy scale, the transport properties are determined on the one hand by the standard Andreev reflection at the interface between the superconductor and the exciton condensate, and on the other hand, by a crossed reflection at the semi-metal/exciton-condensate. The latter converts electrons from one layer to the other [2]. Specifically, we show that the existence of a finite gap manifests in a minimum of the conductance at low voltage bias [3]. [1] A. F. Croxall et al., Phys. Rev. Lett. 101, 246801 (2008). [2] M. Rontani and L. J. Sham, Phys. Rev. Lett. 94, 186404 (2005). [3] D. Bercioux, F. Bergeret, and T. Klapwijk, submitted (2017).

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## Ultralow 1/f Noise in Superconducting Cobalt Dicilside Thin Films on Silicon

Chiu Shao-Pin<sup>(1)</sup>, Yeh Sheng-Shiuan<sup>(2)</sup>, Chiou Chien-Jyun<sup>(3)</sup>, Chou Yi-Chia<sup>(3)</sup>, Lin Juhn-Jong<sup>(2) (3)</sup>, Tsuei Chang-Chyi<sup>(4)</sup>

1 - Institute of Physics, National Chiao Tung University (Taiwan), 2 - Institute of Physics, National Chiao Tung University (Taiwan), 3 - Department of Electrophysics, National Chiao Tung University (Taiwan), 4 - (Emeritus from) IBM Thomas J. Watson Research Center (Taiwan)

High-precision resistance noise measurements indicate that the epitaxial CoSi<sub>2</sub>/Si heterostructures at 150 K and 2 K (slightly above its superconducting transition temperature T<sub>c</sub> of 1.54 K) exhibit an unusually low 1/f noise level in the low frequency range. This corresponds to an upper limit of Hooge constant  $\gamma \leq 3 \times 10^{-6}$ , about 100 times lower than that of single-crystalline aluminum films on SiO<sub>2</sub>. Supported by high-resolution cross-sectional transmission electron microscopy studies, our analysis reveals that the 1/f noise is dominated by excess interfacial Si atoms and their dimer reconstruction induced fluctuators. Unbonded orbitals (i.e., dangling bonds) on excess Si atoms are intrinsically rare at the epitaxial CoSi<sub>2</sub>/Si(100) interface, giving limited trapping-detrapping centers for localized charges. With its excellent normal-state properties, CoSi<sub>2</sub> has been used in Si-based integrated circuits for decades. The intrinsically low noise properties could have high potential for developing quiet qubits and scalable superconducting circuits for future quantum computing.

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## Real-space and plane-wave combination for electronic structure of two-dimensional materials

Do Van-Nam

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We present an approach of combining the plane-wave method and the real-space treatment to characterise the periodic variation and the decay of wave functions in the material plane and from the material surfaces. The proposed approach is natural for 2D material systems, and thus may avoid some intrinsic limits involving the artificial replication of material layer in traditional supercell methods. In particular, we show that the proposed method is easy in the implementation and, especially, efficient in the computation since low-cost computational algorithms, such as iterative and recursive techniques, can be invoked to treat matrices with the block tridiagonal structure. Using the proposed approach we show first-principles evidences to supplement the current knowledge of some fundamental issues in bilayer graphene systems, including the coupling between the two graphene layers, the preservation of the  $\pi$ -band of monolayer graphene in the electronic structure of the bilayer system, and the difference between the low-energy band structure of the bilayer AA- and AB-stacking configurations

## Confinement in 2D materials

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Quantum devices realized in graphene and other 2D materials usually rely on etching which often leads to localized states dominating the electronic properties of the system. Here we show how a stacked gate arrangement in bilayer graphene can be used to define a constriction for current flow which can be completely pinched off and in addition displays plateau-like features in the conductance. We also show that spil-gate geometries on high-mobility MoS2 allow for the realization of an electronic constriction. These developments pave the way for electronically tunable quantum devices in 2D materials.

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## Unconventional superconductivity from magnetism in transition metal dichalcogenides

Governale Michele

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Understanding possible mechanisms for the coexistence and interplay of superconductivity with magnetism has been one of the most long-standing and intensely studied questions in condensed-matter physics [1]. We investigate proximity-induced superconductivity in monolayers of transition metal dichalcogenides (TMDs) that are tunnel-coupled to a conventional singlet s-wave superconductor and subject to an external exchange field generated by a ferromagnetic substrate or an applied magnetic field [2]. A variety of superconducting order parameters is found to emerge from the interplay of magnetism and superconductivity, covering the entire spectrum of possibilities to be symmetric or antisymmetric with respect to the valley and spin degrees of freedom, as well as even or odd in frequency. As a key finding, we reveal the existence of an exotic even-frequency triplet pairing between equal-spin electrons from different valleys, which arises whenever the spin orientations in the two valleys are noncollinear. The opposite-spin-pairing component of this exotic superconducting correlation is a realization of the previously discussed phenomenon of Ising superconductivity. Among the different order parameters, we also identify the existence of induced intra-valley pairings, which are particular instances of the generic pair-density-wave order associated with Cooper pairing at finite momentum. Finally, all types of induced superconducting order parameters turn out to be tunable via manipulations of the external exchange field. [1] L. N. Bulaevskii, A. I. Buzdin, M. L. Kulić, and S. V. Panjukov, Adv. Phys. 34, 175 (1985). [2] M. A. Rahimi, A. G. Moghaddam, C. Dykstra, M. Governale, and U. Zülicke Phys. Rev. B 95, 104515 (2017).

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## Upper critical field in superconducting transition metal dichalcogenide monolayers

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Transition metal dichalcogenide (TMDC) monolayers are recently discovered two-dimensional (2D) materials with a hexagonal lattice structure similar to graphene, but with two inequivalent sites in the unit cell. They exhibit a particularly strong intrinsic spin-orbit coupling, acting as an effective Zeeman field which takes opposite orientations in the two different valleys. Intrinsic superconductivity at high doping has been experimentally confirmed in several of these compounds. We calculate the effect of impurities on the superconducting phase diagram of transition metal dichalcogenide monolayers in the presence of an in-plane magnetic field [1]. Due to the strong intrinsic spin-orbit coupling, the upper critical field greatly surpasses the usual Pauli limit at low temperatures. We find that it is insensitive to intravalley scattering and, ultimately, limited by intervalley scattering. Support by the Laboratoire d'excellence LANEF in Grenoble (ANR-10-LABX-51-01) is acknowledged. [1] S. Ilic, J.S. Meyer, and M. Houzet, preprint arXiv:1705.01865.

# Role of Strain for Manipulating Valley-Isospin in Graphene Nanoribbons

## Myoung Nojoon

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For graphene nanoribbons, the quantum Hall conductance across a p-n junction is characterized by an angle between valley-isospins on each edge. The valley-isospin in graphene nanoribbons is clearly described in Bloch sphere: valley-polarized isospin for zigzag edges and valley-mixing isospin for armchair graphene nanoribbons. In particular, armchair graphene nanoribbons exhibits three-fold quantum Hall conductance according to geometric phases which are determined by their electronic states (metallic or semiconducting). In this study, we demonstrate that local strain in armchair graphene nanoribbons affects the valley-isospin dependence of the quantum Hall conductance across a p-n junction, by causing a rotation of the valley-isospin in Bloch sphere. Moreover, the manipulation of the valley-isospin exhibits a dependence on how the local strain is oriented with respect to the p-n junction interface. We also examine effects of the strain-induced localized states on the quantum Hall conductance, resulting in Fano-type resonances with a possibility of having spin-polarized transport.

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# Electron-state Tuning of MoS2 Thin Film by Electrostatic and Chemical Doping

## Nguyen Thanh Cuong

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Molybdenum disulfide (MoS<sub>2</sub>) has been attracted a lot of research interests because of its two-dimensional layer structure, intrinsic band-gap, and optical properties. Recent experiments observed the superconductivity in this insulator material at a transition temperature of 11 K, by using the electrostatic electron doping technique [1]. However, the mechanism of this superconductivity behavior is still unclear. Therefore, in this work, we investigate the electronic structure of MoS<sub>2</sub> ultrathin film under electrostatic or chemical doping based on the first-principles total-energy calculations [2]. Under the electrostatic electron or chemical doping, we find that the unoccupied nearly-free-electron (NFE) states shift downward, and finally crosses the Fermi level due to the strong electric field induced by accumulated charge near the surface. Because of this shift to lower energy due to electrostatic or chemical doping, the NFE state acts as the conducting channel for the injected carrier. These results indicate that the free-electron-like carriers play crucial roles in determining the superconductivity properties of MoS<sub>2</sub>, as in the case of intercalated graphite materials. [1] J. T. Ye et al., Science 338, 1193 (2012). [2] N. T. Cuong, M. Otani, S. Okada, J. Phys: Condens. Mater 26, 135001 (2014).

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# Graphene high frequency devices for flexible application

## Pallecchi Emiliano

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Graphene is considered a promising material for high frequency devices because of the high saturation velocity, the broadband optical adsorption, and the high mechanical robustness. In this work, we focus on graphene based field effect transistors (GFETs) for flexible applications. Large scale graphene obtained by chemical vapor deposition (CVD) is used as a channel material for back-gated GFETs realized on Kapton. We fully characterize the graphene and the devices performances from DC up to 67 GHz, the devices show state of the art extrinsic performances, with  $f_t/f_{max}$  up to 39/16 GHz. The performances are stable against static bending, moreover the cutoff frequencies' variations remain below 15% even after a fatigue test consisting of 1000 bending cycles. Finally, we highlight the importance of thermal effects by measuring infrared temperature mapping for different devices under bias. These results on state of the art flexible GFETs demonstrates mechanical robustness and stability upon heating, two important elements to assess the potential of GFETs for flexible electronics. reference: W Wei et al. Nanoscale 8 (29), 14097-14103

# Fabrication of atomically flat silicon carbide surface using catalyst-referred etching (CARE)

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A silicon carbide (SiC) has been attracting attention as a material for graphene formation as well as next generation high performance power devices. For these purposes, an atomically flat surface is highly required. In this presentation, we introduce a novel polishing technique called catalyst-referred etching (CARE) which is a chemical polishing method using catalytic reaction and the result of realizing an atomically flat surface of the SiC substrate using CARE process.

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## Quantum Transport along PN-Junctions in Ballistic Graphene

Schönenberger Christian

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We report on our recent experiments in ballistic graphene pn-junctions. Ultraclean graphene is obtained either by suspension [1] or by encapsulation with h-BN [2]. The pn-junctions are formed by electrostatic gating using bottom and/or top gates. All devices show Fabry-Perot oscillations over the whole device size proofing the ballistic nature of electron transport [3]. Since in encapsulated graphene a superlattice can form, secondary Dirac points may appear. We first show that a Fabry-Perot cavity can also be formed by interfaces defined by these satellite Dirac points that mimic a pn-junctions [4]. We compare visibility and gate-defined cavity lengths in these 'secondary' Fabry-Perot cavities. Next, we will focus on transport in magnetic field. At a sufficiently large magnetic field, or small enough carrier density, discrete and localized Landau levels form in the bulk, whereas compressible chiral channels propagating along the edges of the graphene device appear. Due to the reversed chirality between the n and the p region, the edge states arriving from the n and p side at the p-n junction 'combine' to form a conducting channel along the pn-junction, connecting the lower and upper edge. Since the density-of-state goes through zero at the p-n junction, one only has to consider the lowest energy Landau levels. Since there are two channels that arrive from the n and p side to the pn-junction, say at the bottom edge, there are also two each leaving on the top edge. Along the pn-junction there are obviously then at most four channels. The maximum conductance from source to drain corresponds to the full transmission of the incoming populated channels and is therefore equal to  $2e^2/h$ . There have been contradicting observations recently. Oscillations in conductance along a pn-junction in magnetic field were assigned to the appearance of snake-states, which is a classical description of the cyclic motion of an electron wave package along the junction in magnetic field [5], or to Mach-Zehnder like interference [6,7]. The latter occurs naturally if the four-fold degenerate quantum channel along the pn-junctions is lifted in energy, e.g. due to electron-electron interaction and/or Zeeman energy, yielding four channels that are specially separated. What is quite remarkable in our experiment is that we observe both the Mach-Zehnder and 'snake-state'-oscillations simultaneously on the same sample. Moreover, we observe a third quantum transport phenomena, also a sort of oscillation, which is very pronounced [8]. We see that the conductance between source and drain modulates with the position of the pn-junction, which can be moved by changing the gate voltages appropriately, by a large amount of order  $e^2/h$ . We interpret this observation as a signature of isospin polarization at the edges. The two-fold degenerate edge state has a particular isospin configuration depending on the atomic structure of the edge. This isospin changes sign at the pn-junction on the same edge. Depending whether the top and bottom edge have the same or a different edge configuration the conductance will be large (maximal) or small (zero, if the two isospin states are orthogonal). The experimental observation is supported by quantum-transport calculations. While the explanations for the three (different) phenomena seem plausible, it would still be good, if one could describe all on the same footing with one single theory. References [1] R. Maurand, P. Rickhaus, P. Makk, S. Hess, E. Tovari, C. Handschin, M. Weiss, and C. Schönenberger, Fabrication of ballistic suspended graphene with local-gating, Carbon 79:486-492 (2014). [2] C. R. Dean et al., Boron nitride substrates for high-quality graphene electronics, Nature Nano, 5, 722 (2010). [3] P. Rickhaus, R. Maurand, M. Weiss, C. Schönenberger, Ming-Hao Liu, and K. Richter, Ballistic interferences in suspended graphene, Nature Comm. 4, 2342 (2013). [4] C. Handschin, P. Makk, P. Rickhaus, M.-H. Liu, K. Watanabe, T. Taniguchi, K. Richter, C. Schönenberger, Fabry-Pérot Resonances in a Graphene/hBN Moiré Superlattice, Nano Lett. 17, 328 (2016). [5] P. Rickhaus, P. Makk, Ming-Hao Liu, E. Tóvri, M. Weiss, R. Maurand, K. Richter and C. Schönenberger, Snake trajectories in ultraclean graphene p-n junctions, Nature Comm. 6, 6470 (2015). [6] S. Morikawa, S. Masubuchi, R. Moriya, K. Watanabe, T. Taniguchi, T. Machida, Appl. Phys. Lett. 106, 183101 (2016). [7] Di S. Wei, T. van der Sar, J. D. Sanchez-Yamagishi, K. Watanabe, T. Taniguchi, P. Jarillo-Herrero,

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## Lower critical dimension of the symplectic symmetry class in the Anderson localisation problem: Borel-Pade re-summation of the beta-function.

Slevin Keith

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In a previous work [1], we presented evidence that there is an Anderson transition below two dimensions in the symplectic universality class. Recently, this problem is the subject of renewed attention [2]. In a previous work [3], we have shown that the estimates of the critical exponent obtained in the non-linear sigma model formulation of the localisation problem are dramatically improved by incorporating in the Borel-Pade re-summation of the epsilon expansion for the critical exponent the asymptotic behaviour in high dimensions. In this paper [4], we will discuss the application of the Borel-Pade re-summation method directly to the beta functions of the Wigner-Dyson classes of the Anderson localisation problem. Examining the dimensionality dependence of the beta function allows us to estimate the lower critical dimension of the symplectic symmetry class. [1] Y. Asada, K. Slevin, and T. Ohtsuki, Physical Review B 73, 041102 (2006). [2] D. Sticlet and A. Akhmerov, Physical Review B 94, 161115 (2016). [3] Y. Ueoka and K. Slevin, Journal of the Physical Society of Japan 83, 084711 (2014). [4] Y. Ueoka. 2016. Some fundamental studies of critical phenomena of the Anderson transition in the Wigner-Dyson universality class. PhD thesis, Osaka University.

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## Unusual Shubnikov-de Haas oscillations in $\alpha$ -(BEDT-TTF) $\text{I}_3$ organic metal

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Most of the materials studied by the physics of the condensed matter are composed of massive fermions which verify usual parabolic dispersion relations. Since the 2000s, with the discovery of the graphene, the physics of the condensed matter face the emerging of new materials having a linear dispersion relation: the Dirac materials. It is the case of the  $\alpha$ -(BEDT-TTF) $\text{I}_3$  organic conductor (afterward, denoted  $\alpha\text{I}_3$ ), under high hydrostatic pressure ( $P \approx 1.5\text{GPa}$ ). Contrary to the case of the purely two-dimensional graphene, the three-dimensional bulk structure of the  $\alpha\text{I}_3$  compound allows to sound a physics much closer to the Dirac point. However, the coexistence of massive and Dirac fermions within the  $\alpha\text{I}_3$  compound makes this physics particularly complex, but also rich and surprising. The Shubnikov-de Haas oscillations (semi-classical oscillations of the magnetoresistance) in  $\alpha\text{I}_3$  under high pressures and very low temperatures (about  $2\text{GPa}$  and  $200\text{mK}$ ) are totally unusual. Indeed, if the periodic behavior in  $1/B$  of these oscillations at low magnetic fields is well known and understood, it is not the case for the deviation from this behavior, which appears at higher magnetic fields ( $> 10\text{T}$ ). Similar but less pronounced results have been observed very recently in kind of topological insulators samples. We interpret this anomaly with an original theoretical model.

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## Generation and detailed evaluation of spin-orbit interaction in graphene induced by transition metal dichalcogenides

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Spin-orbit interaction (SOI) is an essential building block for novel quantum phenomena such as spin Hall effect or topologically nontrivial states. When applied to two dimensional materials, it can drive graphene into the two-dimensional (2D) topological insulator (quantum spin Hall (QSH) insulator) as first pointed out by Kane and Mele.

However, intrinsic SOI in graphene is much smaller than the value assumed in this first theoretical study, and it makes difficult to realize the QSH state in graphene. In this study, we demonstrate large enhancement of SOI in graphene by means of graphene-transition metal dichalcogenide (TMD) heterostructures. TMDs are also 2D materials similar to graphene, and they have strong intrinsic SOI. In our study, we use MoS<sub>2</sub>, WSe<sub>2</sub> and WS<sub>2</sub>, as TMDs, and measure magnetoresistance of graphene in proximity to these TMDs. We observe weak-antilocalization behaviors for both samples at low temperatures, a clear signature of induced SOI in graphene. We compare the induced SOI in graphene with different TMDs, and interestingly, we find that induced SOI is stronger with MoS<sub>2</sub> than that with WSe<sub>2</sub>, opposite to the intrinsic amplitude of SOI in these TMDs. We also investigate the symmetric (Kane-Mele type) and asymmetric (Rashba type) contribution to SOI. From the detailed analysis we can draw the conclusion that symmetric SOI is much more dominant in Graphene/MoS<sub>2</sub> than the asymmetric one, whereas in Graphene/WSe<sub>2</sub> structure these two contributions are almost comparable. Large symmetric SOI induced in graphene with MoS<sub>2</sub> is promising to exhibit the QSH state. Our findings on introduction of SOI in graphene reveal that graphene can be a promising material for the QSH state and also spintronics.

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## Charge transport and low frequency noise in bilayer graphene

### Yeh Sheng-Shiuan

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We have measured charge transport and low frequency noise in several bilayer graphene devices. We found that the conductivity as a function of temperature can be described by the two-dimensional Mott variable-range hopping (VRH) at various back gate voltages. This implies the existence of localized states within the electric-field-induced band gap. On the other hand, in contrast to monolayer graphene, we found that the noise magnitude reveals a minimum value around the charge neutrality point (CNP), and increases as the gate voltage is swept away from CNP. The noise behavior can be understood in terms of the transport properties. The consistency between transport and noise characteristics provides a unified understanding of the underlying mechanism. This may be helpful to develop low-noise nanoelectronics based on bilayer graphene.

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## 6 High frequency Transport and Noise

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### High frequency emission of a carbon nanotube in the Kondo regime: quantum noise and AC Josephson effect

Delagrang Raphaëlle

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The Kondo effect is a many body phenomenon that results from the interaction between a localized impurity and the conduction electrons in a metal. Quantum dots are famous realization of Kondo effect, in which it is possible to probe the Kondo resonance out of equilibrium and its competition with superconductivity if the quantum dot is contacted with superconducting leads. While dc properties of the Kondo effect have been widely studied, its ac behavior is less understood. In this work, we investigate high frequency transport in a carbon nanotube quantum dot, by coupling it to an on-chip quantum detector through a micro-wave resonator with a resonance frequency of the order of the Kondo temperature [1]. We have investigated the emission noise at frequencies where the Kondo effect may be affected, either due to its dynamics or by out of equilibrium effects, in two different situations. In the first one, we have investigated the influence of the asymmetry on quantum noise measured in a nanotube contacted by normal electrodes. The measurements show the existence of a high frequency cutoff of the electronic emission noise related to the Kondo resonance. This cutoff frequency is of the order of a few time the Kondo temperature when the electronic system is close to equilibrium, which is the case when bias is strongly asymmetrical. On the other hand this cutoff is strongly depressed to lower frequency by out-of-equilibrium decoherence effects, occurring in a symmetrical

bias situations where the Kondo resonance is strongly split [2]. In the second situation, the nanotube is contacted to superconducting reservoirs, allowing to investigate the AC Josephson emission in the Kondo regime thanks to its interplay with the superconducting proximity effect. We show that, while the dc supercurrent is enhanced thanks to the interplay between the Kondo and superconducting correlations, the ac Josephson emission is strongly suppressed. [1] J. Basset et al., PRL 108, 046802 (2012) [2] R. Delagr ange, J. Basset, H. Bouchiat, R. Deblock, in preparation (2017)

## **”0.7 anomaly” in the confined quantum coherent conductor controlled by high frequency oscillation voltage**

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Quantum point contacts (QPCs), which are the basic building blocks of any mesoscopic structure, display quantized conductance, reflecting the quantization of the number of transparent channels. An additional feature, named the ”0.7 anomaly”, has been observed in almost all QPCs. However, its origin is still of intensive debate in the last couple of decades. Proposed theoretical explanations have evoked spontaneous spin polarization[1], ferromagnetic spin coupling[2], the formation of a quasi-bound state leading to the Kondo effect[3], Wigner crystallisation[4] and various treatments of scattering[5]. Here we experimentally study the GHz complex admittance in the quantum coherent conductor formed in the AlGaAs/GaAs heterostructure. Quantized conductance steps together with an extra plateau around  $0.7 \times 2e^2/h$  are observed on both real and imaginary parts of the admittance. Especially, the evolution of this additional plateau can be clearly seen when the conducting channel is moved to either side, away from the center of the QPCs, by biasing the side gates by different  $\phi V_g$ . Finally, the 0.7 plateau disappears as the entrance and exit barrier potentials become increasingly asymmetric. Motivated by the experimental results, we consider the existence of impurities in the one-dimensional channel formed by the split gates, theoretical calculations find that this anomaly depends strongly on the impurity positions and the strength of impurity potential. Both experiment and theoretical investigations prove that the ”0.7 anomaly” is very sensitive to external electrostatic potentials and impurities. Therefore the QPC’s confining potential and existence of impurities may have to be considered for a full understanding of conductance through QPCs and related quantum devices. Reference [1] D. J. Reilly, T. M. Buehler, J. L. O’Brien, A. R. Hamilton, A. S. Dzurak, R. G. Clark, B. E. Kane, L. N. Pfeiffer, and K. W. West, Phys. Rev. Lett., 89, 246801 (2002) [2] K. Aryanpour and J. E. Han, Phys. Rev. Lett., 102, 056805 (2009) [3] M. J. Iqbal, R. Levy, E. J. Koop, J. B. Dekker, J. P. de Jong, J. H. M. van der Velde, D. Reuter, A. D. Wieck, R. Aguado, Y. Meir and C. H. van der Wal, Nature 501, 79 (2013) [4] K. A. Matveev, Phys. Rev. B, 70, 245319 (2004) [5] K. M. Liu, V. Umansky, and S. Y. Hsu, Phys. Rev. B, 81, 235316 (2010)

## **Shot Noise Induced by Nonequilibrium Spin Accumulation**

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In 1918, Schottky showed that the electric flow in a vacuum tube fluctuates and the resulting current noise spectral density is proportional to the unit of charge and to the mean current. This is the shot noise, the direct result of the discreteness of the electron charge. As an electron possesses spin as well as charge, one may ask how the discreteness of electron spin affects the current fluctuation. Although such ”spin shot noise” has been discussed theoretically in various contexts [1-6], it has never been proven experimentally. Here we demonstrate the detection of shot noise induced by nonequilibrium spin accumulation in a lateral all-semiconductor spin valve device. This proves the relevance of the above concept of spin shot noise [7]. By using the Landauer-B uttiker formalism, we successfully extracted charge and spin currents and charge and spin noise and found that the spin degree of freedom is preserved in electron tunneling. Recently, we discuss the dynamics of the spin current in the high-frequency quantum regime [8]. Given the importance of shot noise in various fields, especially in device technology and mesoscopic physics, spin shot noise could serve as a unique probe to explore nonequilibrium electron transport. I appreciate my collaborators of this work, T. Arakawa, J. Shiogai, M. Kohda, J. Nitta, M. Ciorga, M. Utz, D. Schuh, D. Bougeard, D. Weiss and T. Ono. References [1] E. G. Mishchenko, Phys. Rev. B 68, 100409 (2003). [2] W. Belzig, and M. Zareyan, Phys. Rev.

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## Full Counting Statistics of Electron Tunneling in Coulomb-Blockade Devices

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Tunneling of electron into or out of Coulomb-blockade devices such as semiconductor quantum dots or metallic single-electron boxes is a stochastic process that gives rise to both thermal and shot noise. Recent progress in nanotechnology has made it possible to monitor the tunneling in and tunneling out events individually. This allows one to study the full counting statistics (FCS) of electron tunneling both in equilibrium and nonequilibrium and as a function of time. In this talk, we will show how the FCS can be used to acquire information about the system that is inaccessible from measuring the average transferred charge only. In particular, we will demonstrate how so-called generalized factorial cumulants indicate the presence of interaction [1]. In the limit of short measuring intervals, the factorial cumulants directly reveal correlated tunneling events of two electrons in Andreev-reflection processes [2]. They, furthermore, are suitable tools to detect violation of detailed balance in a stochastic system [3]. We also introduce the concept of inverse counting statistics [4] which seeks at identifying a stochastic system from a few measured factorial cumulants only. Finally, we present results of recent experiments that were successfully analyzed with the help of factorial cumulants.

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## Quantum conductors as non-classical light emitters

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Hybrid architectures integrating mesoscopic conductors in microwave cavities have a great potential for investigating unexplored regimes of electron-photon coupling. Quantum circuits can thus be tailored to significantly increase the effective fine structure constant which characterizes matter-light interaction. In this context, producing nonclassical radiation, such as a squeezed vacuum state, is a key step towards quantum communication with scalable solid-state devices. We will discuss how a tunnel junction is able to generate a squeezed steady state in a microwave cavity when excited parametrically by a classical AC voltage source. Photon-assisted tunneling of electrons is accompanied by the emission of pairs of photons in the cavity, thereby engineering a driven squeezed state. The mechanism leading to squeezing differs from parametric amplifiers as it is steered by dissipation. For a tunnel junction, we show theoretically that squeezing can be optimized by a pulse shape consisting of a periodic series of delta peaks. Squeezing is generally enhanced by non-linearities. We also find perfect squeezing in the case of a tunnel junction affected by a strong dynamical Coulomb blockade environment.

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## Charge- and energy noise in ac-driven conductors and their detection from frequency-resolved potential- and temperature fluctuations

Splettstoesser Janine

Splettstoesser Janine <sup>(1)</sup>, Dashti Nastaran <sup>(1)</sup>, Misiorny Macej <sup>(1)</sup>, Samuelsson Peter <sup>(2)</sup>, Battista Francesca <sup>(3)</sup>, Haupt Federica <sup>(4)</sup>

The time-dependent driving of nanoscale conductors allows for the controlled creation of single-electron excitations. This effect has been demonstrated experimentally both by application of time-dependent driving to gates coupled to confined systems, such as quantum dots [1], and by specifically shaped ac-driving of two-dimensional conductors [2,3]. However, the spectral properties of the injected signal are in general not known; moreover, the particle emission goes along with the excitation of electron-hole pairs with some unknown energy distribution. These issues can be addressed by studying fluctuations in the detected currents: not only do such fluctuations provide more insight into how to increase the precision of the single-particle emission, but also they allow for obtaining more information about the character of the emitted signal.

Here, I will present a theoretical study of charge and energy currents and their fluctuations in coherent conductors driven by different types of time-periodic bias voltages, based on a scattering matrix approach [4,5]. Specifically, we investigate the role of electron-like and hole-like excitations created by the driving in the charge current noise, where they only contribute separately. In contrast, additional features due to electron-hole correlations appear in the energy noise. We then compare two different types of driving schemes [6], that is for a driven mesoscopic capacitor [1] as well as for a Lorentzian-shaped bias voltage [3], which do not differ in the number of injected particles, but only in their energetic properties. Finally, I will discuss proposals for the detection of charge and energy noise, either through power fluctuations [4], or via frequency-dependent temperature and electrochemical-potential fluctuations in a probe reservoir [7].

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## 7 Quantum Dots and Nanowires

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### Multiscale modeling of optical and transport properties of nanostructures and low-dimensional materials

Chang Yia-Chung

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Computation methods including density-functional theory (DFT), tight-binding (TB) as well as effective bond-orbital model (EBOM), and k.p model for calculation of optical and transport properties of solids and nanostructures and low-dimensional materials (including quantum wires, quantum dots, and other low-dimensional materials) will be discussed. Transport properties of nanostructure junctions modeled by non-equilibrium Green function method in the Coulomb-blockade regime will also be presented. Examples include optical excitations of solids and nanostructures including the electron-hole interaction obtained within symmetry-adapted basis, time-dependent DFT calculations of optical excitations of semiconductor alloys, and tunneling current spectra as well as thermoelectric characteristics of coupled-quantum dot junctions. A mixed basis approach based on density functional theory (DFT) is also employed for studying one- and two-dimensional systems such as carbon-dimer chain, carbon nanotube, graphene, graphene nanoribbon, semiconductor surfaces, and MoS<sub>2</sub> sheets. The basis functions are taken to be plane waves for the periodic direction multiplied by B-spline functions in the non-periodic direction. B-splines are localized real-space functions, which are low-order polynomials, possessing easy treatment for derivatives. They are flexible, making the geometry optimization easy to implement. With this mixed basis set we can calculate the total energy of a finite-width slab or wire with finite cross-section directly without resorting to the supercell as in the conventional plane-wave based DFT code. One advantage of the mixed-basis code is the easy treatment of charged systems such as positively charged carbon-dimer chain. The spurious Coulomb interaction between the charged defect and its repeated images which appear in the supercell approach can thus be avoided.

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## Strong Correlation Effects in Nanostructure: Theory and Experiment

Choi Mahn-Soo <sup>(1)</sup>

1 - Department of Physics, Korea University (South Korea)

Nanostructures have attracted great attention for the fundamental strong correlation physics as well as nanoscale device applications due to its high and accurate tunability. In this talk, after very briefly reviewing major developments in the field, we introduce a new theoretical finding about the mixed-valence quantum phase transition and an direct experimental probe of the frozen charge at the Kondo resonance. We first study the triad interplay of the Kondo effect, superconductivity, and ferromagnetism, any pair of which compete with and suppress each other. We find that the interplay leads to a mixed-valence quantum phase transition, which is usually a crossover rather than a true transition. The singlet side of the phase diagram is characterized by unexpected Andreev reflection in the fully spin polarized ferromagnetic lead. We later report the direct observation of the frozen charge state at the Kondo resonance using the circuit QED architecture. We couple a quantum dot to a high finesse microwave cavity to measure with an unprecedented sensitivity the dot electronic compressibility. Because it corresponds solely to the charge response, this quantity is not equivalent to the conductance which involves in general other degrees of freedom such as spin. By performing dual conductance/compressibility measurements in the Kondo regime, we uncover directly the charge dynamics of this peculiar mechanism of electron transfer. Strikingly, the Kondo resonance, visible in transport measurements, is 'transparent' to microwave photons trapped in the high finesse cavity. This reveals that, in such a many body resonance, finite conduction is achieved from a frozen charge. This previously elusive freezing of charge dynamics is in stark contrast with the physics of a free electron gas. Our setup highlights the power of circuit QED architectures to study condensed matter problems.

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## Non-equilibrium Noise and Symmetry of the Kondo effect

Ferrier Meydi

Ferrier Meydi <sup>(1)</sup>, Arakawa Tomonori <sup>(2)</sup>, Hata Tokuro <sup>(2)</sup>, Delagrangé Raphaëlle <sup>(3) (4)</sup>, Deblock Richard <sup>(4)</sup>, Sakano Rui <sup>(5)</sup>, Teratani Yoshimichi <sup>(6)</sup>, Oguri Akira <sup>(6)</sup>, Kobayashi Kensuke <sup>(2)</sup>

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Most of the time, electronic excitations in mesoscopic conductors are well described, around equilibrium, by non-interacting Landau quasi-particles. This allows a good understanding of the transport properties in the linear regime. However, the role of interaction in the non-equilibrium properties beyond this regime has still to be established. A paradigmatic example is the Kondo many body state, which can be realized in a carbon nanotube (CNT) quantum dot. As CNT possess spin and orbital quantum numbers, it is possible to investigate the usual twofold degenerate  $SU^{(2)}$  Kondo effect as well as the four fold degenerate  $SU^{(4)}$  state by tuning the degeneracies and filling factor. Combining transport and current noise measurements in such a dot, we have identified the  $SU^{(2)}$  and  $SU^{(4)}$  Kondo states [1]. Our experiment shows that, a two-particle scattering process due to residual interaction emerges in the non-equilibrium regime. The effective charge  $e^*$ , which characterizes this peculiar scattering, is determined to be  $e^*/e = 1.7 \pm 0.1$  for  $SU^{(2)}$  and  $e^*/e = 1.45 \pm 0.1$  for  $SU^{(4)}$ , in perfect agreement with theory [2]. This result demonstrates that current noise can detect unambiguously the many-particle scattering induced by the residual interaction and the symmetry of the ground state. In addition, we managed to induce a continuous transition from  $SU^{(4)}$  to  $SU^{(2)}$  with the magnetic field, which allowed us to monitor the evolution of the fundamental properties (transmission channels and effective charge) along this quantum crossover [3]. [1] Ferrier et al, Nat. Phys. 12, 230-235 (2016) [2] C. Mora et al, Phys. Rev. B 80, 155322 (2009); R. Sakano et al, Phys. Rev. B 83, 075440 (2011) [3] Ferrier et al, Phys. Rev. Lett. 118, 196803 (2017)

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## Are odd-parity states in Andreev Quantum Dots always a nuisance?

Goffman Marcelo

Goffman Marcelo <sup>(1)</sup>

1 - Quantronics Group (France)

An Andreev quantum dot (AQD) is a phase-biased superconducting weak link in which discrete Andreev bound states develop. In particular, a single-channel AQD accommodates one Andreev state that can be occupied by either zero, one or two quasiparticles. In a recent cQED experiment on one-atom weak links we demonstrated the coherent manipulation of the two-level system formed by the even states [1]. Moreover, as a common feature to other superconducting devices, the single-occupied state of the AQD was also observed. We have focused on the role of the odd state in the dynamics of the AQD and I will present our results on the time-domain study of the parity jumps observed due to quasiparticle poisoning. Although the odd states are spin-degenerate, the fact that they are long-lived states makes them appealing for a qubit. I will present our recent progress in the realization of a spin-AQD using a gated InAs-nanowire where degeneracy can be lifted by the combination of strong spin-orbit coupling and a Zeeman field. We show that quasi-ballistic weak links can be obtained, an important requirement to achieve single-spin manipulation. Work done in collaboration with P. Senat, P. F. Orfila, L. Tosi, P. Bertet, P. Joyez, D. Vion, D. Esteve, H. Pothier and C. Urbina from the Quantronics group and P.Krogstrup and J. Nygrd from Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, Denmark. [1] C. Janvier et al., ?Coherent manipulation of Andreev states in superconducting atomic contacts? Science 349, 1199 (2015), arXiv:1509.03961

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## Shot noise of a superconductor/nanotube junction in the $SU^{(2)}$ and $SU^{(4)}$ Kondo regime

Hata Tokuro

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When a quantum dot in the Kondo regime is connected to superconducting electrodes, interplay between the two many-body effects gives rise to a wide variety of transport properties [1, 2]. In a carbon nanotube quantum dot, Kondo effect presents two different symmetries:  $SU^{(2)}$  when the spin is the only degenerate degree of freedom and  $SU^{(4)}$  when spin and orbital momentum are degenerate [3]. Combining conductance and shot noise measurements, we have investigated the competition between Kondo effect and superconducting proximity effect in the unitary limit of the two different Kondo symmetries. Figure 1 shows symmetry is barely distinguishable in the normal state since conductance reaches the same unitary value  $2e^2/h$ [3]. However, we have demonstrated that both conductance and shot noise reveal the symmetry of the Kondo state in the superconducting state.  $SU^{(2)}$  conductance around zero bias is enhanced in the superconducting state, showing that transport takes place through a single perfect channel. However,  $SU^{(4)}$  conductance presents Multiple Andreev Reflections at voltages  $2D/n$ , demonstrating that transport occurs through two half transmitted channels ( $T_1=T_2=0.5$ ). We have also measured the shot noise, which shows a similar behavior and need further theoretical developments to be fully understood. References [1] M. R. Buitelaar, et al., Phys. Rev. Lett. 91, 5 (2003). [2] B. ?K. Kim, et al., Phys. Rev. Lett. 110, 076803 (2013). [3] M. Ferrier T. Arakawa, T. Hata, et al., Nature Physics 12, 230 (2016).

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## Not just an electron waveguide or quantum box - uncovering the structure of carbon nanotubes in transport

Hüttel Andreas

Hüttel Andreas <sup>(1)</sup>

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In all cases from an open quantum system to strong Coulomb blockade, transport measurements on single wall carbon nanotubes reveal fascinating insights into the molecular structure and the behaviour of the electronic wavefunction.

The primary Fabry-Perot interference pattern of electrons passing through a carbon nanotube reflects the distance of the contacts. However, this first-order picture does not take into account band structure or symmetry properties of the macromolecule. We demonstrate how the electronic interference pattern probes the graphene dispersion relation, and find that its details reflect the chirality of the specific nanotube at hand.

In the opposite limit of a single electron strongly confined to a quantum dot, we look at the eight lowermost single-particle quantum states. Their dispersion in a strong axial magnetic field demonstrates how through cross-quantization modification of the boundary conditions shifts the weight of the electron wavefunction. The field not just influences electronic properties but also the Franck-Condon coupling of vibrational side bands.

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## Imaging the Quantum Wigner Crystal of Electrons in One-Dimension

Ilani Shahal

Ilani Shahal <sup>(1)</sup>

1 - Weizmann Institute of Science (Israel)

The quantum crystal of electrons, predicted more than eighty years ago by Eugene Wigner, is still one of the most elusive states of matter. Experiments have searched for its existence primarily via measurements of macroscopic properties, but since these resemble those of non-interacting electrons, a clear-cut observation of this crystal is still lacking. In this talk, I will present our recent experiments that observe the one-dimensional Wigner crystal directly, by imaging its charge density in real space. To measure this fragile state without perturbing it, we developed a new scanning probe platform that utilizes a pristine carbon nanotube as a scanning charge detector to image, with minimal invasiveness, the many-body electronic density within another nanotube. The imaged density looks utterly different than that predicted by single-particle physics, but matches nicely that of a strongly interacting crystal, in which the electrons are ordered like pearls on a neckless. The quantum nature of the crystal emerges when we explore its tunneling through a potential barrier. Whereas for non-interacting electrons only a single electron should tunnel across the barrier, images of the density change upon tunneling show that in our system a small crystal tunnels collectively, involving the motion of multiple electrons. These experiments provide the long-sought proof for the existence of the electronic Wigner crystal, and open the way for studying even more fragile interacting states of matter by imaging their many-body density in real space.

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## Experimental mapping of the quantum phase diagram for the two-impurity Kondo effect

Lin Juhn-Jong

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1 - Institute of Physics, National Chiao Tung University (Taiwan), 2 - Department of Electrophysics, National Chiao Tung University (Taiwan)

Quantum phase transitions are governed by competing interaction parameters in the Hamiltonian of a physical system. They are of fundamental conceptual interest but nontrivial to realize experimentally. The two-impurity Kondo (2IK) effect provides an appealing system to verify theoretical predictions of an interesting and nontrivial quantum phase transition. In a conduction electron Fermi sea containing dilute spin- magnetic moments, the local magnetic moments can be fully screened by the spins of conduction electrons, leading to the Kondo-screened ground state at zero temperature. The local magnetic moments can also interact with each other, leading to a RKKY-coupled (e.g., local spin-singlet) ground state. Theory predicts that a quantum critical point separates these two ground states and evolves into a quantum critical regime at finite temperatures. We demonstrate that the experimental mapping of the quantum phase diagram for the 2IK effect is possible by using an Al/AlOx/Y tunnel junction system. In our design, a few yttrium atoms situating at the AlOx/Y interface can serve as spin- magnetic moments and cause the exotic Kondo effect with an induced magnetic quantum phase transition.

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## Tunable Quantum Criticality and Super-ballistic Transport in a 'Charge' Kondo Circuit

Pierre Frédéric

Pierre Frédéric <sup>(1)</sup>, Zubair Iftikhar <sup>(1)</sup>, Anthore Anne <sup>(1)</sup>, Mitchell Andrew <sup>(2)</sup>, Parmentier Francois <sup>(1)</sup>, Gennser Ulf <sup>(1)</sup>, Ouerghi Abdelkarim <sup>(1)</sup>, Cavanna Antonella <sup>(1)</sup>, Mora Christophe <sup>(3)</sup>, Simon Pascal <sup>(4)</sup>

1 - Centre de Nanosciences et de Nanotechnologies (France), 2 - University College Dublin (Ireland), 3 - Laboratoire Pierre Aigrain (France), 4 - Laboratoire de Physique des Solides (France)

The exotic 'quantum critical' physics that develops in the vicinity of quantum phase transitions is believed to underpin the fascinating behaviors of many strongly correlated electronic systems, such as heavy fermions and high temperature superconductors. However, the microscopic complexity impedes their quantitative understanding. Tunable circuits could circumvent this obstacle. With a device implementing a quantum simulator for the three-channel

'charge' Kondo model [1], we explored the rich strongly correlated physics in two profoundly dissimilar regimes of quantum criticality [2]. The universal scalings, both toward different low-temperature fixed points and along the multiple crossovers from quantum criticality, were observed. Notably, we demonstrated an unanticipated violation of the maximum conductance for ballistic free electrons, in agreement with novel numerical renormalization group calculations.

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## 8 Posters

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### Preparation and Characterization of Chitosan Coated Magnetic Nanoparticles

Asad Qudsia

Asad Qudsia , Javed Arshad <sup>(1)</sup>

1 - UET Taxila (Pakistan)

Magnetic nano-particles (MNPs) were prepared by using the co-precipitation method. In this method an aqueous solutions of ferric chloride hexahydrate ( $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ ) and ferrous chloride tetrahydrate ( $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$ ) were added with a base under an inert atmosphere, followed by the modification of the surface of (MNPs) with chitosan. The characterization of the prepared magnetic nanoparticles was performed by X-ray diffraction (XRD), SEM (scanning electron microscopy) and Fourier transform infrared spectroscopy (FTIR) analyses. The prepared MNPs have many potential applications in biomedicine including targeted drug delivery, magnetic resonance imaging (MRI), and magnetic hyperthermia etc.

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### Manifestation of fermi edge singularity in co-tunnelling regime

Borin Artem

Borin Artem <sup>(1)</sup>, Sukhorukov Eugene <sup>(2)</sup>

1 - University of Genva (Switzerland), 2 - University of Geneva (Switzerland)

The Fermi edge singularity (FES) is a prominent manifestation of the Coulomb interaction. It can be observed in a controllable way in systems consisting of quantum dot (QD) electrostatically coupled to the leads. The tunnelling density of states (DOS) in this case acquires an algebraic dependence on the energy of the level at QD with universal power determined by the scattering phases in the transport channels on the QD potential. In this work we study how FES affects higher-order tunnelling processes (co-tunnelling). Such set-up allows studying of the dependence of the DOS on two energy scales. The behaviour of the current through the QD on the energy of the QD level and on the bias between the leads obtained for the limit of large and small bias. As well as for the sequential tunnelling in these limiting cases DOS depends algebraically on both energy scales with new universal powers determined by the interaction.

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### The gigahertz complex admittance of a quantum R-L circuit in chiral edge channels

Chen Shuwei

Song Li <sup>(1)</sup>, Chen Shuwei <sup>(1)</sup>, Yin Jianzhuang <sup>(1)</sup>, Gao Jie <sup>(2)</sup> <sup>(1)</sup>

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We study experimentally the gigahertz complex admittance of a quantum R-L (an inductor L in series with a resistor R) circuit in the presence of magnetic field at 20 mK. Quantized conductance steps are observed on both real and imaginary parts of the admittance when the transmission of quantum point contact is changed. At low

magnetic fields, the transmission-independent phase of admittance has been observed which allows us to obtain the transit time of the electrons in quantum coherent conductor directly. We found that the admittance phase depends on the transmission of the quantum point contact when the magnetic fields are relatively high. Here, the Coulomb interaction plays a prominent role in the magnetic field dependence of the admittance phase. Hence, a current and charge conserving scattering theory[1,2] is provided to describe these experimental observation quantitatively. In addition, an admittance phase jumping is observed when the transmitted modes are changed. The theoretical model we proposed considered the effects of gate voltage, which is in good agreement with the experimental observations of admittance phase jumping. This experimental and theoretical investigation provide an ideal system to study quantum transport in gigahertz high frequencies, and it is useful to study quantum coherence effects in the time-dependent situations[3]. 1. M. Büttiker, Y. Imry, R. Landauer, and S. Pinhas, Phys. Rev. B 31 6207 (1985). 2. T. Christen and M. Büttiker, Phys. Rev. B 53 2064 (1996). 3. G. Fève, J. M. Berroir, and B. Plaçais, Physica E 76 12 (2016).

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## **Fermi-edge singularity and related interaction induced phenomena in multilevel quantum dots.**

Goremykina Anna

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1 - *Université de Genève (Switzerland)*

We study the manifestation of the non-perturbative effects of interaction in sequential tunnelling between a quasi-one dimensional system of chiral quantum Hall edge channels and a multilevel quantum dot (QD). We use the formal scattering theory approach to the bosonization technique to present an alternative derivation of the Fermi-edge singularity (FES) effect and demonstrate the origin of its universality. This approach allows us to address, within the same framework, plasmon assisted sequential tunnelling to relatively large dots and investigate the interaction induced level broadening. The results are generalised by taking into account the dispersion in the spectrum of plasmons in the QD. We then discuss their modification in the presence of neutral modes, which can be realised either in a QD with two chiral strongly interacting edge channels or in a three dimensional QD in the Coulomb blockade regime. In the former case a universal behaviour of the tunnelling rate is discovered.

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## **Formalism of temperature-driven adiabatic charge pumping via a single level quantum dot in coherent transport region**

Hasegawa Masahiro

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Recently, temperature-driven adiabatic pumping induced by reservoir parameters, i.e. temperatures and electrochemical potentials, has been investigated from a viewpoint of nonequilibrium thermodynamics. However, temperature-driven pumping has mostly been formulated in quantum Master equation method[1], which is applicable in the weak system-reservoir coupling region. Such formalism cannot capture quantum effects induced by strong system-reservoir coupling, e.g. Kondo resonance. To clarify how such quantum effects affect temperature-driven pumping, we study temperature-driven adiabatic charge pumping via a single level quantum dot system in the strong system-reservoir coupling region[2]. We introduce thermomechanical field method to treat time-dependent reservoir temperatures. As the first step, we construct formalism of adiabatic charge pumping applicable to arbitrary strength system-reservoir coupling and Coulomb interaction. By our formalism, adiabatic charge pumping is described by Berry connection in driving parameter space and this Berry connection is found to be closely related to dynamic conductance. Also, by considering low frequency limit of the dynamic conductance, we clarify adiabatic pumping is understood in terms of delayed response of the quantum dot. [1] J. Ren, P. Hänggi and B. Li, Phys. Rev. Lett. 104, 170601 (2010). [2] M. Hasegawa and T. Kato, J. Phys. Soc. Jpn. 86, 024710 (2017).

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## **Coherent dynamics and mesoscopic capacitance oscillations in quantum coherent capacitors**

He Jianhong

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The dynamic transport properties of quantum coherent conductors are governed by a frequency dependent admittance [1], showing significant discrepancies with their dc properties [2]. We experimentally study capacitance oscillations in a quantum coherent capacitor, consisting of a gated double-dot coupled to an electron reservoir by a quantum point contact. By applying a gate voltage to the quantum point contact, the state of the system is changed from the weak coupling to completely transparent channel. For low transmissions, we observe a periodic modulation in the amplitude of capacitance oscillations without application of a magnetic field. The period of the amplitude modulation gives expression to the cyclic depopulation of each of the energy strips in the double-dot system. Furthermore, we find that the Coulomb blockade oscillations in capacitance persist for a single fully transmitting channel, which is in excellent agreement with the previous theoretical predication [3]. This oscillation behavior can therefore be considered as one of the remarkable manifestations of phase coherence [4] in dynamic transport, strongly depending on magnetic field and temperature. [1] M. Büttiker, H. Thomas, and A. Prtre, Phys. Lett. A 180, 364 (1993). [2] J. Gabelli, G. Fève, J.-M. Berroir, B. Plaçais, A. Cavanna, B. Etienne, Y. Jin, and D. C. Glattli, Science 313, 499 (2006). [3] M. Büttiker and S. E. Nigg, Nanotechnology 18, 044029 (2007). [4] S. Amasha, I. G. Rau, M. Grobis, R. M. Potok, H. Shtrikman, and D. Goldhaber-Gordon, Phys. Rev. Lett. 107, 216804 (2011).

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## Chiral Magnetic Effect in Weyl semimetals: the interplay of the bulk and the boundary

Ivashko Artem

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Weyl semimetals provide us an outstanding platform to probe the properties of three-dimensional relativistic massless electrons in condensed-matter setup. One of the theoretical predictions for such excitations that goes back to 1980 is the so-called Chiral Magnetic Effect. This effect lies in appearance of electric current proportional to the external magnetic field, but is known to vanish in thermal equilibrium. A simple and yet experimentally accessible way to probe the effect is to drive the system out of equilibrium is to make the magnetic field time-dependent. We attempt to resolve the controversy present in the literature regarding the value of the coefficient entering the expression for the current, and to clarify the contributions of the bulk and the boundary states therein. We confirm a recent surprising finding of [1] that the boundary states may dominate the current, and that their contribution survives in the limit of large sample sizes. At the same time, we find that the value of the coefficient is non-universal.

[1] P. Baireuther, J. A. Hutasoit, J. Tworzydło, C. W. J. Beenakker, New J. Phys. 18, 045009 (2016)

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## Magnetocapacitance oscillations in a mesoscopic RC circuit

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The dynamical response of mesoscopic conductors constitutes a mostly unexplored area of quantum transport. We here report on the measurements of the high frequency magnetoconductance of a mesoscopic RC circuit. The RC circuit consists of a quantum dot (QD) capacitively coupled to a macroscopic electrode on top of it and tunnel coupled to a wide two dimensional electron gas through a quantum point contact. The QD works in the quantum Hall regime, where two well separated compressible regions are formed. By varying the magnetic fields, electrons in the dot redistribute among these two regions. We found that this process could lead to magnetocapacitance oscillations. Using single electron magnetocapacitance spectroscopy, we can map the magnetic field dependence of the ground state energies of the QD.

## Damage-free dry etching processing of SiC substrates by using high-pressure plasma

Mukai Risa

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Silicon carbide (SiC) is a semiconductor material employed in manufacturing graphene, nanodevices, photonics materials, and so on. SiC substrates require perfect crystal quality and smooth surfaces to make them high quality. When SiC substrates are processed using mechanical processing methods, damaged layers are generated. It is difficult to remove these by conventional wet etching owing to their chemical inertness. To remove the damaged layers, we suggested plasma etching using high-pressure plasma; accordingly, we achieved damage-free surfaces with a high removal rate of more than 15 m/min, and smooth surfaces with a surface roughness of 1.71 nm (root mean square value).

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## Strain induced superconductivity of Li intercalated bilayer Boron Phosphide by first principles study

Nguyen Duc-Long

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Monolayer hexagonal Boron phosphide (BP) is a two dimensional narrow direct band gap semiconductor which has an ultra high carrier mobility [1]. Recent experimental and theoretical works show that Li intercalation can induce superconductivity of Black Phosphorous [2] and Graphene [3]. Using first principles calculation, we studied the strain induced superconductivity of Lithium intercalated bilayer BP. From electronic structure, lattice dynamic and electron-phonon coupling calculations, it is suggested that bilayer BP can transform from direct band gap semiconductor to phonon-mediated superconductor under Li intercalation [4]. The inference of tensile strain on superconductivity property of Li intercalated bilayer BP will also be presented. [1] M. Xie, S. Zhang, B. Cai, Z. Zhu, Y. Zou, and H. Zeng, *Nanoscale* 8, 13407 (2016). [2] R. Zhang, J. Waters, A. K. Geim, and I. V. Grigorieva, *Nature Communications* 8, 15036 (2017). [3] G. Profeta, M. Calandra, and F. Mauri, *Nature Physics* 8, 131 (2012). [4] D.L. Nguyen, C.R. Hsing, and C.M. Wei, *On preparation* (2017).

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## Overview of melting graphene nanoribbon

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The melting process of graphene nanoribbon (GNR) are studied via variation of sizes and edge types (armchair and zigzag). Different thermodynamic quantities have been devoted to study the mechanism of melting process. The results show that the phase transition has first order behaviour; the formation of different defects, ring sizes and coordination number is dependent on the size and the edge type of GNR; at the melting point, the system still remains honeycomb structure indicating that the melting of GNR in 2D space does not satisfy by classical nucleation theory; the melting state of GNR can contain the distorted honeycomb structure or the defects, but not simple liquid; the melting process also shows the case that the results of Berezinsky-Kosterlitz-Thouless-Nelson-Halperin-Young theory cannot be applied. Authors thank for financial support from the National Foundation for Science and Technology Development (NAFOSTED) under grant 103.01.2015.101.

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## Modeling Electrical Conductivity and Transfer Characteristics of n- and p-Type Graphene/MoS2 Hetero-structures

Nguyen Khoe

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Graphene being a gapless semimetal intrinsically has very high mobility but rather low on/off ratio. MoS<sub>2</sub> is an indirect semiconductor with a band gap of 1.2 eV, and it becomes a direct semiconductor with a bigger band gap of 1.9 eV when being exfoliated as a monolayer two-dimensional material. MoS<sub>2</sub> has much lower mobility but can reach rather higher on/off ratio than graphene. Therefore, they are expected to complement each other in their hetero-structures with high mobility and high on/off ratio. Here we present a model calculation of electrical conductivity and transfer characteristics of n- and p-type graphene/MoS<sub>2</sub> hetero-structures for different numbers of MoS<sub>2</sub> monolayers and, accordingly, of different types and values of the band gap, at various temperatures under a large range of gate voltages. Our model takes account of electron-phonon interactions and many-body effects. Our calculated results for I-V characteristics and carrier densities as functions of gate voltages agree rather well with the available experimental data with the use of a few physical parameters (including the band offset, defect scattering rates, and fraction of the applied gate voltage in the active region), which all fall into a reasonable range. Therefore, our approach can also be applicable to graphene/transition metal dichalcogenides (TMDs) hetero-structures.

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## Nanoprecision process for improving thickness uniformity of top silicon layer of silicon-on-insulator wafer by using a multi-electrode plasma generator

Okayama Shinya

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In order to use the silicon-on-insulator (SOI) wafer as the substrate in nanodevices, a very thin and uniform top silicon layer is required. We attempt to improve the silicon layer of commercially available SOI wafer via a numerically controlled thinning process by using atmospheric-pressure plasma. Furthermore, to realize a high-efficiency process, we developed a multi-electrode plasma generator capable of processing the entire surface of the wafer simultaneously, and succeeded in improving the P-V value of the thickness of silicon layer from 2.85 nm to 0.86 nm within about 10 min.

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## Entanglement negativity of a single-channel Kondo system

Shim Jeongmin

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Negativity is an entanglement measure applicable to thermal mixed states. Based on the numerical renormalization group (NRG) approach, we develop a method of computing the negativity between the impurity and the bath of a quantum impurity system. The computational cost is reduced exponentially by adopting the energy-scale separation structure of the NRG. We apply the method to the single-impurity Kondo model and the Anderson model, and find a power-law temperature dependence of the negativity near the Kondo-fixed point. The power-law exponent is 2, which is identical to the exponent [1] of the entanglement of formation. [1] S. S. B. Lee, J. Park, and H. S. Sim, Macroscopic Quantum Entanglement of a Kondo Cloud at Finite Temperature, Phys. Rev. Lett. 114, 057203 (2015)

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## Dynamics of Pure Spin Current in High-frequency Quantum Regime

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Pure spin current is a powerful tool for manipulating spintronic devices, and its dynamical behavior is an important issue. By using mesoscopic transport theory for electron tunneling induced by spin accumulation, we investigate

the dynamics of the spin current in the high-frequency quantum regime, where the frequency is much larger than temperature and bias voltage. Besides the thermal noise, frequency-dependent finite noise emerges, signaling the spin current across the tunneling barrier. We also find that the autocorrelation of the spin current exhibits sinusoidal oscillation in time as a consequence of the Pauli exclusion principle even without any net charge current.

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## Experimental mapping of the quantum phase diagram for the two-impurity Kondo effect

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Quantum phase transitions are governed by competing interaction parameters in the Hamiltonian of a physical system. They are of fundamental conceptual interest but nontrivial to realize experimentally. The two-impurity Kondo effect provides an appealing system to verify theoretical predictions of an interesting and nontrivial quantum phase transition. In a conduction electron Fermi sea containing dilute magnetic moments, the local magnetic moments can be screened by the spins of conduction electrons, leading to a Kondo-screened ground state at zero temperature. The local magnetic moments can also interact with each other, leading to a RKKY-coupled ground state. Theory predicts that a quantum critical point separates these two ground states and evolves into a quantum critical regime at finite temperatures. We demonstrate that the experimental mapping of the quantum phase diagram for the two-impurity Kondo effect is possible by using an Al/AlO<sub>x</sub>/M tunnel junction system with a selected transition metal M. In our design, a few M atoms situating at the AlO<sub>x</sub>/M interface act as local magnetic moments and cause the exotic Kondo effect with an induced magnetic quantum phase transition.

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## Non-Hermitian Floquet Topological Phase

Yuce Cem

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We study the existence of Floquet topological insulators for a class of non-Hermitian Hamiltonians. We consider an array of waveguide in 1D with periodically changing non-Hermitian potential and predict the existence of Floquet topological insulators in the system. We also extend the concept of Floquet topological phase to a two dimensional non-Hermitian system.

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