The 13th Capri Spring School on Transport in Nanostructures 2017

	Sunday 23.04.2017	Monday 24.04.2017	Tuesday 25.04.2017	Wednesday 26.04.2017	Thursday 27.04.2017	Friday 28.04.2017	Saturday 29.04.2017
Chair		Grabert	Schönenberger	Tagliacozzo	Egger	Bercioux	
9:00-9:55		DiVincenzo (1)	DiVincenzo (2)	DiVincenzo (3)	Altland (1)	Altland (2)	
10:00-10:55		Loss (1)	Loss (3)	Solano (1)	Eisert (1)	Eisert (3)	
11:00-11:30		Coffee Break					
11:30-12:25		Cleland (1)	Cleland (2)	Devoret (2)	Solano (2)	Cleland (3)	
13:00-16:00		Lunch Break					
Chair		Bercioux	Egger		De Martino	Grabert	
16:00-16:55		Loss (2)	Devoret (1)		Eisert (2)	Short Talks (3)	
17:00-17:30		Coffee Break			Coffee Break		
17:30-18:25	Registration Hotel Senaria	Shumeiko	Poster Session	Free Afternoon	Solano (3)	Devoret (3)	School excursion to Ercolano/ Sorrento (if weather permits) Start at 9 am, Capri Harbour Return by 6 pm
18:30-19:30	19:00-19:30	Short Talks (1)			Short Talks (2)	Concluding remarks & excursion information	
20:00 Dinner	Le Arcate	Il Solitario	Le Arcate		Le Arcate	Le Arcate	

Altland	Majorana surface codes
Cleland	Introduction to 2D surface codes
Devoret	Protecting Quantum Superpositions in Josephson Circuits
DiVincenzo	Hybrid devices for Quantum Information Processing
Eisert	Entanglement, tensor networks and topological order
Loss	From spin qubits to topological qubits in nanostructures
Solano	Novel paradigms for quantum simulations

Contributed Talks

Monday long (45+15)	Shumeiko	Quantum parametric phenomena in cavity QED
Monday Session (12+3)	Plugge	Majorana Box Qubits
	Munk-Nielsen	Dephasing of Majorana box qubits
	Dartiailh	Synthetic spin orbit interaction for Majorana devices
	Pendharkar	A materials perspective on 1D and 2D electron systems for topological quantum computation
Thursday Session (12+3)	Litinski	Combining Topological Hardware and Topological Software: Color Code Quantum Computing with Topological Superconductor Networks
	Iemini de Rezende Aguiar	Majorana Quasi-Particles Protected by Z2 Angular Momentum Conservation
	Ferguson	Spin coherent dot-cavity electronics
	Bouman	Magnetic field induced 4pi periodic Josephson effect in InAs nanowires
Friday Session (12+3)	Pelc	Transport properties of stacking domain walls in bilayer graphene
	Trifunovic	Bott periodicity for the topological classification of gapped states of matter with reflection symmetry
	David	Exchange Interaction for Double Quantum Dots on Transition Metal Dichalcogenides
	Bordoloi	Towards Synthetic Spin-Orbit Interaction in InAs Nanowires using Ferromagnetic Side Gates

Abstract short talks: Monday Session

From 17:30 to 18:25

Vitaly Shumeiko (Chalmers University of Technology) — *Quantum parametric phenomena in cavity QED*

I will discuss properties of parametric resonance in tunable superconducting cavity. The topics will be outlined: nonlinear amplification in degenerate and non-degenerate parametric regimes, parametric oscillations, noise squeezing, and frequency conversion.

Abstract short talks: Monday Session

From 18:30 to 19:30

Stephan Plugge (HHU Düsseldorf) — *Majorana Box Qubits*

We discuss quantum bits taking advantage of the topological protection and non-local properties of Majorana bound states in networks of parallel wires. The elementary unit is made from three topological wires, two wires coupled by a trivial superconductor and the third acting as an interference arm. Coulomb blockade of the combined wires spawns a fractionalized spin, non-locally addressable by quantum dots used for single-qubit readout, initialization, and manipulation. The same tools allow for measurement-based protected implementation of the Clifford gates, in total making the architecture universal. Proof-of-principle demonstration of topologically protected qubits using existing techniques is therefore within reach.

Morten Ib Munk-Nielsen (Niels Bohr Institute) — *Dephasing of Majorana box qubits*

A popular recent proposal for applying topological physics in quantum computation is the Majorana box qubit. Here two sets of Majorana bound states are situated on a Coulomb blockaded island. Together they constitute a two level system, and Pauli operations may be implemented by tunneling electrons through two of the four Majoranas. In this study we investigate how the state of the Majorana box qubits may decohere in the presence of a fluctuating potential.

Matthieu Dartiailh (LPA — École normale supérieure) — *Synthetic spin orbit interaction for Majorana devices*

The engineering of topological superconducting correlations in quantum devices hold promise for new schemes of quantum computation. A wide class of systems which are expected to exhibit such exotic states are based on conductors with strong spin-orbit interaction subject to a strong external magnetic field. Here, we show how these states can be autonomously induced by using a magnetic texture coupled to any quasi one dimensional conductor- a single wall carbon nanotube in our case. Our findings could be used for advanced experiments, including microwave spectroscopy and braiding operations.

Mihir Pendharkar (University of California Santa Barbara) — *A materials perspective on 1D and 2D electron systems for topological quantum computation*

III-V semiconductors have been fundamental to the prediction and subsequent realization of Majorana fermions which form the basis of topological quantum computation. This work focusses on the design, growth and low temperature characterization of superconductor-semiconductor hybrid 1D and 2D electron systems, hosting Majorana zero modes. Molecular Beam Epitaxy growth of highly spin orbit coupled InAs and InSb nanowires (1D) and quantum wells (2D), will be discussed. Coupled with in-situ evaporation of superconductors, these systems pave the way for realization of proposed braiding schemes, necessary for topologically protected quantum computation.

Abstract short talks: Thursday Session

From 18:30 to 19:30

Daniel Litinski (FU Berlin) — *Combining Topological Hardware and Topological Software: Color Code Quantum Computing with Topological Superconductor Networks*

We present a scalable architecture for fault-tolerant topological quantum computation using networks of voltage-controlled Majorana Cooper pair boxes, and topological color codes for error correction. 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. In this way, we establish color codes as the natural fit to topological superconductor networks, which enables the Majorana-based qubits to exploit the color code's software-based topological protection and still retain their hardware-based topological protection. We provide a complete description of our architecture, from the underlying physical ingredients to the arrangement of logical qubits for fault-tolerant quantum computation.

Fernando Iemini de Rezende Aguiar (The Abdus Salam Institute Centre for Theoretical Physics) — *Majorana Quasi-Particles Protected by Z_2 Angular Momentum Conservation*

We show how angular momentum conservation can stabilise a symmetry-protected quasi-topological phase of matter supporting Majorana quasi-particles as edge modes in one-dimensional cold atom gases. We investigate a number-conserving four-species Hubbard model in the presence of spin-orbit coupling. The latter reduces the global spin symmetry to an angular momentum parity symmetry, which provides an extremely robust protection mechanism that does not rely on any coupling to additional reservoirs. The emergence of Majorana edge modes is elucidated using field theory techniques, and corroborated with density-matrix-renormalization-group simulations. Our results pave the way toward the observation of Majorana edge modes with alkaline-earth-like fermions in optical lattices, where all basic ingredients for our recipe — spin-orbit coupling and strong inter-orbital interactions — have been experimentally realized over the last two years.

Michael Ferguson (Institute for theoretical physics ETHZ) — *Spin coherent dot-cavity electronics*

Spin-coherent transport in all electronic dot-cavity systems has been recently demonstrated in an experiment with a dot-cavity hybrid implemented in a high-mobility two-dimensional electron gas [Phys. Rev. Lett. **115**, 166603 (2015)]. Its spectroscopic signatures have been interpreted in terms of a competition between Kondo-type dot-lead and molecular-type dot-cavity singlet-formation. I will present a framework which can be used to provide guidelines for future device design as well as a thorough understanding of the underlying physics governing the singlet formation.

Daniel Bouman (TUDelft) — *Magnetic field induced 4π periodic Josephson effect in InAs nanowires*

Majorana zero modes in nanowires are promising candidates for topological quantum computing. Signatures other than zero-bias conductance peaks, have so far remained elusive in these systems. We report direct measurement of Josephson radiation from an InAs nanowire junction with an epitaxial Al shell by utilizing photon-assisted tunnelling through superconducting tunnel junctions capacitively coupled to the nanowire junction. We detect a 2π-periodic signal evolving into a 4π-periodic signal at increased magnetic field. The signals are measured as a function of chemical potential and transmission of the nanowire junction. We interpret these results using both topological and non-topological models.

Abstract short talks: Friday Session

From 16:00 to 16:55

Marta Pelc (Donostia International Physics Center) — *Transport properties of stacking domain walls in bilayer graphene*

We study the electronic transport in various realizations of stacking domain walls in gated bilayer graphene. We discuss the properties and the role in transport of the topologically protected states. Although they give no contribution to the conductance between the domains, they occur to be conducting channels along the boundary. We consider the smooth, defectless transitions on the example of the top layer corrugation, as well as connections through the grain boundaries with atomic-scale topological defects. In the second case the number of gap states depends on the gate polarization, yielding an asymmetric conductance along the boundary under gate reversal.

Luka Trifunovic (FU Berlin) — *Bott periodicity for the topological classification of gapped states of matter with reflection symmetry*

Using a dimensional reduction scheme based on scattering theory, we show that the classification tables for topological insulators and superconductors with reflection symmetry can be organized in two period-two and four period-eight cycles, similar to the Bott periodicity found for topological insulators and superconductors without spatial symmetries. With the help of the dimensional reduction scheme the classification in arbitrary dimensions $d \geq 1$ can be obtained from the classification in one dimension, for which we present a derivation based on relative homotopy groups and exact sequences to classify one-dimensional insulators and superconductors with reflection symmetry. The resulting classification is fully consistent with a comprehensive classification obtained recently by Shiozaki and Sato [Phys. Rev. B **90**, 165114 (2014)]. The use of a scattering-matrix inspired method allows us to address the second descendant Z_2 phase, for which the topological nontrivial phase was previously reported to be vulnerable to perturbations that break translation symmetry.

Alessandro David (University of Konstanz) — *Exchange Interaction for Double Quantum Dots on Transition Metal Dichalcogenides*

We study the properties of double quantum dots in Transition Metal Dichalcogenides (TMDCs) where trapped electrons comprise not only the usual spin and valley degrees of freedom, but also a spin-orbit splitting in the spectrum. The spin-orbit coupling splits the four-fold spin and valley degeneracy into two Kramers pairs with correlated spin and valley states. Our aim is to use such systems filled with only two electrons for quantum information processing. With a simple redefinition of Pauli matrices, we can obtain a CNOT gate in the same way it was obtained in the quantum computer proposed by Loss and DiVincenzo.

Arunav Bordoloi (University of Basel) — *Towards Synthetic Spin-Orbit Interaction in InAs Nanowires using Ferromagnetic Side Gates*

Semiconducting InAs nanowires (NWs) are ideal for electron spin control due to their large spin-orbit interaction (SOI) and g-factors. We present our progress on using Permalloy strips [1] as ferromagnetic side gates (FSGs) [2] to locally create magnetic (and electric) fields to induce electron spin rotations along a NW. Such close to helical magnetic fields are equivalent to a Rashba-type SOI, a key ingredient for Majorana and fractional fermions [3].

[1] J. Samm *et al.*, J. Appl. Phys. **115**, 174309 (2014)
[2] G. Fabian *et al.*, PRB **94**, 195415 (2016)
[3] J. Klinovaja *et al.*, PRL **19**, 236801 (2012)

Poster session

From 17:30 to 19:00

1. Carolin Gold (ETH Zürich) — *Scanning Gate Microscopy - Towards spatial imaging of electronic states in cavities?*
2. Michael Buchhold (University of Cologne) — *Absorbing state phase transition with competing quantum and classical fluctuations*
3. Arnau Sala (Norwegian University of Science and Technology) — *The exchange-only singlet-only spin qubit*
4. Shan Jolin (Royal Institute of Technology) — *Quantum correlations in microwave frequency combs*
5. Ananda Roy (RWTH Aachen University) — *Phase transitions in the Majorana toric code*
6. Olga Skryabina (Institute of Solid State Physics RAS) — *Superconducting devices based on single nanowires*
7. Jéssica Fernanda Da Silva Barbosa (CEA & University Paris Saclay) — *Strong Coupling of a Single Spin to a Superconducting Qubit*
8. Yong Lu (Chalmers University of Technology) — *Towards wideband tunable single photon source in microwave domain*
9. Winston Pouse (Stanford University) — *Two Impurity Kondo Physics with Quantum Dots*
10. Aleksandra Kulakova (Moscow Institute of Physics and Technologie) — *Fabrication of quantum phase-slip hybrid structures*
11. Katharina Kopper (University of Augsburg) — *Lévy walk-like diffusion in two dimensions: a Langevin approach*
12. Markus Heinrich (University of Cologne) — *Surface States in Holographic Weyl Semimetals*
13. Luca Petit (TUDelft) — *Universal quantum computation with silicon quantum dots operating up to 4K*
14. Max Hering (FU Berlin) — *Functional-renormalization-group analysis of Dzyaloshinsky-Moriya and Heisenberg spin interactions on the Kagome lattice*
15. Bogusz Bujnowski (DIPC) — *Coherent Exciton Transport in Bilayer Graphene*
16. Piotr Busz Institute of Molecular Physics, Polish Academy of Sciences) — *Spin Correlation and Entanglement Detection in Cooper Pair Splitters by Current Measurements Using Magnetic Detectors*
17. Max Hays (Yale University) — *Andreev bound states in semiconducting nanowire Josephson junctions*
18. Stephanie Matern (University of St. Andrews) — *Entanglement in 3D Kitaev Spin Liquids*
19. Pragya Shekhar (University of Wuerzburg) — *Non-Invasive Lithography of HgTe quantum wells*
20. Jelmer Boter (TU-Delft) — *QuTech-Intel collaboration towards large scale integration of spin qubits in silicon*