Scope:

The main focus of the symposium are Majorana modes and other topological low-energy excitations. The topics include the current evidence of Majorana modes in different systems, alternative interpretations of the experiments, novel topological phases, topological low-energy excitations beyond the Majorana modes, applications and different approaches for demonstration of the non-Abelian statistics.

Organizers:

Marcin Płodzień, Timo Hyart, Tomasz Dietl, Andrzej Wiśniewski.

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Majorana modes and beyond 2019

26-27.02.2018, IF PAN, Warsaw

Schedule

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11:00	**Coffee break**	10:45	Wojciech Brzezicki
Session 2.	*Chair: Alberta Bonanni*	**11:15**	**Coffee break**
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Session 3.	*Chair: Andrzej M. Oleś*	15:30	Oladunjoye Awoga
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Abstracts

1. **Tomasz Story** (26.02, 10:00)

   Affiliation: Institute of Physics, Polish Academy of Sciences, Poland

   Title: Topological states in IV-VI semiconductors

   Abstract:
   New class of 3D topological materials - topological crystalline insulators (TCI) – was experimentally discovered by angle- and spin-resolved photoemission spectroscopy (ARPES) and scanning tunneling spectroscopy (STS) techniques. In contrast to topological materials based on Bi and Sb chalcogenides, in TCIs the topological protection of surface electronic states is warranted not by time reversal but by crystalline (mirror-plane) symmetry [1]. The TCI states were found experimentally in IV-VI narrow-gap semiconductors $Pb_{1-x}Sn_xTe$ (x=0.3-1) and $Pb_{1-x}Sn_xSe$ (x=0.18-0.4) for (001) and (111) crystal surfaces of both bulk crystals and epitaxial layers [2-4]. These materials possess direct bulk energy gap at four L-points of the Brillouin zone and undergo a band inversion at specific Sn content and temperature. In the inverted bands regime one observes topological in-gap states with 4 surface Dirac cones. These topological states were also observed for (001) surface of bulk SnTe crystals in high magnetic field studies of Shubnikov - de Haas and de Haas - van Alphen quantum oscillations [5]. In very recent magnetoconductance studies of CdTe/SnTe/CdTe//GaAs (001) layered heterostructures the experimentally observed contribution of weak antilocalisation effect was assigned to topological/trivial SnTe/CdTe interface states [6]. Variety of new proposals involving IV-VI materials relies on layered quantum heterostructures and the effects of strain, hybridization or size quantization. It requires detailed knowledge of the topological states at realistic surfaces (with atomic steps or other defects) as well buried topological interface states. The unique electronic properties of atomic steps were demonstrated [7] with STM/STS technique, identifying 1D channel of high density electronic states along the odd-monolayer-high atomic steps at (001) surface of $Pb_{1-x}Sn_xSe$. By in-situ capping the TCI surface of $Pb_{0.7}Sn_{0.3}Se$ bulk crystal with an ultrathin topologically trivial layer of PbSe ARPES studies were carried out to demonstrate the robustness of Dirac cones at $Pb_{1-x}Sn_xSe$/PbSe interface and the important role of atomic steps that may induce a collapse of the pair of split Dirac cones into a single one [8]. Several theoretical proposals will be discussed that still await experimental confirmation: quantum spin Hall effect in IV-VI quantum well structures [9], Dirac or Weyl semimetallic phase [10], ferromagnetic TCI, and higher order topological insulator states [11].

   [1] T.H. Hsieh, H. Lin, J. Liu, W. Duan, A. Bansil, L. Fu, Nat. Commun. **3**, 982 (2012).
   [2] B.M. Wojek, P. Dziawa, B.J. Kowalski et al., Phys. Rev. B **90**, 161202(R) (2014).
   [3] I. Zeljkovic, Y. Okada, M. Serbyn et al., Nat. Mat. **14,** 318 (2015).
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   [5] K. Dybko, M. Szot, A. Szczerbakow et al., Phys. Rev. B **96**, 205129 (2017).
   [6] K. Dybko, G.P. Mazur, W. Wołkanowicz et al., arXiv:1812.08711.
   [7] P. Sessi, D. Di Sante, A. Szczerbakow et al., Science **354**, 1269 (2016).
   [8] C.M. Polley, R. Buczko, A. Forsman et al., ACS Nano **12**, 617 (2018).
   [9] S. Safaei, M. Galicka, P. Kacman, R. Buczko, New J. Phys. **17,** 063041 (2015).
   [10] A. Łusakowski, P. Bogusławski, T. Story, Phys. Rev. B **98** 125203 (2018).
   [11] F. Schindler, A.M. Cook, M.G. Vergniory et al., Sci. Adv. 4, eaat0346 (2018).

2. **Ryszard Buczko** (26.02, 10:30)

Affiliation: Institute of Physics, Polish Academy of Sciences, Poland

Title: Valley splitting of Dirac cones at topological/trivial semiconductor interface and at uneven (Pb,Sn)Se surface.

Abstract:
The family of IV-VI topological crystalline insulator (TCI) materials feature band inversions located away from the Brillouin zone center. The resulting possibility of both valley interactions and mirror symmetry protection is responsible for splitting of Dirac cones and generation of secondary Dirac points away from time reversal invariant momenta. Our study of bulk (Pb,Sn)Se (001) crystals overgrown with PbSe atomic layers has shown that such valley splitting is extremely sensitive to atomic-scale details of the TCI-trivial interface and the top layer, exhibiting non-monotonic changes as PbSe deposition proceeds [1]. This includes an apparent total collapse of the splitting for sub-monolayer coverage. The detailed theoretical analysis supported by realistic tight binding model calculations has led to the conclusion that in the case of a small number of PbSe layers the collapse of valley splitting depends mainly on the coverage of surface by a sufficiently dense array of terraces or steps. Similar calculations have been also performed for rough (001) surface of (Pb,Sn)Se [2]. Within the envelope function model it has been shown that valley mixing and the collapse of Dirac cone splitting depend crucially on the surface structure. When atomic terraces are wide enough the valley splitting is recovered and the odd-height steps define domain boundaries with additional 1D topological states reported by Sessi *et al*. [3]. The adjacent terraces turn out to be described by different values of the winding number topological invariant.

[1] C. Polley et al., *ACS Nano* **12**, 617-626 (2018).

[2] R. Rechciński and R. Buczko, Phys. Rev. B 98, 245302 (2018).

[3] P. Sessi et al., *Science* 354, 1269-1273 (2016).

3. **Attila Geresdi** (26.02, 11:30)

   Affiliation: QuTech Delft, the Netherlands

   Title: Experimental signatures of Majorana bound states: how close are we to braiding?

   Abstract:
   In this talk, I will discuss recent experimental progress with the detection of Majorana zero modes (MZMs) in semiconductor nanowire-superconductor platform. Initial experiments focused on voltage bias spectroscopy of the MZM, where the experimental signature is a zero bias conductance peak. I will show how the improved materials enabled more subtle checks on the spectroscopical signatures of MZMs. Another class of experiments addresses the topological Josephson junction, where the supercurrent flows through a weak link between two topological superconductors hosting MZMs. Here, the measurements concern the phase periodicity of the Josephson effect, which is expected to pick up a factor of two in the topological regime. I will discuss our efforts to detect MZMs by measuring the Josephson radiation frequency of nanowire Josephson junctions and comment on the experimental results from the perspective of braiding, the coherent manipulation of prospective quantum bits.

4. **Tadeusz Domański** (26.02, 12:15)

Affiliation: Marie Curie-Sklodowska University, Poland

Title: Majorana quasiparticles in nanoscopic hybrid structures

Abstract:
Topological superconducting phase can be induced in nanostructures via the proximity effect, making use of either (i) the spin-orbit interactions combined with strong enough magnetic field or (ii) spiral ordering of the local magnetic moments. It is has been shown that boundaries of finite-size topological superconductors host the exotic Majorana quasi-particles. Indeed their localised versions have been observed at the ends of proximitized nanowires/nanochains [1] and nanostripes confined between superconducting reservoirs [2,3], whereas chiral mutations have been seen in the STM measurements at the edges of magnetic (Shiba) islands deposited on superconducting substrates [4-6]. Natural tendencyof the Majorana quasiparticles towards the boundaries or internal defects is responsible for their leakage on various side-coupled objects [7]. We explore efficiency of such leakage onto dim=0 [8,9] and dim=2 regions [10], and propose useful methods for their empirical detection [11].

[1] R.M. Lutchyn et al, Nature Rev. Mat. 3, 52 (2018).
[2] A. Fornieri et al & C.M. Marcus, arXiv:1809.03037 (2018).
[3] H. Ren et al & A. Yacoby, arXiv:1809.03076 (2018).
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[7] M.-T. Deng et al & C.M. Marcus, Phys. Rev. B 98, 085125 (2018).
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[10] A. Kobia lka, T. Domański & A. Ptok, arXiv:1808.05281 (2018).
[11] M.M. Maśka and T. Domański, Sci. Rep. 7, 16193 (2017).

5. **Maciej Maśka** (26.02, 12:45)

   Affiliation: University of Silesia, Poland

   Title: Finite-temperature stability of self-organized topological state in a chain of magnetic atoms.

   Abstract:
   It is known that a chain of magnetic moments deposited on a bulk superconductor self-organizes into a helical structure. The ordering is driven by an effective RKKY-type interaction that is mediated by itinerant electrons. It is interesting that for wide range of system parameters the wave vector characterizing the helix self-tunes to support a topological state with Majorana edge modes. This feature has been demonstrated in the ground state, also in the presence of some forms of disorder. In this work we study the stability of this self-organized topological state at finite temperatures. We show how the correlation length of the spiral order decreases with increasing temperature. In most cases the destruction of the helical order drives the system into a topologically trivial state. For some parameters, however, the topological state survives up to infinite temperature despite the absence of the helical order.

6. **Ion Cosma Fulga** (26.02, 13:15)

   Affiliation: IFW DresdenFW Dresden, Germany

   Title: Electrically-switchable second order topological superconductor

   Abstract:
   Second order topological superconductors (SOTSC) have a gapped D-dimensional bulk, gapped boundaries, but host protected modes on (D-2)-dimensional regions of the boundary, such as the corners or hinges of a system. Motivated by recent advances in Majorana nanowire experiments, we propose to realize a tunable SOTSC as a two-dimensional nanowire array. We show that the coupling between the Majorana modes of adjacent wires can be controlled by current-biasing the device, allowing to access a variety of topological phases. We characterize the system using scattering theory, which provides access to its transport properties and its topological invariants. Further, we show that the setup is robust against disorder, and that the latter can drive the system from a trivial to a topological phase.

7. **Carlo Beenakker** (26.02, 15:00 ***Colloqium***)

Affiliation: University of Leiden, the Netherlands

Title: Majorana edge modes in topological superconductors

Abstract:
Two-dimensional superconductors with broken time-reversal symmetry have been predicted to support topologically protected chiral edge states, providing a superconducting counterpart to the quantum Hall effect in semiconductors. The edge states carry charge-neutral quasiparticles, coherent superpositions of electrons and holes referred to as "Majorana fermions". The first observations have been reported recently, after several decades of unsuccesful search. We present an overview of electrical and thermal probes of the superconducting edge states, focusing on unique signatures of their Majorana nature and on applications for topological quantum computation.

8. **David van Zanten** (26.02, 16:30)

Affiliation: University of Copenhagen, Denmark

Title: Probing coherent coupling of Majorana modes via single-electron photon assisted tunneling

Abstract:
The coherent coupling between Majorana zero modes localized in distinct topological islands mixes the 1e charge states of islands. This coherent superposition of even and odd parity states is a necessary condition for the operation of topological qubits. We demonstrate the coherent coupling of zero modes in a superconducting double island created in a InAs/Al nanowire. This is achieved by tracking microwave induced charge transitions between the islands. The dispersion of photon assisted tunneling features is 1e periodic and shows the presence of an anti-crossing between even and odd parity charge states. In this talk I will first discuss the magnetic field induced transition from 2e to 1e periodic charge states of a superconducting double island device measured using a RF charge sensor. Next, I will discuss the observation of photon assisted tunneling features and show that the 1e periodicity results from discrete zero-energy states which emerge in magnetic field.

9. **Krzysztof Sacha** (26.02, 17:15)

Affiliation: Jagiellonian University, Poland

Title: Time Crystals

Abstract:
Time crystals are systems which can reveal solid state behavior in the time domain. Periodically driven systems that can spontaneously break time translation symmetry and also systems where condensed matter behavior emerges in the time evolution will be introduced. We show that a bunch of solid state phenomena ranging from Anderson localization to topological phases can be also observed in the time domain.

10. **Tomasz Szołdra (27.02, 15:00)**

Affiliation: Jagiellonian Universtiy, Poland

Title: Measuring topological invariants in optical lattices

Abstract:
Ultracold atoms in optical lattices form a clean quantum simulator platform to examine topological phenomena and test exotic topological materials. In this talk we will propose an experimental scheme to measure Chern number of two-dimensional multiband topological insulators with bosonic atoms. We will show how to extract the topological invariants out of a sequence of time-of-flight images applying a phase retrieval algorithm to Bose-Einstein Condensate matter waves. We will illustrate advantages of using bosonic atoms as well as efficiency and robustness of the method with two prominent examples: the Harper-Hofstadter model with an arbitrary commensurate magnetic field and the Haldane model on a brick-wall lattice.

11. **Servaas Kokkelmans** (27.02, 8:30)

Affiliation: Eindhoven University of Technology, the Netherlands

Title: Dynamical formation of the unitary Bose gas

Abstract:
We study the structure of a Bose-condensed gas after quenching interactions to unitarity. Using the method of cumulants, we decompose the evolving gas in terms of clusters. Within the quantum depletion we observe the emergence of two-body clusters bound purely by many-body effects, scaling continuously with the atomic density. As the unitary Bose gas forms, three-body Efimov clusters are first localized and then sequentially absorbed into the embedded atom-molecule scattering continuum of the surrounding depletion. These results highlight the interplay of quantum depletion and evolving scaling laws in the formation of the unitary Bose gas.

12. **Bernard van Heck** (27.02, 9:00)

Affiliation: Microsoft Station Q, USA

Title: Topological quantum computing with Majoranas: the search for robust design

Abstract:
Majorana-based devices hold the promise for topologically protected quantum gates, but require carefully engineered conditions in order to perform as desired. I will describe some of the prominant scalable schemes for Majorana qubits, discussing the merits as well as the challenges. I will also introduce full-shell wires as a recent, potentially robust alternative for creating Majoranas.

13. **Grzegorz Mazur** (27.02, 10:15)

Affiliation: International Research Centre MagTop, Institute of Physics, Polish Academy of Sciences, Poland

Title: Experimental search for the origin of zero-energy modes in topological materials

Abstract:
Point-contact spectroscopy of several topological materials reveals a phase transition to a low temperature phase that is characterized by zero-energy modes superimposed on an energy gap showing a Bardeen-Cooper-Schrieffer-type of criticality. This behavior is not accompanied by a bulk superconductivity, which points to either local superconductivity or to the emergence of an unfamiliar ground state specific to topological matter. As found theoretically [Brzezicki et al., arXiv:1812.02168], one of these is a correlated many body state at surface atomic steps in topological crystalline insulators, whose domain walls, in an analogy to Su-Schrieffer-Heeger atomic chain systems, show low-energy excitations. We demonstrate, employing a soft point-contact method, that features characteristic for superconducting point contacts develop at the topological surfaces of diamagnetic, paramagnetic, and ferromagnetic $Pb_{1-y-x}Sn_yMn_xTe$. The temperature and field dependencies of the spectrum show BCS-type of critical behaviors that, however, is not accompanied by a global superconductivity. We examine possible sources of low-energy excitations and show that our data are consistent with Brzezicki's et al. theory.

The authors acknowledge partial support of Polish National Science Centre UMO-2015/19/N/ST3/02626 and UMO-2017/27/B/ST3/02470.

14. **Wojciech Brzezicki** (27.02, 10:45)

Affiliation: International Research Centre MagTop, Institute of Physics, Polish Academy of Sciences, Poland

Title: Topological properties of multilayers and surface steps in the SnTe material class

Abstract:
Surfaces of multilayer semiconductors typically have regions of flat terraces separated by atom-high steps. We investigate the properties of the low-energy states appearing at such atomic steps in Sn(Pb)Te(Se) [1]. We identify the important approximate symmetries and use them to construct the topological invariants. We calculate the dependence of mirror- and spin-resolved Chern numbers on the number of layers and show that the step states appear when these invariants are different on the two sides of the step. Since the density of states is large at the step the system is susceptible to different types of instabilities, and we consider an easy-axis magnetization as one realistic possibility. We show that magnetic domain walls support low-energy bound states because the regions with opposite magnetization are topologically distinct in the presence of non-symmorphic chiral and mirror symmetries, providing a possible explanation for the zero-bias conductance peak observed in the recent experiment[2].

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[2] G.P. Mazur, K. Dybko, A. Szczerbakow, M. Zgirski, E. Lusakowska, S. Kret, J. Korczak, T. Story, M. Sawicki, and T. Dietl, “Majorana-like excitations in a ferromagnetic topological crystalline insulator”, arXiv:1709.04000.

15. **Teemu Ojanen** (27.02, 11:45)

Affiliation: Tampere University of Technology, Finland

Title: Designer topological phases in engineered atomic chains and lattices

Abstract:
In my talk I explore possibilities for custom-made topological states in artificial systems. Anticipating the next phase in the search for Majoranas, I consider different scenarios for engineering tuneable 2d chiral superconductors with impurity lattices and magnetic superstructures. These systems can realize remarkably complex topological phase diagrams with dozens of different phases and high Chern numbers. I also review some recent experimental developments in fabricating atomically perfect 1d topological insulators and domain wall states. I conclude by a brief introduction to a rising field of amorphous topological matter and its perspectives for designer topology.

16. **Jacek Dziarmaga** (27.02, 12:30)

Affiliation: Jagiellonian University, Poland

Title: Determining topological order from infinite projected entangled pair states

Abstract:
A unique ground state of an infinite strongly correlated two-dimensional system can be efficiently computed with a tensor network known as an infinite projected entangled pair state (iPEPS). When the iPEPS is wrapped on an infinite torus it becomes a superposition of degenerate ground states. With infinite matrix product operators (MPO) we construct projectors on ground states with a definite anyon flux in each direction. The construction is repeated for three different tori related by modular transformations. Infinite MPO's are employed again for an efficient computation of overlaps between all the different ground states. From the overlaps we obtain the topological matrices S and T determining the topological order. The algorithm is tested on the toric code and the double semion model. It is shown to be robust against a perturbation driving them across a phase transition to a ferromagnetic order. It is also tested on a numerically optimized ground state of the Kitaev model.

17. **Andrzej M. Oleś** (26.02, 13:00)

Affiliation: Jagiellonian University, Poland

Title: Topological Phases by Spatially Inhomogeneous Pairing Centers

Abstract:
We investigate the effect of periodic and disordered distributions of pairing centers in a one-dimensional (1D) itinerant system to obtain the microscopic conditions required to achieve an end Majorana mode and the topological phase diagram. Remarkably, we observe [1] that the topological invariant can be generally expressed in terms of the physical parameters for any pairing center configuration. We identify the phase diagram with topologically nontrivial domains where Majorana modes are completely unaffected by the spatial distribution of the pairing centers [1]. These results are general and apply to several systems where inhomogeneous perturbations generate stable Majorana modes. One realization is the 1D orbital model with Majorana modes, obtained for a ruthenium oxide with charge impurities replacing a doublon by a holon orbital degree of freedom in the ferromagnetic regime [2].
We acknowledge support by Narodowe Centrum Nauki (NCN, Poland), Project No. 2016/23/B/ST3/00839.

[1] W. Brzezicki, A. M. Oleś, and M. Cuoco, Phys. Rev. B 95 , 140506(R) (2017).
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18. **Nicholas Sedlmayr** (26.02, 14:30)

Affiliation: Rzeszów University of Technology, Poland

Title: High Chern Numbers and Majorana Zero Modes in 2D Topological Superconductors

Abstract: The bulk-boundary correspondence establishes a connection between the bulk topological index of an insulator or superconductor, and the number of topologically protected edge bands or states. For topological superconductors in two dimensions the first Chern number is related to the number of protected bands within the bulk energy gap, and is therefore assumed to give the number of Majorana band states in the system. Here we show that this is not necessarily the case. As an example we consider a hexagonal-lattice topological superconductor based on a model of graphene with Rashba
spin orbit coupling, proximity induced s-wave superconductivity, and a Zeeman magnetic field. We explore the full Chern number phase diagram of this model, extending what is already known about its parity. We then demonstrate that despite the high Chern numbers that can be seen in some phases these do not strictly always contain Majorana bound states.

19. **Jakub Zakrzewski:** (26.02, 17:45)

Affiliation: Jagiellonian University, Poland

Title: Many body localization in the presence of cavity mediated long-range interactions

Abstract:
We consider a one-dimensional Hubbard model with all-to-all couplings mediated by the interaction with the cavity field. The model exhibits many-body localization in the presence of local disorder. We numerically identify the parameter space where many-body localization occurs using exact diagonalization and finite-size scaling. The time evolution from a random initial state exhibits features consistent with the localization picture. The localization can be revealed through the time-dependent dynamics of light leaving the cavity.

20. **Oladunjoye Awoga** (27.02, 15:30)

Affiliation: Upsalla University, Sweden

Title: Disorder robustness and protection of Majorana bound states in ferromagnetic chains on conventional superconductors

Abstract:
Majorana bound states (MBSs) are well established in the clean limit in chains of ferromagnetically aligned impurities deposited on conventional superconductors with finite spin-orbit coupling. Here we show that these MBSs are very robust against disorder. By performing self-consistent calculations we find that the MBSs are protected as long as the surrounding superconductor show no large signs of inhomogeneity. We also find that longer chains offer more stability against disorder for the MBSs, albeit the minigap decreases, as do increasing strengths of spin-orbit coupling and superconductivity.

[1] O. A. Awoga, K. Bjornson, A. M. Black-Schaffer, Phys. Rev. B 95, 184511 (2017).
[2] S. Nadj-Perge et. al., Science 346 (6209) (2014).

21. **Andrzej Ptok** (27.02, 16:00)

Affiliation: Institute of Nuclear Physics, Polish Academy of Sciences, Poland

Title: Formation of the Majorana bound states on defects

Abstract:
Zero-energy Majorana bound states can emerge at the edge of a low dimensional systems [1]. Due to the Non-Abelian statistics of such states, Majoranas are a good candidate for the realization of qubit for topological quantum computer. However, If they are to be used in creation of quantum computer, it is crucial to obtain an intentional creation and manipulation of this type of bound states. We show such a possibility in a setup of several systems (e.g. optical trap [2] or quantum dot-nanoring [3] hybrid system) in which we artificially create a 'defect' (inhomogeneity) region via electrostatic means. In such scenario, apart from non-trivial Majorana bound states, some trivial states like Andreev bound states can also be detected. We study the differences between those bound states and the possibility of their manipulation.

[1] A. Y. Kitaev, Phys.-Usp. **44**, 131 (2001).
[2] A. Ptok, A. Cichy and T. Domański, J. Phys.: Condens. Matter **30**, 355602 (2018)
[3] A. Kobialka and A. Ptok, arXiv:1801.08021

22. **Paweł Szumniak** (27.02, 16:30)

Affiliation: AGH University of Science and Technology, Poland

Title: Spin and Charge Signatures of Topological Superconductivity in Rashba Nanowires

Abstract:
Topological phases of condensed matter systems have attracted a lot of attention over many years. One of the hallmarks of such phases, in particular of topological superconductivity, are Majorana fermions which are promising candidates for topological quantum computing [1]. As a result, most of the theoretical and experimental work so far has focused on such Majorana modes [2] and their detection. However, this has turned out to be a very challenging task, especially for experimentalists searching for them [3], since the unambiguous identification of Majorana fermions (typically via transport data) is not easy and often even meet with controversy due to masking effects e.g. from disorder or Kondo physics. Thus, it is of great interest and importance to look for alternative signatures of topological phases that are not relying on the presence or absence of Majorana fermions but test the topological superconductivity itself. Here, we show that the topological phase of a proximitized Rashba nanowire can be identified via the bulk properties of the states, in particular, by the spin and charge of low-energy bulk states close to the topological gap. Quite remarkably, we find that the sign of the spin component along the magnetic field as well as of charge of these low-energy states reverses as the system passes through the topological phase transition [4]. This sign reversal is a direct consequence of the band inversion and is directly accessible in experiments by spin and energy resolved measurements. We show that proposed new signature is highly robust to the static onsite and magnetic disorder. We suggest experimental method for detecting spin inversion assisted with topological phase transition by employing quantum dot acting as a spin filter [5]. Our predictions thus provide an entirely novel approach in the search for topological superconductivity, which is complementary to Majorana one.

[1] A. Y. Kitaev, Ann. Phys. 303, 2 (2003).
[2] L. Fu and C. L. Kane, Phys. Rev. Lett. 100, 096407 (2008).
[3] V. Mourik, K. Zuo, S. M. Frolov, S. R. Plissard, E. P. A. M. Bakkers, and L. P. Kouwenhoven, Science 336, 1003 (2012).
[4] P. Szumniak, D. Chevallier, J. Klinovaja, and D. Loss, Phys. Rev. B 96, 041401(R), (2017).
[5] D. Chevallier, P. Szumniak, S. Hoffman, D. Loss, and J. Klinovaja, Phys. Rev. B 97, 045404 (2018).

23. **Michał Nowak** (27.02, 17:00)

Affiliation: AGH University of Science and Technology, Poland

Title: Multiple Andreev reflections: characterization of hybrid nanostructures and novel supercurrent

Abstract:
Under application of a voltage bias to a superconductor-semiconductor-superconductor junction sequential Andreev reflections on the superconducting contacts result in a dc-current whose magnitude is a non-linear function of the junction transparency and the number of current-carrying modes. We exploit this phenomenon to demonstrate few-mode current transport in InSb [1] and Ga-Si core-shell nanowires [2] favorable for creating topological superconductivity. Finally, we show that in a multiterminal junction the DC-current consists of supercurrent components when the bias voltages are commensurate despite the absence of bound-states that carry disspationless current [3].

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[3] M. P. Nowak, M. Wimmer, A. R. Akhmerov, arXiv:1811.00916 (2018).

24. **Aksel Kobiałka** (27.02, 17:30)

Affiliation: Marie Curie-Sklodowska University, Poland

Title: Delocalisation of Majorana Bound States in 1D/2D hybrid structures.

Abstract:
Interplay between superconductivity, spin-orbit coupling and magnetic field can lead to realisation of the topologically non--trivial states. In finite 1D Rasha nanowires those states are manifested by emergence of a pair of zero-energy Majorana bound states. On the other hand, in 2D systems spin currents contributed by the edge states might appear. Creation of junction between those two systems opens new possibilities for probing the behaviour of Majorana Bound States. Therefore, we investigate properties of such bound states in multi-dimensional hybrid structures consisting of 1D Rashba nanowire and bounded 2D surfaces.