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Book of Abstracts

IV International Scientific School

Superconducting Functional Materials for Advanced Quantum Technologies 2026

21–25 September 2026

Peterhof, Saint Petersburg, Russia

SCIENCE • PEOPLE • IDEAS

FOR A BRIGHTER QUANTUM FUTURE

Contents

21–25 SEPTEMBER 2026 · PETERHOF

School programme

The programme below follows the supplied School timetable. For each scientific lecture, the speaker, lecture title, and affiliation are shown. Affiliations are taken preferentially from the submitted lecture abstracts; where no lecture abstract was supplied, the affiliation is taken from the conference materials or the lecturer's institutional profile.

SCHOOL PROGRAMME / DAY 1

Monday, 21 September

Opening and superconducting quantum materials

Peterhof · School venue

Time	Monday, 21 September	Ref.
10:00–10:30	**Prof. Alexander GOLUBOV** Andreev physics in magnetic and topological systems Moscow Institute of Physics and Technology; University of Twente	
11:00–11:30	Coffee break	
11:30–12:30	**Prof. Mauro DORIA** The onset of Quantum Commensurate States Universidade Federal do Rio de Janeiro; Universidade Federal Fluminense; Instituto Militar de Engenharia, Brazil	
12:30–14:00	Lunch	
14:00–15:00	**Prof. Vadim GRINENKO** Flux quantum fractionalization and unquantized vortices in superconductors Tsung-Dao Lee Institute & School of Physics and Astronomy, Shanghai Jiao Tong University, China	
15:00–15:15	Break	
15:15–16:15	**Prof. Dmitriy USACHOV** Photoemission insight into the electronic structure of lanthanide compounds Saint Petersburg State University; Moscow Institute of Physics and Technology	
16:15–16:30	Break	
16:30–17:30	**Prof. Marcia Christina Bernardes BARBOSA** · Welcome remarks Rector, Universidade Federal do Rio Grande do Sul (UFRGS), Brazil	

SCHOOL PROGRAMME / DAY 2

Tuesday, 22 September

Photoelectron spectroscopy, topology, and vortex matter

Peterhof · School venue

Time	Tuesday, 22 September	Ref.
10:00–11:00	**Prof. Denis VYALIKH** From Maxwell to Modern Photoelectron Spectroscopy Donostia International Physics Center; IKERBASQUE, Basque Foundation for Science, Spain	
11:00–11:30	Coffee break	
11:30–12:30	**Prof. Wei JIANG** Quantized spin Hall effect in 3D nodal-ring semimetal: geometric scaling and symmetry-engineered spin response Beijing Institute of Technology, Beijing; International Center for Quantum Materials, BIT, Zhuhai, China	
12:30–14:00	Lunch	
14:00–15:00	**Dr. Alexander FROLOV** Atomic Disorder in Topological Insulators Center for Advanced Mesoscience and Nanotechnology, MIPT; Lomonosov Moscow State University, Russia	
15:00–15:15	Break	
15:15–16:15	**Prof. Yu-Hui CHEN** The Clock That Ticks by Itself: A Tutorial on Continuous Time Crystals School of Physics, Beijing Institute of Technology, Beijing, China	
16:15–16:30	Break	
16:30–17:30	**Prof. Alexander MELNIKOV** Electronic structure of vortex matter in superconductors and hybrid superconducting structures Moscow Institute of Physics and Technology; Institute for Physics of Microstructures RAS, Russia	

SCHOOL PROGRAMME / DAY 3

Wednesday, 23 September

Topological materials, superconductivity, and poster session

Peterhof · School venue

Time	Wednesday, 23 September	Ref.
10:00–11:00	**Prof. Alexey ALADYSHKIN** Probing hidden defects and bias dependence of visible heights of monatomic steps in thin Pb films: An STM/STS study Institute for Physics of Microstructures RAS; Center for Advanced Mesoscience and Nanotechnology, MIPT; Lobachevsky University, Russia	
11:00–11:30	Coffee break	
11:30–12:30	**Prof. Alexander SHIKIN** Topological insulators, Weyl and nodal-line semimetals based on MnBi2Te4 and related topological phase transitions Saint Petersburg State University, Russia	
12:30–14:00	Lunch	
14:00–15:00	**Dr. Ilya SHIPULIN** Calorimetric and Ultrasound Evidence for a Novel Intermediate Phase in $Ba_{1-x}K_xFe_2As_2$ Tsung-Dao Lee Institute & School of Physics and Astronomy, Shanghai Jiao Tong University, China	
15:00–15:15	Break	
15:15–16:15	**Prof. Rafael ZADOROSNY** Solution Blow Spinning: A Versatile Route for the Design and Scalable Processing of Advanced Ceramic Materials Universidade Estadual Paulista (UNESP), Ilha Solteira, Brazil	
16:15–16:30	Break	
16:30–17:30	Poster session for students Best poster competition	

SCHOOL PROGRAMME / DAY 4

Thursday, 24 September

Topological electronics and quantum devices

Peterhof · School venue

Time	Thursday, 24 September	Ref.
10:00–11:00	**Prof. Artem RYBKIN** Magneto-Spin-Orbit Graphene on the Path to Topological Electronics Saint Petersburg State University, Russia	
11:00–11:30	Coffee break	
11:30–12:30	**Prof. Si-Li WU** Gate-tunable Josephson diode effect mediated by topological surface states in BiSbTeSe2 (BSTS) Josephson junctions Centre for Quantum Physics, School of Physics, Beijing Institute of Technology, China	
12:30–14:00	Lunch	
14:00–15:00	**Prof. Lada YASHINA** Crystal growth for advanced studies and applications Lomonosov Moscow State University; Moscow Institute of Physics and Technology, Russia	
15:00–15:15	Break	
15:15–16:15	**Prof. Daniel DOMINGUEZ** Superconducting qubits and strong driving protocols for fast quantum gates Centro Atómico Bariloche; Instituto Balseiro, Bariloche, Argentina	
16:15–16:30	Break	
16:30–17:30	**Prof. Irina BOBKOVA** Hybrid Light-Matter States in Superconducting Nanostructures: Magnon and Ferron Polaritons Moscow Institute of Physics and Technology, Russia	

SCHOOL PROGRAMME / DAY 5

Friday, 25 September

Microscopy, magnetic topological insulators, and quantum optics

Peterhof · School venue

Time	Friday, 25 September	Ref.
10:00–11:00	**Prof. Yutao XING** Applications of high-resolution electron microscopy: from fundamental physics to materials engineering Institute of Physics, Fluminense Federal University (UFF), Brazil	
11:00–11:30	Coffee break	
11:30–12:30	**Prof. Evgeniy CHULKOV** Advances in Physics and Materials Science of Magnetic Topological Insulators Saint Petersburg State University, Russia; Donostia International Physics Center (DIPC), Spain	
12:30–14:00	Lunch	
14:00–15:00	**Prof. Ling-Jun KONG** Quantum holography and its application in image encryption School of Physics, Beijing Institute of Technology, Beijing, China	
15:00–15:15	Break	
15:15–16:15	**Prof. Shyam SUNDAR** Study of Superconducting Quantum Materials Using Spin Polarized Muons Instituto de Fisica, Universidade Federal do Rio de Janeiro, Brazil	
16:15–16:30	Break	

Saturday, 26 September: departure. The supplied timetable also marks 27 September as a departing day.

IV INTERNATIONAL SCIENTIFIC SCHOOL · 21–25 SEPTEMBER 2026

School Information

The **IV International Scientific School "Superconducting Functional Materials for Advanced Quantum Technologies 2026"** is held on **21–25 September 2026** in Peterhof, Saint Petersburg, Russia. The School brings together invited lecturers, students, and young researchers working on quantum materials, superconductivity, magnetism, and superconducting quantum technologies.

Russian Science Foundation project

The School is organised within the framework of the Russian Science Foundation project **No. 23-72-30004**, *Superconducting Functional Materials for Advanced Quantum Technologies* (agreement dated 13 April 2023). The project is implemented at the Moscow Institute of Physics and Technology under the leadership of **Prof. Alexander A. Golubov**.

Project information: https://rscf.ru/project/23-72-30004/ School website: https://mezo-mipt.ru/conferences/17

Scientific focus

- Magnetic topological insulators
- Topologically protected electronic subsystems
- Hybrid superconductor–ferromagnet systems
- Coexistence of superconductivity and magnetism
- Control elements of superconducting quantum circuits
- Superconducting quantum devices
- Cryogenic thermometry in the millikelvin range
- Functional quantum materials for post-silicon electronics

Program Committee

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Key dates and contact

School: 21–25 September 2026. **Abstract submissions:** 1 April–10 May 2026.

Poster session: Wednesday, 23 September 2026.

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IV INTERNATIONAL SCIENTIFIC SCHOOL · PETERHOF 2026

Welcome Address

Dear Colleagues, Lecturers, Students, and Guests,

It is our pleasure to welcome you to the IV International Scientific School *Superconducting Functional Materials for Advanced Quantum Technologies 2026*. The School continues a programme designed to connect fundamental quantum-materials research with the development of future superconducting and post-silicon technologies.

The School is held within Russian Science Foundation Project No. 23-72-30004. Its scientific programme spans magnetic topological insulators, hybrid superconductor–ferromagnet systems, superconducting quantum circuits and devices, and cryogenic thermometry at millikelvin temperatures. These themes are united by a common objective: understanding and controlling functional quantum states so that fundamental physical phenomena can become the basis of new electronic technologies.

A central part of the School is the exchange between established researchers and the next generation of scientists. We therefore particularly welcome the student poster session, discussions with lecturers, and the opportunities for informal scientific communication during the week.

We thank all lecturers and authors for their contributions, the Program and Organizing Committees for preparing the School, and the Russian Science Foundation for supporting Project No. 23-72-30004.

We wish you a productive, inspiring, and enjoyable School in Peterhof.

Prof. Alexander A. Golubov

Project Leader, RSF Project No. 23-72-30004

Moscow Institute of Physics and Technology

Prof. Vasily Stolyarov

Program and Organizing Committees

INVITED LECTURES · SUBMITTED ABSTRACTS

Lecture abstracts

The lecture abstracts are ordered by the numbering of the submitted lecturer archive. The supplied timetable defines lecture blocks but does not assign lecturer names to individual time slots.

L-01 | Lecture abstract · 21–25 September 2026

Photoemission insight into the electronic structure of lanthanide compounds

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Photoemission spectroscopy is one of the most direct and powerful methods for studying the electronic structure of solids. By measuring the kinetic energy and angular distribution of the electrons photoemitted from a sample, one can obtain detailed information on both the energy and momentum of the electrons propagating inside a crystalline material. This is of high importance for uncovering the relation between electronic, magnetic, and chemical properties of solids. By analyzing angular distributions of core-level photoelectrons, additional information on the atomic structure can be obtained using a photoelectron diffraction technique.

In this lecture, we provide guidance on using photoemission spectroscopy to study the electronic structure, magnetism and related properties of materials using the examples of lanthanide compounds LnT_2X_2, where Ln is a rare-earth element, T – transition metal and X = Si or P. Some of these materials exhibit strongly correlated electronic behavior and unusual magnetic properties. We demonstrate the capabilities of using photoemission techniques to reveal the features of the electronic and spin structure of bulk and surface electronic states, spin-orbit interaction effects, variations of the valency of 4f elements, differences in the magnetic properties of surface layers from bulk ones, changes in the crystal field near the surface and corresponding changes in the direction of 4f magnetic moments, electronic correlations and structural characteristics of quantum materials [1-5].

References

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L-02 | Lecture abstract · 21–25 September 2026

The onset of Quantum Commensurate States

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Keywords: Fano-Feshbach resonances, localized states, commensurability

Through coupling, particles form extended matter in several levels ranging from the sub-nuclear to the micron scale. From a Quantum Mechanical perspective, the onset of extended matter is a consequence of joining particles into bound states. Nevertheless, while bound states are spatially localized, the free states are not, which raises the interesting question about the stability of extended matter, of fundamental concern not only for Physics, but also for Chemistry and Biology. In this context, the so-called Fano-Feshbach resonances [1,2,3] are a significant contribution as they show that interaction is enhanced whenever a continuum energy level matches a discrete one. However, the Fano-Feshbach resonance does not fully addresses the stability of extended matter, since particles in a bound state can also tunnel to the continuum level by the same token. The stability of extended matter is a subject of constant investigation in Quantum Mechanics due to the presence of the reverse process that makes extended matter able to spontaneously disintegrate into its constituents. Here I address a particular situation where coexistence between spatially localized and unconfined states is possible, being enabled by the commensurability of fundamental lengths [4]. We show the existence of such Quantum Commensurate States in conducting films and layered structures.

M.M.D. acknowledges support from the INCT project “Advanced Quantum Materials”, Brazil.

References

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L-03 | Lecture abstract · 21–25 September 2026

Flux quantum fractionalization and unquantized vortices in superconductors

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Keywords: vortices, time-reversal symmetry breaking, unconventional superconductivity

Abstracts Magnetic flux quantization is a defining hallmark of superconductivity, traditionally constraining vortices to carry integer multiples of the flux quantum Φ_0. Recent advances in multiband superconductors challenge this paradigm by demonstrating the emergence of vortices carrying fractional and continuously tunable flux [1-3]. Here, we overview recent experimental breakthroughs to present a unified picture of vortex deconfinement, and emergent composite excitations in multicomponent superconducting systems.

Three years ago, scanning SQUID magnetometry in $Ba_{1-x}K_xFe_2As_2$ reveals mobile vortices carrying a nonuniversal, temperature-dependent fraction of Φ_0, demonstrating that flux quantization can be continuously violated in multiband systems [1]. Complementary spectroscopic imaging via scanning tunneling microscopy further shows that integer vortices can split into multiple fractional core singularities, establishing a direct link between multiband phase structure and vortex-core fractionalization [2]. These findings are consistent with theoretical predictions that multicomponent superconducting condensate can support phase windings in the individual components of the order parameter [4,5].

Extending these observations, recent scanning SQUID magnetometry visualized the real-space deconfinement of fractional vortices: integer vortices can spontaneously split into spatially separated, yet correlated, fractional-flux objects stabilized by pinning and thermal fluctuations [2,3]. Notably, the flux of these constituents exhibits anti-correlated temperature dependence while preserving total flux conservation, forming a “see-saw” redistribution mechanism. This behavior reveals a striking analogy to quark confinement and deconfinement, where fractional vortices act as linearly interacting constituents of composite topological objects.

Together, these studies establish fractional flux unquantized vortices as robust, mobile, and tunable excitations in multiband superconductors. Their existence expands the fundamental understanding of topological defects beyond conventional quantization arguments and opens new avenues for engineering novel fluxonics devices. Moreover, the stability of unquantized vortices establishes it as a candidate for observing anyons, which may be represented, as shown by Frank Wilczek [6], as a charge bound to a fractional flux tube. These results position multicomponent superconductors as a promising platform for exploring emergent topology and fractionalized quantum matter.

References

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L-04 | Lecture abstract · 21–25 September 2026

From Maxwell to Modern Photoelectron Spectroscopy

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The photoelectric effect, discovered by Heinrich Hertz in 1887 and later explained by Albert Einstein in 1906, forms the basis of a broad range of spectroscopic techniques collectively known as photoelectron spectroscopy (PES), often referred to as “photon in, electron out” techniques. They include ultraviolet photoelectron spectroscopy (UPS), X-ray photoelectron spectroscopy (XPS), angle-resolved photoelectron spectroscopy (ARPES), as well as spin- and time-resolved photoelectron spectroscopies.

Today, PES together with X-ray absorption spectroscopy (XAS) belongs to the most widely used and continuously developing experimental methods for studying the electronic structure of molecules, solids, surfaces, and interfaces. These techniques provide valuable insight into the electronic, magnetic, and dynamic properties of materials and have important applications in surface chemistry, materials science, and solid-state physics.

This lecture, including historical background, gives an introduction to photoelectron spectroscopy, with particular emphasis on ARPES. Several examples from our own PES studies of graphene and magnetic phenomena in lanthanide (Ln) materials will also be presented. These materials have attracted considerable interest not only because of their advanced magnetic and optical properties relevant for technological applications, but also due to their remarkable low-temperature phenomena, including complex magnetic phases, valence fluctuations, heavy-fermion behavior, and Kondo effects. Such properties mainly originate from the interplay between nearly localized 4f electrons and itinerant electronic states.

In this context, lanthanide intermetallic compounds of the LnT2Si2 family (T = transition metal) attract particular interest. Besides their remarkable bulk phenomena and properties mentioned above, these materials provide an excellent platform for systematic studying how the corresponding electronic and magnetic properties evolve near the surface region, represented by Si-T-Si-Ln surface block, where novel effects and related temperature scales emerge.

Moreover, these surface properties can be systematically tuned in several ways. For instance, the strength of spin-orbit coupling increases when going from Co (3d) to Rh (4d) and further to Ir (5d)-based systems, giving rise to pronounced Rashba effect. Magnetic exchange interaction can be introduced by lanthanide elements with strong magnetic moments, such as Gd, while crystal-electric-field effects become important for elements with non-zero orbital momentum, such as Dy or Ho. In addition, elements with unstable 4f shells, such as Ce, Eu, or Yb, allow the investigation of Kondo-related phenomena.

Thus, a Si–T–Si–Ln structure may serve as a beautiful playground for studying the fundamental properties of 2D electron systems, also relevant for the development of novel functional nanomaterials. It can be regarded as a versatile platform, where spin–orbit coupling, Kondo effect, crystal-electric-field interactions, and magnetic exchange interactions represent the essential building blocks. Combining them provides the opportunity to realize different physical scenarios and to explore the behavior of 2D electrons in the presence of these competing interactions.

L-05 | Lecture abstract · 21–25 September 2026

Atomic Disorder in Topological Insulators

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Keywords: topological insulators, antisite disorder, 124 compounds, surface states, electron transport

Layered chalcogenides with the 124 structure and related homologues provide a platform for crystal-chemical design, encompassing nonmagnetic and antiferromagnetic topological insulators and In-alloyed superconductors. Extensive cation intermixing, however, makes atomic disorder an essential part of their electronic structure. We combine structural characterization, photoemission, STM/STS, transport measurements, and electronic-structure calculations to examine how site occupancy and local chemistry affect electronic spectra and transport. Disorder cannot generally be represented by energy-independent band broadening [1,2].

In $GeBi_2Te_4$ and $SnBi_2Te_4$, partial Te/Se substitution produces 1222 phases with preferential occupation of outer anion sites by Te and inner sites by Se. The bulk gap increases from 85 to 175 meV in the Sn compounds and from 180 to 195 meV in the Ge compounds, while the conduction-band edge becomes nearly parabolic and the surface-state group velocity reaches approximately $4.0–4.1 \times 10^5$ m s^{-1}. The accompanying changes in spectral damping are energy- and element-dependent, with stronger broadening in the Sn-based materials [1].

Cation intermixing also redistributes orbital weight near the band edges. In $Ge_2Bi_2Te_5$, melt- and vapor-grown crystals have ordering parameters $\alpha \approx 0.41$ and 0.33. Bi occupation of the central cation site modifies spin-orbit coupling and the inverted gap, while the calculated strong topological index remains (1;000). In $Mn(Bi,Sb)_2Te_4$, Mn antisites alter magnetic exchange: approximately 17% Mn occupation of the outer cation sites reverses the sign of the interlayer coupling J_2 in the reported model, favoring ferromagnetic rather than antiferromagnetic order.

In-alloyed $SnBi_2Te_4$ illustrates the coexistence of strong scattering and superconductivity. The estimated $k_F\ell \approx 1.13$ indicates a strongly disordered normal state; a resistive transition occurs at Tc = 2.16 K, and tunnelling spectroscopy yields $\Delta \approx 0.232$ meV. Resonant scattering involving In 5s states is a proposed explanation for the short mean free path. In $GeBi_4Te_7$, Bi-on-Ge antisites are implicated in charge transfer between quintuple and septuple blocks, producing band bending and an approximately 160 meV separation of the termination-dependent Dirac points [2]. These results show why material design must account for defect location and electronic character as well as concentration.

Acknowledgments. The work was supported by RSF Grant 22-72-10074-P.

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L-06 | Lecture abstract · 21–25 September 2026

The Clock That Ticks by Itself: A Tutorial on Continuous Time Crystals

Yu-Hui Chen

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What if a material could keep time all on its own, without any external prompts? This is the strange and fascinating promise of a ”time crystal”, a new state of matter that has captured the imagination of physicists. In this tutorial, we will explore the fundamental ideas behind this concept. We will start by asking a simple question: what is a crystal? We'll see how a normal crystal, like a diamond, has a repeating pattern in space. A time crystal, by contrast, has a repeating pattern in time—its internal properties oscillate spontaneously, like a clock that winds itself.

We will then discuss our recent experiment that created a continuous time crystal using a special crystal doped with erbium ions. By shining a steady laser on it, they observed that the light passing through became unstable and started to pulse in a regular rhythm. This rhythm was not imposed by the laser; it emerged from the complex interactions among billions of erbium ions, which spontaneously organized to ”tick” in unison. This state of matter is ”self-protected,” meaning its collective rhythm is surprisingly robust and lasts longer than the individual quantum states of the ions themselves.

This tutorial will break down the core concepts of this discovery, explaining how many-body interactions can lead to such an exotic phase of matter and what it means for the future of quantum science.

L-07 | Lecture abstract · 21–25 September 2026

Electronic structure of vortex matter in superconductors and hybrid superconducting structures

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In this lection I will give a review of basic physics underlying the modern works on electronic structure of vortex matter in superconductors and superconducting hybrid structures. In particular, we will discuss the mechanisms of formation of subgap bound states inside the vortex cores and their modification by different types of defects scattering the electrons. The review will also include the discussion of the transformation of the vortex core structure in superconductor-ferromagnet and superconductor – normal metal (SN) hybrid structures, spin-orbit and exchange field effect as well as the manifestation of unconventional superconducting pairing and nontrivial topology of electronic spectra in vortex systems.

We will discuss different theoretical approaches aimed to describe the features of the above core states as well as experimentally measurable quantities which allow to probe these electronic spectrum peculiarities.

L-08 | Lecture abstract · 21–25 September 2026

Probing hidden defects and bias dependence of visible heights of monatomic steps in thin Pb films: An STM/STS study

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This lecture presents the results of an experimental investigation of the local electronic properties of thin Pb(111) films on a Si(111)7×7 surface using low-temperature STM/STS [1-7]. It is well known that standing electronic waves formed across the film modify the transparency of the ”substrate – Pb film – vacuum spacer – tip” system. Consequently, both the tunneling current I and the differential conductance dI/dU depend strongly on the bias voltage U and the local film thickness. STM/STS measurements allow us to detect tiny variations in thickness, internal stresses, and subsurface defects such as dislocation loops. We find that the apparent height h of monatomic and multi-atomic steps on Pb(111) exhibits an oscillatory dependence on U. These oscillations arise from resonant tunneling via quantum-well states. The maximum and minimum apparent heights occur at bias voltages where the local densities of states of Pb(111) terraces of different thicknesses are equal. Such oscillations vanish at bias voltages exceeding the work function.

References

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L-09 | Lecture abstract · 21–25 September 2026

Topological insulators, Weyl and nodal-line semimetals based on MnBi2Te4 and related topological phase transitions

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Keywords: topological insulators, Weyl and nodal-line semimetals, electronic structure, topological superconductivity

Last time, a large number of new topological materials with unique features of their electronic and spin structures and radically new physico-chemical properties have emerged and been proposed for development. Among them are systems based on magnetic topological insulators (TIs) with spin-polarized topological surface states, Weyl and Dirac semimetals with separated nodal points and surface Fermi arcs connecting the Weyl (nodal) points, as well as nodal-line semimetals with drumhead surface states and a high density of states in the nodal line region. These different types of topological systems are typically realized in different materials and overlap only slightly. This report will demonstrate and analyze how all these types of topological systems can be realized in one starting system—based on the magnetic TI MnBi2Te4. This paper will demonstrate how and under what conditions the electronic structure of a magnetic TI can be transformed into an electronic structure characteristic of Dirac and Weyl semimetals, and then into a trivial insulator state with the gradual substitution of non-magnetic (Ge) atoms for magnetic (Mn) atoms. In addition to it, the possibility of transforming magnetic TI into nodal-line and Weyl semimetal states in the layered MnBi2Te4/MnV(Ti)Te4-type systems with antiferromagnetic and ferromagnetic interlayer interaction, as well as under modulation of the magnetic moment and effective spin-orbit interaction (including through controlled Te/Se substitutions) will be analyzed. The features of the electronic and spin structures of the resulting topological phases and the conditions for their formation will be analyzed. Changes in the electronic structure of topological surface states during the formation of topological superconductivity will be analyzed.

L-10 | Lecture abstract · 21–25 September 2026

Superconducting qubits and strong driving protocols for fast quantum gates

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Keywords: quantum gates, superconducting qubits, fluxonium

In recent years, significant progress has been made in the design of quantum processors using superconducting qubits, which have become one of the most promising platforms due to their scalability, long coherence times, and potential for fast high-fidelity operations. I will first review the basics of super-

conducting quantum circuits made with Josephson Junctions considering the transmon and fluxonium devices in particular. The standard protocols for implementation of single quantum gates based on resonant Rabi driving will be presented. However, quantum gates based on resonant Rabi oscillations are inherently slow for small-frequency qubits, as in the fluxonium architecture. They are also prone to errors due to counter-rotating terms. Alternative manipulation protocols based on strong driving can outperform standard resonant driving. I will present in this lecture the Landau-Zener-St¨uckelberg-Majorana (LZSM) protocol and the Bang-Bang protocol. Analytical expressions that simplify the exploration of the parameter space while accounting for the multi-level structure of the fluxonium circuit will be derived. For this analysis the Floquet theory for the quantum master equation will be presented. The role of leakage and the impact of dissipation on gate fidelity will be analyzed in detail.

*Work in collaboration with J. Caceres, S. Ferreyra, V. Reparaz, L. Tosi and M. J. Sanchez.

L-11 | Lecture abstract · 21–25 September 2026

Solution Blow Spinning: A Versatile Route for the Design and Scalable Processing of Advanced Ceramic Materials

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Keywords: Solution blow spinning (SBS), Ceramic nanofibers, Advanced ceramics, Fiber-based processing, Microstructure control, Materials processing

Solution blow spinning (SBS) has emerged as a versatile and cost-effective technique for the production of micro- and nanostructured fibers, offering significant advantages over conventional fabrication routes in terms of flexibility, scalability, and material design. In this lecture, an overview of the fundamental principles of SBS will be presented, including solution preparation, rheological control, fiber formation mechanisms, and key processing parameters. Particular emphasis will be placed on the application of SBS in advanced ceramic materials, where the technique enables the fabrication of highly homogeneous and tunable microstructures. Examples will be discussed in the context of superconducting ceramics and related functional systems, highlighting how fiber-based processing can influence phase formation, defect distribution, and overall functional performance. Beyond laboratory-scale synthesis, the potential of SBS as a scalable manufacturing approach will be addressed, with discussion on its compatibility with continuous production, low-cost processing, and adaptability to different material systems. These characteristics position SBS as a promising tool within current global efforts to develop advanced functional materials aligned with energy, sustainability, and technological innovation challenges. The lecture will also explore how SBS-based approaches can contribute to key directions in international collaborative frameworks, such as BRICS initiatives in advanced functional materials and materials for energy applications, particularly by enabling the integration of materials design, processing, and performance in a scalable and application-oriented perspective.

L-12 | Lecture abstract · 21–25 September 2026

Magneto-Spin-Orbit Graphene on the Path to Topological Electronics

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Keywords: Graphene, SiC, Rashba effect, QAHE, ARPES, XPS, STM, spintronics, valleytronics, topotronics

Manipulating the spin structure in graphene, i.e., inducing spin splitting of its electronic states and opening a topologically non-trivial band gap at the Dirac point, is one of the most pressing challenges in materials science today. Solving this problem is essential for integrating graphene into spintronics and topological electronics (topotronics) that rely on dissipationless currents.

It is well established that strong spin-orbit coupling (SOC) is a prerequisite for observing phenomena such as the quantum spin Hall effect [1,2], the quantum anomalous Hall effect (QAHE) [2–4], the Rashba–Edelstein effect, and others. A second key factor governing the spin structure is the exchange interaction in graphene. Consequently, research into possible magnetic ordering in two-dimensional carbon systems – such as superatomic graphene [5], twisted bilayer graphene, triangulene [6], nanographenes [7], and others – has garnered significant attention. Although the original Haldane model [8] – which describes a hexagonal lattice with a staggered magnetic field of zero net flux – has not yet been realized experimentally, it remains a cornerstone of topological physics for its prediction of the QAHE in two dimensions.

The magnetic proximity effect also plays a crucial role by inducing exchange splitting of electronic states without an external magnetic field, thereby providing a direct pathway to realize the QAHE. Previous studies have demonstrated that interfacing graphene with an antiferromagnetic oxide can give rise to either the QAHE or the quantum valley Hall effect, depending on the magnetization direction [9].

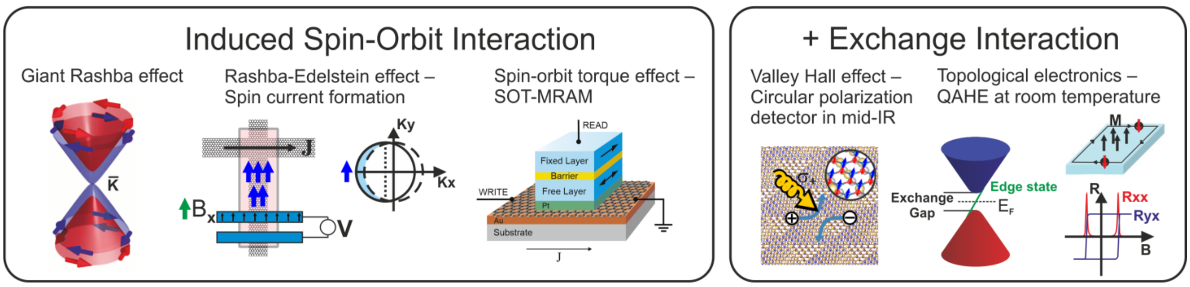

Fig.1 Spin-orbit and exchange interactions in graphene and the corresponding effects suitable for practical implementation in spintronic devices.

This presentation will introduce novel methods for fabricating well-ordered, epitaxial graphene-based systems, along with results from investigations into their electronic, magnetic, and crystal structures. The studies employed a broad range of complementary techniques, including photoelectron spectroscopy, scanning tunneling microscopy/spectroscopy, and density functional theory. Utilizing the effects observed in graphene – namely, the giant Rashba effect, the magnetic proximity effect, and sublattice ferrimagnetism – we propose conceptual models for spintronic devices: a spin filter, an MRAM recording device, and a circularly polarized infrared radiation detector (Fig. 1). Additionally, potential directions for future research aimed at developing topological electronic devices based on quantum Hall effects, i.e., exploiting the topologically non-trivial electronic structure of graphene, will be discussed.

The authors acknowledge Saint-Petersburg State University for a research project 125022702939-2.

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L-13 | Lecture abstract · 21–25 September 2026

Crystal growth for advance studies and applications

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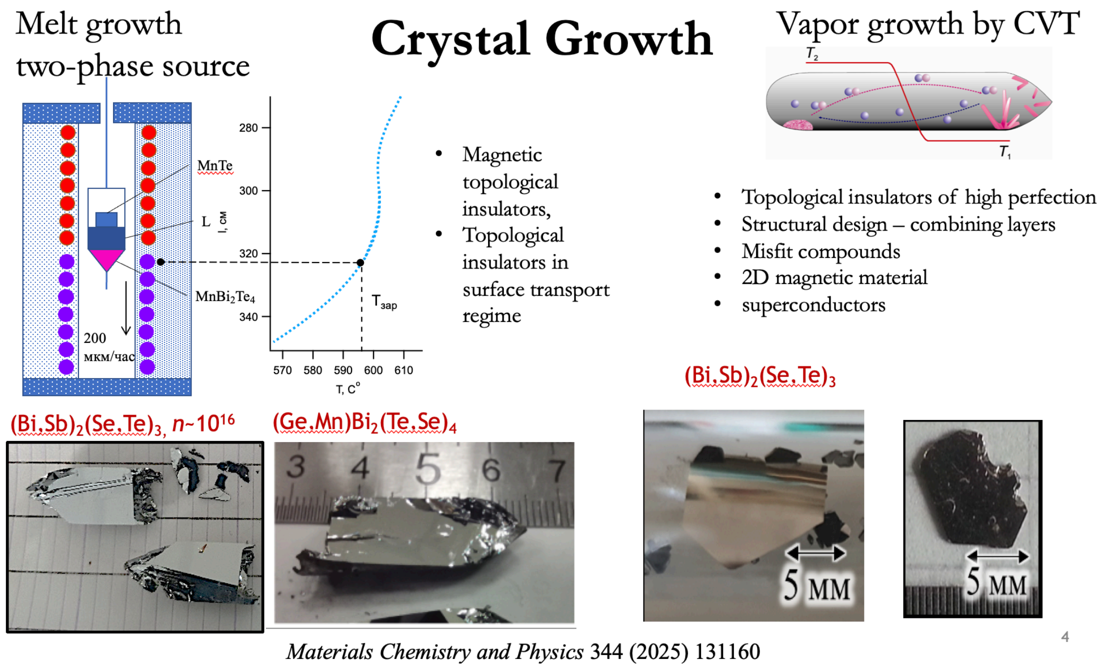
Keywords: crystal growth, melt growth, chemical vapor transport, topological insulators

Bulk crystals are still needed for application purposes and especially for researches. For the latter highly tunable, simple and universal methods applicable in laboratory practice are required. Among them melt and vapor growth covers many practical cases. Crystal growth theory and practice already have long history which evolves from a simple atomistic view to an accurate quantitative description of growth process in realistic time and space scale, crystal composition and properties. Many industrial systems operate in interactive mode. For search of new materials Bridgman direct crystallization is attractive due to its simplicity and possibility to vary composition of multicomponent phases and solid solutions. The class of material is limited by not high melting point and reactivity to quartz ampoule. Vapor growth is even more flexible if transport agents are used. It give generally smaller crystals but with better crystal perfection.



Pic.1 Grystal growth of topological insulators

L-14 | Lecture abstract · 21–25 September 2026

Calorimetric and Ultrasound Evidence for a Novel Intermediate Phase in $Ba_{1-x}K_xFe_2As_2$

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Keywords: fermion quadrupling; multicomponent superconductivity; time-reversal symmetry breaking; calorimetry; ultrasound spectroscopy; iron-based superconductors

Recent studies on the iron-based superconductor $Ba_{1-x}K_xFe_2As_2$ reveal compelling evidence for an unconventional electronic state characterized by fermion quadrupling and multicomponent superconductivity. Calorimetric measurements demonstrate the existence of two distinct thermodynamic anomalies: a higher-temperature transition associated with spontaneous breaking of time-reversal (Z_2) symmetry, and a lower-temperature transition corresponding to the onset of conventional superconductivity with zero resistance. These findings provide direct thermodynamic evidence for an intermediate phase a fluctuation-driven four-fermion (charge-4e) condensate—emerging above the superconducting critical temperature [1].

Complementary ultrasound spectroscopy further supports this picture by revealing anomalous elastic responses consistent with a multicomponent order parameter and symmetry-breaking superconducting state. Distinct signatures in longitudinal and transverse acoustic modes indicate coupling between lattice strain and both superconducting and quadrupling order parameters, offering a sensitive probe of their symmetry and interactions [2]. The observed ultrasound anomalies, particularly near the superconducting transition, are consistent with models of broken time-reversal symmetry (e.g., s+is or s+id pairing) and provide indirect constraints on the structure of the underlying order.

Together, these calorimetric and acoustic results establish a unified phase diagram in which a fermion-quadrupling phase with broken Z_2 symmetry exists in a finite temperature window between the normal metal and the superconducting state. This phase is stabilized by fluctuations and characterized by composite order without long-range pairing coherence. The combined experimental and theoretical framework highlights the richness of multicomponent superconductivity and demonstrates the emergence of higher-order electronic condensates as a new paradigm in correlated quantum materials.

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L-15 | Lecture abstract · 21–25 September 2026

Quantum holography and its application in image encryption

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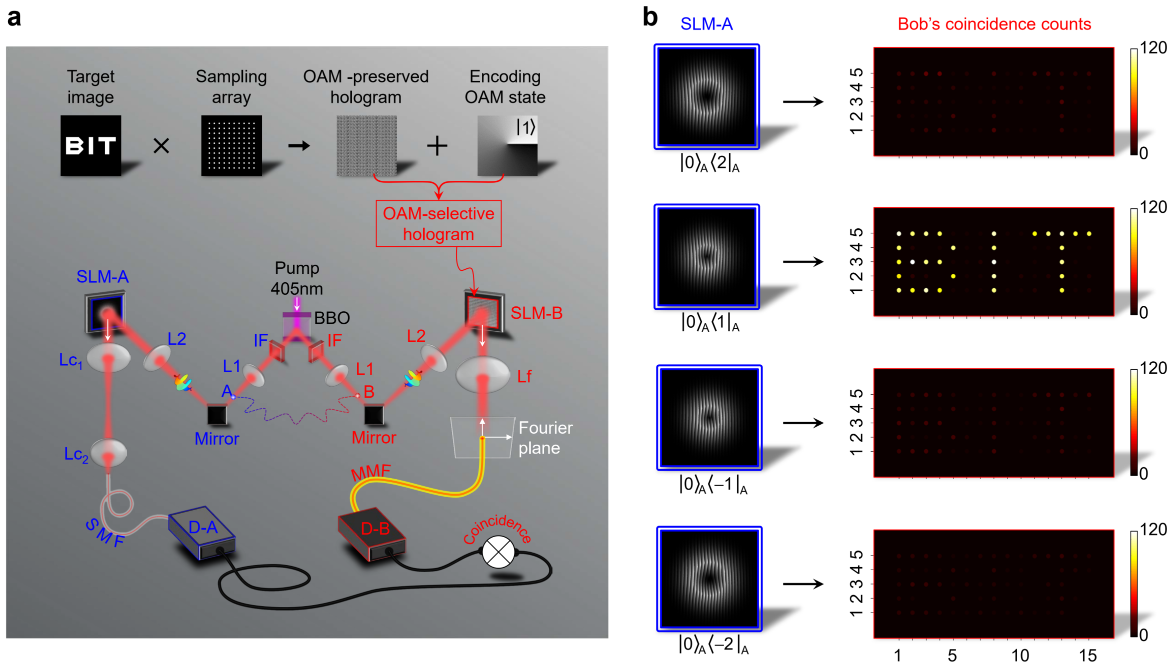
Keywords: holography, quantum entanglement, encryption

As an important imaging technique, holography has been realized with different physical dimensions of light, including polarization, wavelength, and time. Recently, quantum holography has been demonstrated by utilizing polarization entangled state with the advantages of high robustness and enhanced spatial resolution, comparing with classical holography. However, the polarization is only a two-dimensional degree of freedom, which greatly limits the capacity of quantum holography. Here, we propose a method to realize high-dimensional quantum holography by using high-dimensional orbital angular momentum (OAM) entanglement. A high-capacity OAM-encoded quantum holographic system can be obtained by multiplexing a wide range of OAM-dependent holographic images. Proof-of-principle experiments with four- and six-dimensional OAM entangled states have been implemented and verify the feasibility of our idea. Our experimental results also demonstrate that the high-dimensional quantum holography shows a high robustness to classical noise. What is more, the level of security of the holographic imaging encryption system can be greatly improved in our high-dimensional quantum holography.



Pic.1 OAM entanglement-enabled quantum holography.

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L-16 | Lecture abstract · 21–25 September 2026

Study of Superconducting Quantum Materials Using Spin Polarized Muons

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Muon spin relaxation/rotation (μSR) is a unique technique for investigating the details of magnetic interactions in quantum materials, including superconductors. This technique uses nearly 100% spin-polarized muons implanted into a sample to study their subsequent precession, relaxation, and resonance. By detecting the positrons produced through muon decay, μSR provides critical information about the material properties of interest.

In this lecture, I will discuss the fundamentals of μSR techniques, detailing the various experimental configurations and methodologies employed. Through specific case studies, I will demonstrate how μSR can be used to determine fundamental length scales in superconductors and, consequently, shed light on their superconducting pairing symmetry. Additionally, I aim to provide a comprehensive overview of μSR and highlight its invaluable role in advancing our understanding of quantum materials.

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WEDNESDAY, 23 SEPTEMBER 2026 · 09:30–13:00

Poster session

The poster section contains 34 unique submitted contributions. Two pairs of duplicate source files with identical content were included only once.

P-01 | Poster session · Wednesday, 23 September 2026

State-of-the-art methods of heterogeneous technology in quantum optics and electronics

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Keywords: SiN photonics, superconducting single-photon detectors, microfluidics

We present heterogeneous technology which combines fabrication of silicon nitride (SiN_(x)) photonic chips, superconducting devices and technologies of microfluidics for robust connection of photonic chips with single-mode optical fibres.

Silicon nitride photonic chips are one of the standards of quantum optical technologies at 1500 nm wavelength. SiN_(x) waveguides feature compact size and low losses. Besides, this is one of the platforms that enables efficient integration with single-photon superconducting detectors (SNSPD) providing almost 100% detection efficiency. In our case the waveguides are covered by the SiO_2 cladding, and we use chemical–mechanical polishing to make the cladding surface suitable for the deposition of high-quality superconducting film. A critical point in any photonic technology is coupling between the chip and optical fibres. For this purpose, we use the methods of microfluidics for positioning and mounting of the fibres. With the Bosch process we etch 62.5-μm-deep trenches in silicon and glue the fibres in them with the microfluidic methods.

Using heterogeneous integration of the technologies we:

- fabricated single-photon detectors SNSPD on the waveguides of the photonic chip and demonstrated single-photon spectroscopy of the waveguide material,
- developed radiophotonic generator based on NbN hot-electron bolometer mixer (HEB mixer) integrated with the optical waveguide,
- demonstrated a method to couple small-area SNSPD to the optical fibre using parabolic micro-mirrors fabricated in the silicon wafer.

The study was supported by project No. 125020501540-9 of the Ministry of Education and Science of the Russian Federation. Fabrication and technology characterization were carried out at large scale facility complex for heterogeneous integration technologies and silicon+carbon nanotechnologies.

P-02 | Poster session · Wednesday, 23 September 2026

Evolution of topological surface states at $MnBi_2Te_4$ interfaces with heavy and magnetic metals

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Keywords: topological surface states, magnetic topological insulator, $MnBi_2Te_4$, interface engineering, Dirac-point gap

Magnetic topological insulators (MTIs) are a promising class of quantum materials combining non-trivial band topology with magnetic order. One of the key parameters governing their potential for spintronic and quantum-device applications is the energy gap in the topological surface states (TSS) [1]. Among the most studied MTIs is $MnBi_2Te_4$, a layered antiferromagnet composed of septuple layers separated by van der Waals gaps. Although the TSS gap is theoretically predicted to be 80–90 meV [2], experiments often reveal significantly smaller values, including nearly gapless dispersions [3], likely due to structural defects.

One of the route for tuning the TSS gap is the formation of interfaces with metals capable of modifying the surface electronic structure. While such effects have been extensively studied in nonmagnetic topological insulators [4], they remain much less explored in MTIs. In this work, we theoretically investigate the influence of heavy and magnetic metals (Au, Co, and Eu) on the electronic structure of $MnBi_2Te_4$ within density functional theory. We consider adsorption, intercalation, and substitution of Mn atoms in the surface region to identify the key mechanisms governing TSS modification.

Our results show that both the chemical nature of the incorporated atom and the incorporation mechanism strongly affect the TSS. Au induces only weak hybridization: the Dirac cone remains preserved, while the gap may increase. In contrast, Co and Eu produce much stronger modifications under adsorption and intercalation. Co strongly hybridizes with the TSS, distorting the Dirac cone and suppressing the gap, whereas Eu shifts the Dirac cone to lower energies and induces Rashba-like states near the

Fermi level. For substitutional defects, where Mn atoms are replaced by Co or Eu, the Dirac cone remains robust and the gap can even increase. That indicating a remarkable robustness of the TSS against this type of defect.

We further demonstrate that introducing an intermediate Au buffer layer between $MnBi_2Te_4$ and magnetic overlayers weakens hybridization and restores a well-defined Dirac-like dispersion. The gap magnitude is additionally sensitive to the relative orientation of magnetic moments, suggesting the possibility of tuning the TSS gap by an external magnetic field.

Overall, our results demonstrate that interface engineering with heavy and magnetic metals provides an effective strategy for tailoring TSS and controlling the gap magnitude in $MnBi_2Te_4$.

This work was supported by the Russian Science Foundation (Project No. 25-22-00615).

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P-03 | Poster session · Wednesday, 23 September 2026

Photoinduced current in superconductors without an inversion symmetry

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Keywords: superconductivity, photoinduced current, effective action

The photovoltaic effect is a phenomenon in which an alternating external electromagnetic field causes a uniform current to flow in a system. This phenomenon is possible only in materials whose crystal lattice lacks an inversion center, or in structures where the symmetry with respect to inversion is violated by the system's geometry. Of particular interest is the study of this effect in a superconductor, since there is no resistance in it.

Despite the existence of theoretical models of the photovoltaic effect developed for normal metals and semiconductors, their application to superconductors is limited. Approaches used for these systems require significant modifications or are completely unsuitable for describing the nonlinear response of superconductors to an electromagnetic field. As a result, a generally accepted theory describing the generation of direct current by light in non-centrosymmetric superconductors, and especially in hybrid systems based on them, remains absent.

In this paper, based on symmetry considerations, we construct an effective action that describes the dynamics of the gauge invariant phase of the order parameter of a superconductor in which there is no inversion center. The vector of the preferred direction is introduced as a parameter of non-centrosymmetry. The proposed approach is motivated by the fact that the superconducting current is associated with the phase gradient of the order parameter in conventional superconductors, and therefore it is a reliable candidate for constructing the theory of interest to us. With the help of the effective action we study the nonlinear response of current to an external electromagnetic field in the second order. The resulting expression for the current demonstrates the presence of a time-constant component, characteristic of a superconductor without an inversion center.

P-04 | Poster session · Wednesday, 23 September 2026

Simultaneous Microwave CZ Gates on the Fluxonium Architecture Superconducting Processor

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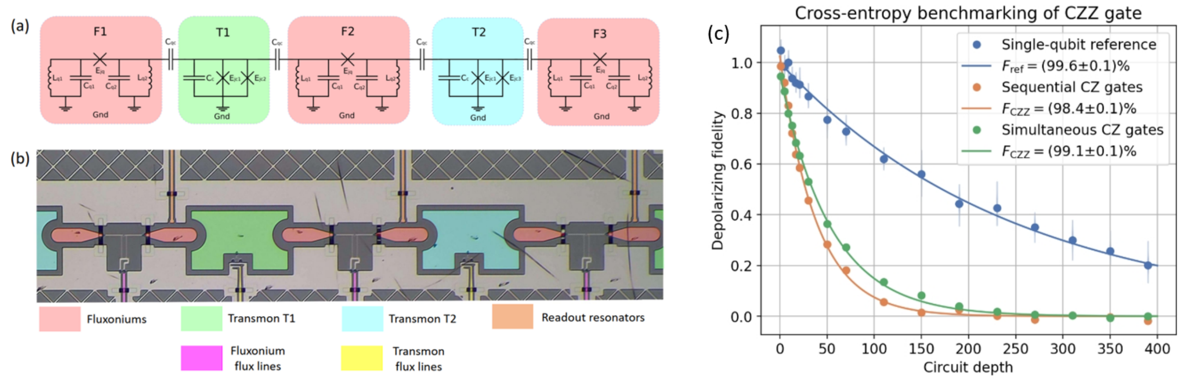
Keywords: superconducting qubits, fluxonium, transmon, CZZ gate, simultaneous gates

For the realization of a superconducting processor with high-fidelity entangling operations and low parasitic interactions between qubits, one of the most promising architectures is the “fluxonium–transmon–fluxonium” configuration, where fluxoniums serve as computational qubits and transmons act as couplers. In this architecture, two-qubit operations are performed via microwave excitation of the couplers [1]. In this work, we present an experimental implementation of simultaneous microwave-driven CZ gates on the superconducting processor consisting of a linear chain of 20 fluxonium qubits and 19 transmon couplers. The specific configuration of the couplers in our superconducting processor [2] enables simultaneous CZ gates on adjacent qubit pairs, effectively implementing a three-qubit CZZ gate. This operation constitutes a valuable resource for quantum algorithms, most notably for quantum error correction codes [3, 4]. The CZZ gates is realized by applying simultaneous microwave 2π pulses to adjacent couplers. On a three-qubit subarray of the experimental device (Pic. 1), we perform calibration and benchmarking of both sequential and simultaneous CZ operations. We experimentally established that the simultaneous execution of CZ gates reduces the error by more than 40% compared to sequential CZ operations. This corresponds to an increase in CZZ operation fidelity from 98.4% to 99.1% (Pic. 1(c)). Furthermore, we demonstrate the application of simultaneous CZ gates in a quantum error detection code.



Pic.1 (a) Equivalent electrical circuit of the three-qubit subarray used in the experiment. F1, F2, F3 are fluxonium computational qubits; T1, T2 are transmon coupler qubits. (b) False-colored optical micrograph of the quantum processor. (c) Results of cross-entropy benchmarking of the three-qubit CZZ gate constructed from sequential and simultaneous CZ operations.

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P-05 | Poster session · Wednesday, 23 September 2026

Field free superconducting diode effect in S/MTI/S hybrid structures

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Keywords: magnetic topological insulator, quantum anomalous Hall effect, superconducting diode effect, Josephson junction, Kwant

The superconducting diode effect (SDE) allows dissipationless supercurrent to flow in only one direction. Usually, it requires the simultaneous breaking of time-reversal and spatial inversion symmetries [1]. Magnetic topological insulators (MTIs) in the quantum anomalous Hall (QAH) state already inherently break time-reversal symmetry [2]. This makes them a promising platform for a field-free SDE. In this work, we theoretically investigate Josephson transport in a superconductor/MTI/superconductor (S/MTI/S) hybrid structure and show that the junction geometry itself can lead to the diode effect. We consider an effective four-band Bogoliubov-de Gennes (BdG) Hamiltonian on a discrete square lattice to model the proximitized QAH insulator. The superconducting regions are created by adding a local pairing potential Δ with a phase difference ϕ (This simulates the proximity effect in MTI/S bilayer). We employ Kwant tight-binding package to construct the lattice setup [3]. The Josephson current is calculated using standard BdG formalism [4]. We consider two geometric setups: a symmetric one, where the superconductors are attached to opposite edges (Pic. 1a), and an asymmetric one, where both superconductors are on the same edge (Pic. 1b).

The spatial configuration drastically changes the transport properties. The symmetric setup yields a standard reciprocal supercurrent. This is due to the fact that the supercurrent is caried by the chiral edge state so that in the symmetric case the supercurrent path is the same in the opposite directions. However, that is not the case in the assymetric Josephson junction. We calculate the current-phase relations (Pic. 1c) to confirm this.

In the asymmetric case we can notice that the critical currents in opposite directions are not equal ($|I_{c+}| \neq |I_{c-}|$), which is highlighted by the gray dashed line in Pic. 1c. This observation confirms a pronounced field-free SDE. We estimate the diode quality to quantify the efficiency. Our findings demonstrate that asymmetric S/MTI/S structures are an effective platform for studying field-free superconducting diodes.

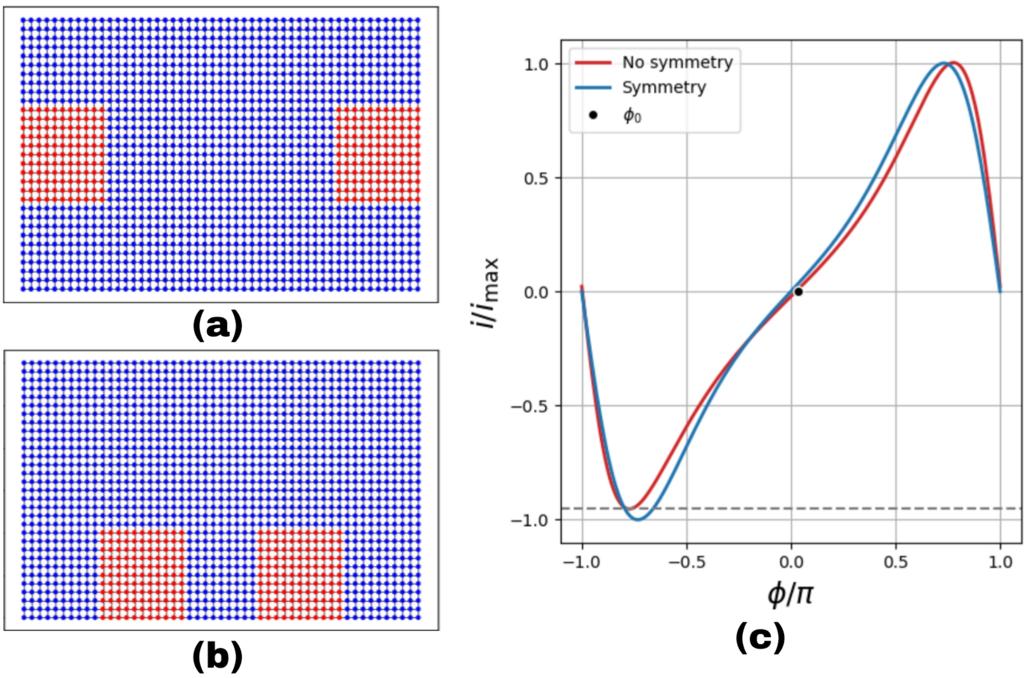

Fig. 1. Tight-binding lattice geometries for symmetric and asymmetric S/MTI/S configurations and normalized current-phase relations.

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P-06 | Poster session · Wednesday, 23 September 2026

Analog Circuit-QED Simulator of Quantum Spin Dynamics Through the Extended Bose-Hubbard Model

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Keywords: quantum computation, spin dynamics, superconducting qubits, Bose-Hubbard model, Heisenberg model, Josephson junctions

We propose and validate a framework for analog simulation of the Heisenberg spin model using a circuit quantum electrodynamics (circuit-QED) platform. Our method involves the Dyson-Maleev transformation, for which we develop a procedure to circumvent its inherent non-Hermiticity, yielding the extended Bose-Hubbard (EBH) Hamiltonian. We demonstrate the equivalence of this approach to the Holstein-Primakoff encoding for spin-1/2 systems. For the experimental realization of this EBH model, we design a scalable circuit-QED architecture based on an engineered Josephson junction array. Numerical simulations confirm that the microwave photon dynamics in this simulator accurately reproduces the original spin dynamics. Our work establishes an experimentally accessible method for investigating complex quantum spin dynamics in a highly controllable bosonic setting.

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P-07 | Poster session · Wednesday, 23 September 2026

Dirac gap evolution of transition metal-based XBi_2Te_4 compounds

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Keywords: topological matter, antiferromagnetism, Dirac gap, topological surface states

Magnetic topological insulators are a unique class of materials in which the topological properties of the electronic structure are closely related to magnetic ordering. One of the best-studied examples is $MnBi_2Te_4$, a layered compound with antiferromagnetic order that contains topological surface states (TSSs) with a nonzero band gap (the Dirac gap).

In this paper [1], we systematically simulated the band structure of a series of XBi_2Te_4 compounds derived from $MnBi_2Te_4$ and formed by the complete substitution of Mn atoms with atoms of other 3d transition elements (X = Sc–Cu). The calculations were performed within the framework of density functional theory with full accounting of the spin-orbit interaction and electron correlations in the 3d shells of transition metals within the DFT+U method. All systems were considered in an antiferromagnetic configuration with magnetic moments oriented along the z-axis, which allows for a correct comparison of the influence of chemical composition.

It has been shown that substituting most transition metals for Mn does not disrupt the topological surface states, which exhibit significant structural similarity for various X elements. (Mn, Fe, Co)-based compounds exhibit a Dirac gap of approximately 30–50 meV, while (Ti, V)-based systems are characterized by significantly smaller values of 10–15 meV. $ScBi_2Te_4$ and $CuBi_2Te_4$ compounds in non-magnetic state exhibit gapless TSS. The TSS gaps depends not only on the magnetic moment of the X atom but also on X contribution to the orbital composition of the TSS. Magnetic-weighted localization characteristic is proposed to account for both factors, allowing for a quantitative description of the TSS gap dependence the nature of the substitution element X.

The results obtained in this study are of fundamental importance for the design of new topological systems and spintronic devices based on antiferromagnetic topological insulators of the XBi_2Te_4 type.

This work was performed with the support of the Saint Petersburg State University (Project No. 125022702939-2).

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P-08 | Poster session · Wednesday, 23 September 2026

Pt Deposition on Bi_2Se_3 and $Bi_2Te_{2.4}Se_{0.6}$ Topological Insulators: Probing Intercalation versus Surface Alloy Formation

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Keywords: ARPES, XPS, STM, topological insulators, intercalation, topological superconductivity

The intercalation of metal atoms into the van der Waals gaps of layered topological insulators provides a versatile platform for engineering quasi-two-dimensional quantum materials [1]. Recently, unconventional ferromagnetism has been reported in Au-implanted Bi_2Se_3 [2]. Conversely, thermal annealing of Bi_2Te_(2.4)Se_(0.6) at 300–400 °C is known to drive surface reconstruction and the formation of Bi bilayers [3]. Since metal incorporation under ultrahigh vacuum (UHV) conditions typically requires thermal activation to overcome diffusion barriers, the process may inadvertently promote the formation of surface intermetallic phases, several of which exhibit low-temperature superconductivity [4,5]. Consequently, two distinct outcomes are possible during synthesis: (i) true intercalation yielding a metal-modified topological insulator, or (ii) surface alloying/intermetallic formation. Both pathways are critically important for probing the interplay between defect-mediated magnetism and interface-induced topological superconductivity.

In this work, we systematically investigate Pt deposition and subsequent thermal treatment on two representative topological insulators, Bi_2Se_3 and Bi_2Te_(2.4)Se_(0.6). We employ angle-resolved photoemission spectroscopy (ARPES) to track modifications in the electronic band structure, complemented by low-energy electron diffraction (LEED), X-ray photoelectron spectroscopy (XPS), and scanning tunneling microscopy (STM) to characterize surface reconstruction, chemical bonding, and atomic-scale morphology. The competition between bulk-like intercalation and surface alloy formation will be critically evaluated, with implications for the emergence of exotic quantum states discussed.

The authors acknowledge Saint-Petersburg State University for a research project 125022702939-2.

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P-09 | Poster session · Wednesday, 23 September 2026

Decay Rates in Interleaved Benchmarking with Single-Qubit References

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Keywords: XEB, RB, cross-entropy benchmarking, quantum gates, multi-qubit operations, benchmarking.

Cross-entropy benchmarking (XEB) with single-qubit reference sequences is widely used to characterize quantum operations in multi-qubit processors. However, a rigorous theoretical justification for this approach has been lacking. In this work, we show that the commonly used additive approximation for the joint fidelity decay in simultaneous single-qubit benchmarking is invalid and leads to a systematic overestimation of the interleaved gate fidelity. We derive an analytical expression for the fidelity decay in terms of individual qubit depolarizing errors. We establish a criterion for sufficient averaging in the interleaved protocol when single-qubit references are employed: the output probability distribution must follow the Porter–Thomas distribution. Experiments on a superconducting fluxonium-based quantum processor demonstrate that the proposed method yields CZ gate fidelity consistent with standard interleaved randomized benchmarking (IRB) [2], while achieving higher precision due to the use of single-qubit reference sequences. These results provide a theoretical foundation for XEB with single-qubit references and offer practical guidance for accurate fidelity estimation of multi-qubit quantum operations.

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P-10 | Poster session · Wednesday, 23 September 2026

Scattering and Schmid Transition in Qubits Based on Chains of Josephson Junctions

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In recent years, superconducting qubits based on Josephson junctions have been actively investigated. A promising method for reading out their state is the measurement of the retarded response in circuits based on superconducting elements [1, 2]. This work theoretically analyzes a system consisting of a Josephson qubit coupled to a long transmission line formed by a chain of Josephson junctions. Interest in this configuration is driven by the possibility of observing the Schmid phase transition, controlled by the dissipation parameter [3].

We have constructed a theoretical model of the experiment described in [1]. In the long-wavelength approximation, an effective Hamiltonian describing the interaction of the qubit with the transmission line has been derived. It is shown that in the limit of an infinite chain, the transmission line is equivalent to an ohmic resistor with a linear spectral density, which ensures energy dissipation. Using the formalism of the path integral in the Keldysh technique, the Schmid phase transition has been analyzed.

The main focus is on the calculation of the nonlinear response of the system. Within the Keldysh formalism, a perturbation theory in the Josephson coupling energy E_(J)/E_(C) has been constructed. In the limit of a small E_(J)/E_(C) ratio, an expression for the second-order correction to the retarded qubit propagator has been obtained and investigated both numerically and analytically. For the measurement setup, the signal reflection coefficient from the system has been calculated, expressed in terms of the retarded Green's function of the qubit. The obtained results allow one to describe the measurement of the Josephson qubit state via the retarded response in a dissipative environment and may be useful for the development of new readout methods in quantum computing.

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P-11 | Poster session · Wednesday, 23 September 2026

KITWPA based on NbN/Mo superconducting thin film structure

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Keywords: kinetic inductance, traveling-wave parametric amplifier, bi-layer thin films, proximity effect

Quantum-limited microwave parametric amplifiers are genuine key pillars for rising quantum technologies and in general for applications that rely on the successful readout of weak microwave signals at cryogenic temperatures by adding only the minimum amount of noise allowed by quantum mechanics.

The main advantages of traveling-wave parametric amplifiers (TWPA) based on the nonlinear kinetic inductance demonstrate are a broad gain-bandwidth and a 1 cycle process flow fabrication.

Kinetic Inductance TWPAs based on dirty superconductors (or high-kinetic inductance materials) utilize the strong, intrinsic nonlinear kinetic inductance L_(k) of disordered thin films to provide amplification. However, the maximum achievable current in these devices, e.g. based on NbN, does not exceed 50% of the critical current, which corresponds to a relative change of L_(k)(0) no more than

10%. Therefore it determines a physically possible limit of signal amplitudes used for parametric microwave interaction.

The purpose of this work is to design a KITWPA based on bi-layered structure of superconductors. Such stack of thin films allows to increase the current up to 81% of critical current and demonstrate a relative change of L_(k) up to 50% due to proximity effect. Thus, it is possible to increase the gain value of the parametric amplifier.

The study was supported by project No. 125020501540-9 of the Ministry of Education and Science of the Russian Federation. Fabrication and technology characterization were carried out at large scale facility complex for heterogeneous integration technologies and silicon+carbon nanotechnologies.

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P-12 | Poster session · Wednesday, 23 September 2026

Magnetically controlled Josephson transport in hybrid S/NFN/S-structures based on AuNi-NW

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Keywords: superconductivity, nanowires, Josephson junction, ferromagnetism

The combination of superconductivity and ferromagnetism enables controllable Josephson states with 0 and π phases [1,2]; however, in planar S/F structures this is hindered by the need to fabricate ferromagnetic layers with nanometer-scale thickness. The use of segmented Au/Ni nanowires makes it possible to control both the weak-link geometry and the magnetic state of the Ni segment [3,4]. In Nb/AuNi-NW/Nb structures (d ≈ 68 nm, L = 285 nm), hysteretic behavior of the critical current in magnetic field was observed, associated with magnetization switching, whereas reference Nb/Au/Nb samples exhibited a smooth dependence. In shorter structures (d = 39 ± 2 nm), critical currents of 33 μA (L = 267 nm) and 45 μA (L = 210 nm) were achieved, corresponding to a current density of up to $3.8 \cdot 10^6$ A/cm^2. The high transport performance is attributed to the single-crystalline Au segments and highly transparent interfaces. Measurements of the current-voltage characteristics in a perpendicular magnetic field revealed a pronounced dependence of both the curve shape and the critical current on the applied field, confirming the magnetically controlled nature of Josephson transport. These results demonstrate the potential of such structures for realizing controllable π-junctions and phase-programmable elements for superconducting spintronics.

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P-13 | Poster session · Wednesday, 23 September 2026

Magnetic force microscopy of superconducting structures

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Keywords: magnetic force microscopy, superconductivity, Abrikosov vortices, niobium films, defects

Magnetic force microscopy (MFM) is a powerful and highly sensitive method for studying magnetic properties and defects in superconducting materials. In this work, the principles of MFM operation and its application to the investigation of superconducting structures are discussed. The method is based on the interaction between a magnetic cantilever and stray magnetic fields above the sample surface, enabling high spatial resolution imaging of magnetic features.

Experiments were carried out using an AttoCube AttoDry 1000 cryogenic scanning probe microscope operating at temperatures down to 4 K. Different operation modes of MFM, including static, dynamic, and dual-pass techniques, were employed to enhance sensitivity and separate topographic and magnetic signals. Special attention was given to the dynamic mode, which provides improved detection of magnetic force gradients.

The study focuses on the visualization and analysis of Abrikosov vortices in niobium thin films. It was shown that vortices are predominantly localized at grain boundaries, indicating a strong influence of the granular structure on magnetic field distribution. The pinning properties of vortices were found to depend on grain size, orientation, and the presence of structural defects. Measurements performed at different lift heights demonstrate the evolution of phase and amplitude contrast in MFM images.

The obtained results confirm that MFM is an effective tool for studying both magnetic structures and defects in superconductors, which is important for the development of advanced superconducting technologies.

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P-14 | Poster session · Wednesday, 23 September 2026

Оптимизация квантовых генераторов случайных чисел за счёт инжекционной синхронизации лазерных диодов

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Keywords: квантовый генератор случайных чисел, полупроводниковые лазеры, оптическая инжекция

Истинная случайность выбора базиса кодирования и значения бита является критически важной для систем квантового распределения ключей. Квантовый генератор случайных чисел (КГСЧ), использующий фундаментальную неопределенность физических величин, является необходимым решением.

В качестве источника случайности может быть использована фаза лазерного импульса, которая, в силу квантовой природы спонтанного излучения, является истинно случайной. Для извлечения последовательности случайных битов из фазы импульсов используют несбалансированный интерферометр, обеспечивающий интерференцию n-го и n+1-го импульсов, и измеряют интенсивность результата интерференции [1]. Однако из-за фазовой модуляции, джиттера и релаксационных колебаний лазерных импульсов интерференционный сигнал таких КГСЧ имеет сниженную видность в сравнении с идеальной моделью [2].

В данной работе предложена схема КГСЧ, исключающая описанные недостатки. В качестве источника лазерных импульсов используется схема оптической инжекционной синхронизации лазерных диодов вместо одиночного лазерного диода (рисунок 1). Для обеспечения интерференции импульсов реализован несбалансированный интерферометр Майкельсона с длиной линии задержки 12,25 м. Лазерные диоды работали в режиме переключения усиления с частотой 8,144 МГц. Результат интерференции регистрировался фотодетектором и осциллографом с полосой пропускания 16 ГГц. Функция плотности вероятности (ФПВ), отражающая распределение количества импульсов определенной интенсивности, построена по результатам измерения площади 10k импульсов. Измерения выполнены для двух режимов работы источника лазерных импульсов: с инжекционной синхронизацией и без неё.

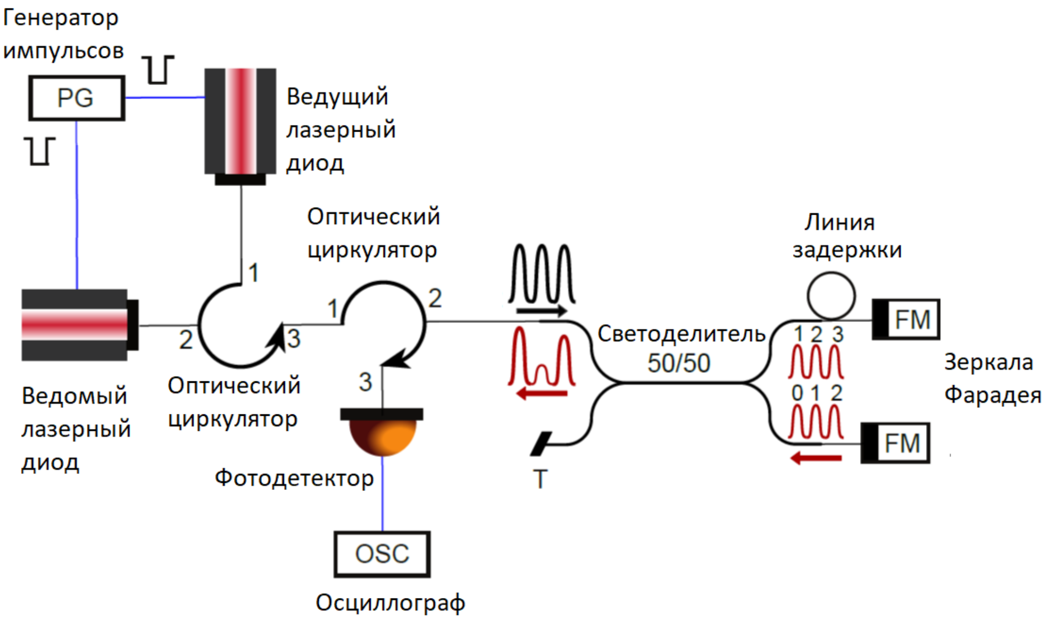

Рисунок 2 демонстрирует ФПВ интенсивности интерференции для двух случаев. Обнаружено, что использование оптической инжекции приводит к лучшему достижению бимодального распределения ФПВ, что означает лучшее согласование с математической моделью и существенное повышение надежности работы устройства за счет исключения влияния неконтролируемых факторов.

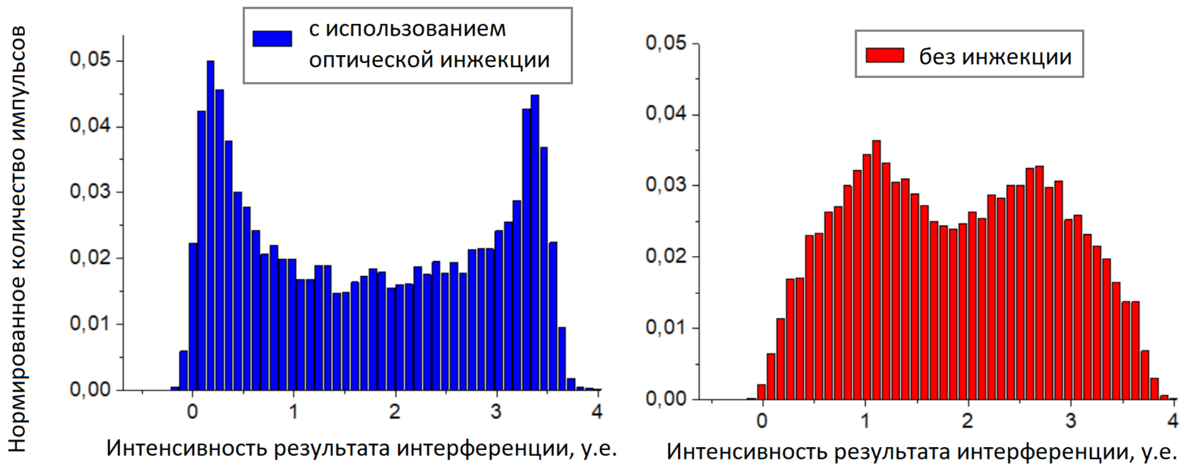

Рис.1 Схема КГСЧ

Рис.2 Функция плотности вероятности: а) схема с оптической инжекцией; б) схема с одиночным лазером.

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Peculiarities of the vortex dynamics in a granular niobium superconducting bridge

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Keywords: superconductivity, vortex dynamics, niobium, nanostructures, negative differential resistance

We investigate the peculiarities of vortex dynamics in a submicron superconducting bridge fabricated from a granular niobium (Nb) film. The voltage–current (V-I) characteristics of the structure reveal anomalous regions with negative differential resistance (NDR), where the voltage decreases with increasing current. Such behavior cannot be explained by conventional overheating effects and is instead attributed to complex vortex motion in an inhomogeneous superconducting medium.

Magnetic force microscopy (MFM) and scanning quantum vortex microscopy (SQVM) measurements demonstrate that the granular structure of the Nb film forms a network of superconducting clusters separated by weaker intergranular boundaries. These boundaries act as preferential channels for Abrikosov vortex motion. The experiments show that vortices enter the bridge at currents exceeding the critical value and propagate along these weak links, forming a nanoscale transport network.

Theoretical modeling based on the time-dependent Ginzburg-Landau equations reproduces the observed nonmonotonic V-I characteristics. It is shown that even a system with only two interacting vortices moving along nearby defects can exhibit NDR and plateau-like behavior. The physical origin of this effect lies in vortex–vortex interaction, which reduces the average vortex velocity and leads to a decrease in voltage in a certain current range.

The results demonstrate that structural disorder in granular superconductors plays a crucial role in transport properties by controlling vortex dynamics. The observed effects can be tuned by engineering defect configurations, opening перспективы for designing superconducting devices with controllable nonlinear transport characteristics.

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P-16 | Poster session · Wednesday, 23 September 2026

Synthesis and investigation of the electronic structure of Graphene on thin Co/Pt layers for spintronics application

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Keywords: electronic and spin structure, graphene, spintronics, spin current and torque, ARPES

The investigation of hybrid systems based on a two-dimensional graphene layer in contact with heavy metals and ferromagnets has attracted increased interest in recent years due to the unique properties of graphene, caused by the linearity of the dispersion dependence of electronic states near the Fermi level - the Dirac cone, and the possibility of its using as an element of nanoelectronics and spintronics. The spin-orbit interaction in graphene can be controlled by heavy metal atoms intercalation under the graphene monolayer. It has been established that noble-metal intercalation (e.g., Au or Pt) gives rise to giant spin–orbit splitting of graphene electronic states, with value of 100–200 meV [1-3]. This value depends on the substrate and the amount of intercalated metal. Additionally, proximity coupling between graphene and Pt/Co layers is of significant interest because it facilitates strong spin momentum transfer originating from the spin-orbit torque effect [4]. Also, in epitaxial graphene/Co/Pt structures, the formation of chiral domain walls or vortices and anti-vortices due to the Dzyaloshinsky-Moriya interaction is observed at the interface between layers [5]. At the same time the use of single-crystal substrate is necessary for the formation of epitaxial graphene.

In this study, graphene was synthesized on a single-crystal SiC(0001) substrate and intercalated with Co and Pt atoms, and its electronic structure was experimentally studied. The following methods were used: angle-resolved photoelectron spectroscopy, X-ray photoelectron spectroscopy, low-energy electron diffraction, scanning electron microscopy, and SQUID magnetometry. As a result of sequential intercalation of Pt and Co atoms, the appearance of a Dirac cone in the electronic band structure was demonstrated - a characteristic feature of quasi-free-standing graphene. A superstructure associated with the intercalation of Co and Pt atoms also forms on the surface. The studies confirm the ferromagnetic ordering in the synthesized system in the temperature range from 2 to 300 K, and the presence of Co electron states near the Fermi level can induce exchange coupling in graphene. The obtained results open up prospects for the creation of spintronic devices based on modified graphene on a semiconductor substrate.

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P-17 | Poster session · Wednesday, 23 September 2026

Realization of the Magnetic Weyl Semimetal Phase Based on the XBi_2Te_4 Family (X = Transition Metal)

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Keywords: topological materials, semimetals

Recently, much attention has been paid to the study of the topological properties of the $MnBi_2Te_4$ family [1,2,4]. These compounds have a layered structure consisting of septuple layers of the type Te-Bi-Te-X-Te-Bi-Te, where X is a transition metal atom. The electronic and magnetic properties of such systems are determined by the combined effect of magnetism and spin-orbit coupling (SOC), which creates conditions for the realization of topological phases of matter, like topological insulators, Dirac semimetals (DSM) and Weyl semimetals (WSM)[3]. In this work, he influence of stoichiometry, choice of magnetic metal, magnetism, and spin-orbit coupling on the band gap width was investigated, and conditions optimal for the existence of the WSM phase were investigated.

The calculations were performed within the framework of density functional theory using the OpenMX 3.9.9 software package and pseudopotentials.

Band structures of materials of the type XBi_2Te_4, where X is a transition metal, were obtained and analyzed. For $MnBi_2Te_4$, as expected [4], the Weyl semimetal phase is realized. Among remaining materials, those exhibiting band inversion at the Γ point of the Brillouin zone were chosen for futher analysis. These materials exhibit an inversion of Bi-Te contributions at the Γ point, which indicates a nontrivial topological phase.

Upon magnetic dilution with Ge, it was found that for the system with Ti, the transition from a topological insulator to a trivial insulator occurs through the DSM phase at a Ge concentration of 50%; for the system with V – through the DSM at 40-50%; for the system with Fe – through the DSM at 25% and through the WSM at 33%; for the system with Co – through the DSM at 50%.

Variation of SOC was carried out in two ways: by artificially changing the corresponding contribution in the Hamiltonian and by replacing Te atoms with Se atoms. artificially varying the SOC shows, that for the system with Ti, the phase change occurs through the DSM phase, as in the case of magnetic dilution. For systems with V, Fe, Co, and Ni, transitions of the type topological insulator – WSM – trivial insulator are observed at different SOC magnitudes for each system. Varying the Se concentration is equivalent to artificially varying the SOC for systems with Ti, Fe, and Co. For the system with V, at a Se concentration of 56.3%, the formation of a nodal line occurs.

Thus, optimal conditions for the formation of DSM and WSM phases were found. The most favorable are magnetic dilution with Ge at concentrations of about 40-50% and the substitution of Te atoms with Se atoms in an amount of 50% for systems with Ti, V, and Co, and 13% for the system with Fe.

The authors acknowledge SPbU for a research project 125022702939-2

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P-18 | Poster session · Wednesday, 23 September 2026

Simulation of Phonon Caustics for Superconducting Detector Applications

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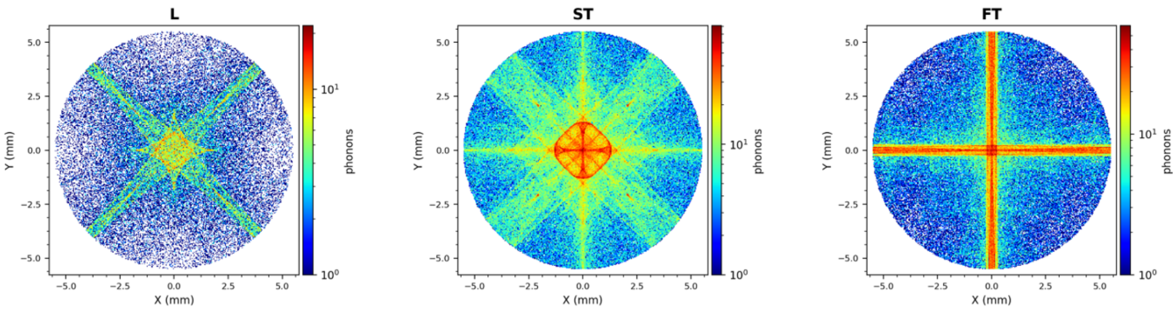
Keywords: simulation, phonon transport, phonon caustics, superconducting devices.

Modern simulation frameworks, such as the Geant4 Toolkit with the G4CMP [1] extension, enable detailed studies of phonons, electron-hole pairs, and Bogoliubov quasiparticles at cryogenic temperatures ($T \ll 1$ K). This capability is critically important for a wide range of scientific problems, particularly in dark matter search experiments. The behavior of phonons in materials plays a key role in cryogenic particle detectors, helping to enhance sensitivity, improve background suppression, and enable more reliable interpretation of rare-event signals.

In anisotropic crystalline materials such as silicon, phonon propagation occurs preferentially along specific crystallographic directions rather than isotopically. This phenomenon, known as phonon focusing, leads to the formation of high-intensity regions — caustics — in the phonon flux distribution. Acoustic phonons can exist in three different polarization states: one longitudinal (L) and two transverse modes — fast transverse (FT) and slow transverse (ST). Phonon caustics depend on the phonon polarization and are most pronounced for transverse modes (FT and ST), as demonstrated by simulations of ballistic phonons at cryogenic temperatures [2].

A phonon caustic pattern may be useful for designing quasiparticle traps used together with TES within the framework of the SATURN experiment (Sarov Tritium-Ultra-Rich Neutrino Experiment) [3]. Simulation of phonon caustics in a cylindrical Si crystal with a point-like phonon source, assuming specular reflection at boundaries according to the Acoustic Mismatch Model (AMM) is presented on Pic. 1.



Pic.1 Simulation of phonons in Si. Flux intensity for every polarization: L (left), ST (center) and FT (right).

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P-19 | Poster session · Wednesday, 23 September 2026

Surface Properties of Correlated Systems (La, Ce)Co_2P_2 and (Pb, Sn)Bi_2Te_4 Investigated by Scanning Tunneling Microscopy and Spectroscopy

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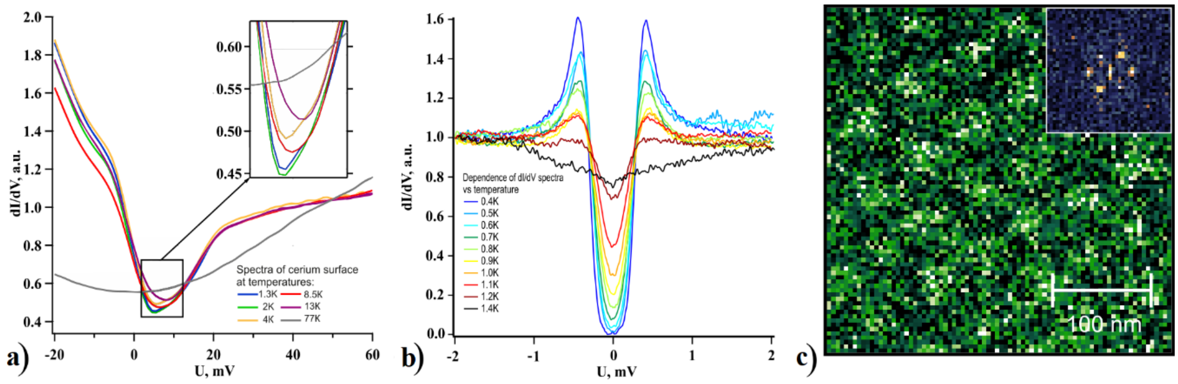
Keywords: STM, superconductivity, kondo effect

In recent years, considerable attention has been drawn to strongly correlated 4f-compounds and topological insulators, in which surface states remain insufficiently explored. Scanning tunneling microscopy and spectroscopy (STM/STS) enable the investigation of local electronic structure with atomic resolution, providing direct access to such phenomena as the surface Kondo effect [1] and superconducting properties of materials [2].

On the surface of $CeCo_2P_2$, three distinct atomic terminations have been identified: phosphorus termination and two types of reconstructed cerium surfaces — magnetic and non-magnetic. Differential conductance spectra (dI/dV) acquired over the Ce-terminated regions exhibit a pronounced temperature-dependent gap near the Fermi level (Fig. 1a). This gap gradually fills with increasing temperature and vanishes completely at T = 77 K, indicating the manifestation of the surface Kondo effect. In the isostructural compound $LaCo_2P_2$, analogous surface structures are observed, including a reconstructed lanthanum lattice, a square phosphorus lattice, and a disordered lanthanum surface. Since lanthanum atoms lack 4f electrons, the Kondo effect is absent in this material. Each surface termination is characterized by a distinct set of defects (vacancies and adatoms) and unique dI/dV spectral behavior, enabling unambiguous identification of the surface type.

In layered topological insulators of the (Pb,Sn)Bi_2Te_4 family, indium doping induces superconductivity, offering a promising platform for the realization of Majorana modes. STM investigations of $Pb_{0.3}In_{0.7}Bi_2Te_4$ performed at 4.2 K revealed a hexagonal atomic lattice with a lattice constant a = 0.41

nm, containing various types of defects, some of which originate from subsurface inhomogeneities. The differential conductance spectra (dI/dV) demonstrate the presence of a superconducting gap at the Fermi level (Fig. 1b), which progressively diminishes with increasing temperature and closes at approximately T ≈ 1.4 K. Fitting the temperature dependence of the gap using Dynes and Maki models yields a critical temperature of Tc = 1.44 K, which is substantially lower than the bulk value of Tc ≈ 2.3 K determined from transport measurements. The zero-temperature gap amplitude was found to be Δ_0 = 340 μeV, resulting in a coupling ratio of $2\Delta_0$/kBTc = 5.34. This value significantly exceeds the weak-coupling BCS prediction and is consistent with previous reports on InxSn1-xBi_2Te_4 compounds. Under applied magnetic fields ranging from 0.05 to 1.0 T, the formation of an Abrikosov vortex lattice is observed (Fig. 1c). The vortex lattice period decreases proportionally to H^{-1/2}, in agreement with theoretical expectations, while the vortex core size scales as H^{-0.25}. Such behavior may indicate the multiband character of superconductivity. Notably, the tunneling spectra show no clear evidence of multiple superconducting gaps, which is attributed to the high surface sensitivity inherent to STS measurements.



Pic.1 Temperature evolution of (a) the Kondo gap in $CeCo_2P_2$, (b) the superconducting gap in $Pb_{0.3}In_{0.7}Bi_2Te_4$, and (c) Abrikosov vortices observed in the STS conductance map of $Pb_{0.3}In_{0.7}Bi_2Te_4$ at a magnetic field of 0.6 T.

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P-20 | Poster session · Wednesday, 23 September 2026

Determination of the Magnetic Properties of the Topological Insulator $MnSb_2Te_4$ from Ferromagnetic Resonance Spectra

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Keywords: ferromagnetic resonance, magnetic topological insulator, magnetocrystalline anisotropy, gyromagnetic ratio

Magnetic topological insulators are a new class of materials that combine magnetic and topological properties [1], enabling the observation of exotic quantum phenomena (e.g., the quantum anomalous Hall effect). In the future, such materials may find applications in spintronics and quantum computing. However, to date, their magnetic properties remain rather poorly understood.

The phenomenon of ferromagnetic resonance (FMR), experimentally discovered and theoretically described in the mid-20th century, is now widely used to determine the gyromagnetic ratio and anisotropy constants in novel magnetic materials [2]. This work presents the results of an analysis of FMR spectra of the magnetic topological insulator $MnSb_2Te_4$ (MST), grown using a modified Bridgman method.

The temperature dependences of the effective anisotropy fields were experimentally measured and fitted with theoretical curves obtained within the classical single-ion approximation [3]. The dependence of the resonance linewidth on frequency and temperature was also investigated. It was shown that Gilbert-type damping [4] is not well-applicable to MST.

Thus, a comprehensive analysis of the magnetic properties of MST was carried out using FMR spectroscopy. It was demonstrated that the ferromagnetic resonance line broadening is not satisfactorily described by the Landau–Lifshitz–Gilbert equation, and good agreement was shown between the theoretical and experimental temperature dependences of the anisotropy fields.

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P-21 | Poster session · Wednesday, 23 September 2026

Comparative Study of Morphological and Superconducting Properties of Granular Niobium Films

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Keywords: superconductivity, granular niobium films, vortex core, scanning tunneling spectroscopy

In clean, homogeneous type-II superconductors, a vortex line has a well-known spatial structure: the superconducting gap Δ(r) vanishes at the vortex core and increases monotonically with distance, reaching its equilibrium value Δ_0 outside the core on length scales exceeding the coherence length ξ [1–3]. In granular superconducting samples, where the grain size (3–10 nm) is comparable to the effective coherence length, the spatial evolution of the gap inside a vortex can be significantly modified due to the influence of intergranular boundaries. Investigating this effect is the main objective of the present study.

[]Figure 1. Left: a spatial map of the superconducting gap Δ(x, y) for the core of a single-quantum vortex. Right: the gap profile Δ(r) taken along a line passing through the vortex center. The black dashed line shows the surface topography profile along the same direction.

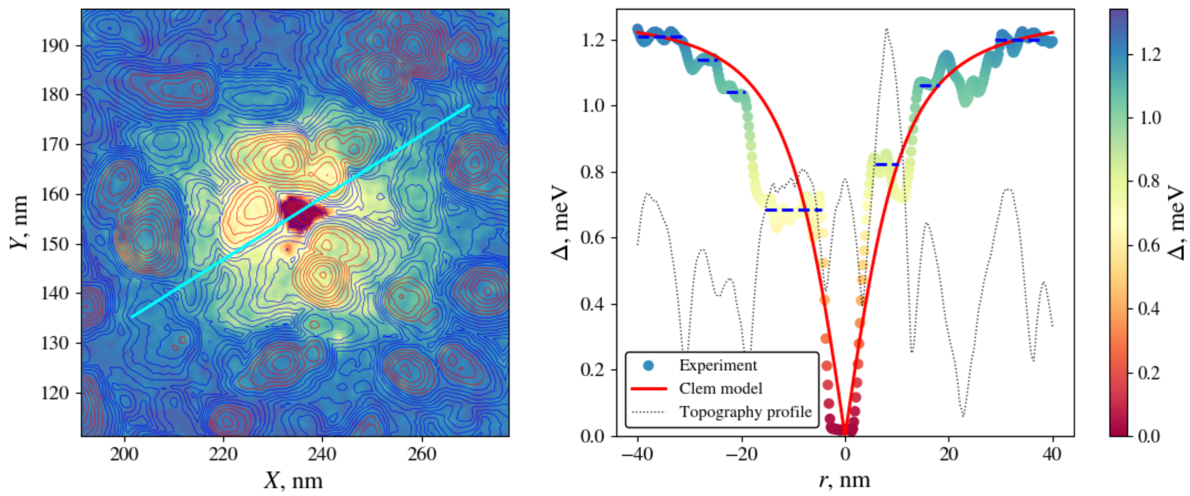

Figure 1 shows a map of the superconducting gap distribution for a single-quantum vortex, extracted from scanning tunneling spectroscopy data and the profile Δ(r) taken along a line passing through the vortex center. For comparison with the sample morphology, surface topography profiles are also plotted along the same directions. We show that the increase of the superconducting gap with distance from the vortex center occurs in a step-like manner: within individual grains, Δ remains nearly constant, whereas abrupt changes are observed when crossing intergranular boundaries. Thus, the spatial structure of vortex cores in a granular niobium film strongly depends on the local granular structure of the sample. The results of this study are presented in Ref. [4].

Further work will involve numerical modeling of vortex core structure within the framework of the Bogoliubov–de Gennes equations for model inhomogeneous superconducting systems. The main objective is to identify the effect of spatial inhomogeneity on the distribution of the order parameter and the local density of states near a vortex. Particular attention will be paid to analyzing modifications of the spectrum of bound states in the vortex core [2] and to comparing the modeling results with experimentally observed features of the spatial evolution of the superconducting gap in granular films.

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P-22 | Poster session · Wednesday, 23 September 2026

SIN thermometers for sub-K range

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Keywords: SIN junction, cryogenic thermometry, on-chip thermometers

We report the work dedicated to development and measurements of on-chip SIN junctions, which characteristics strongly depend on phonon temperature. The array of these SIN junctions implements the concept of a primary thermometer for measuring electron temperature. The main constraint on the sensitivity of this thermometric concept is the stochastic noise floor from the read-out amplifier [1].

The design of the chip is shown on the left side of Fig.1. SIN junctions are indicated in black, while contact pads, DC wiring and particle traps are shown in orange. Sensitive structures are fabricated using combined Al-Hf technology to improve quality of aluminum oxide layer [2].

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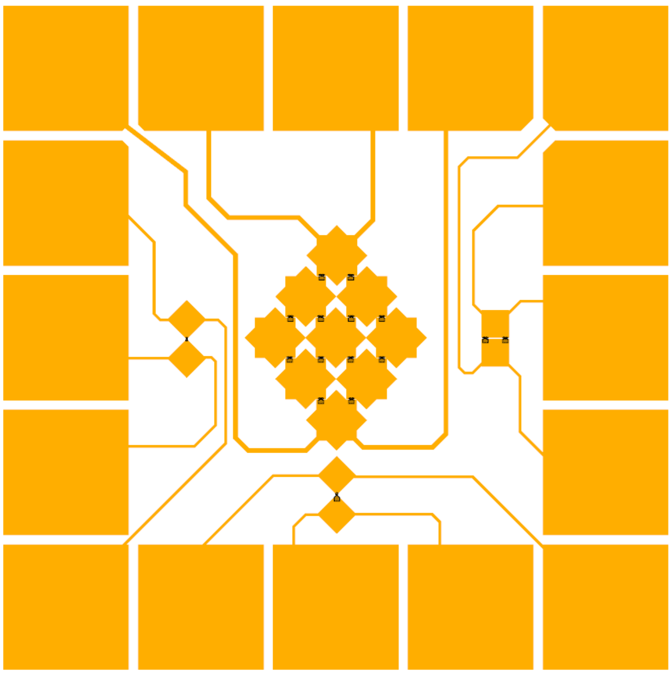
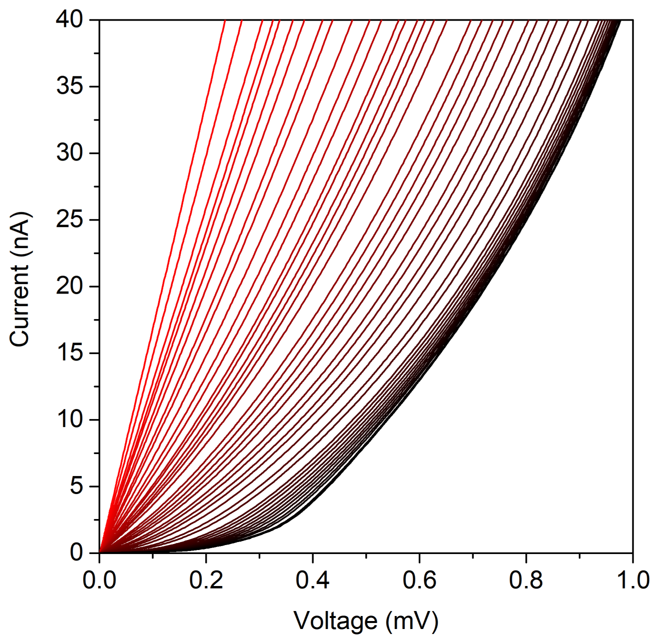


Fig.1. Chip design (on the left side). I-V curves of the sensitive structure (on the right side).

The I-V curves show a visible variation in the range from 1 K to 20 mK, as can be seen on the right side of Fig.1. The lower the temperature, the darker the corresponding I-V characteristic curve on the plot. The theoretical accuracy limit for such kind of thermometers is ±100 μK [1].

This work was supported by the Russian Science Foundation, Project 21-79-20227.



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P-23 | Poster session · Wednesday, 23 September 2026

Изучение локальной магнитной структуры антиферромагнитного топологического диэлектрика Ge_(0.4)Mn_(0.6)Bi_2Te_4

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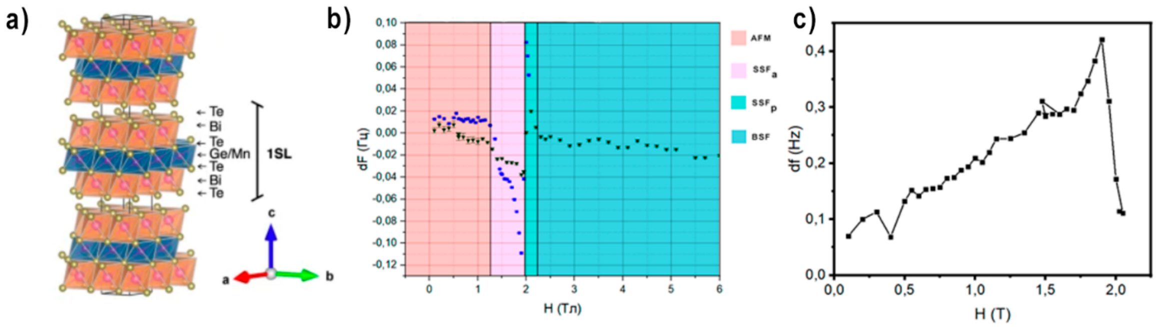
Keywords: magnetic topological insulators, spin-flop

The interest in topological insulators is motivated by their unique electronic structure and a special type of surface states. A special role in the formation of their properties is played by the spin-orbit interaction, which initiates the inversion of the zones. In combination with the symmetry of time reversal, this leads to the appearance of metallic spin-polarized states on the crystal surface, which are described by the Dirac cone [1].

If magnetic impurities are present in the material, the symmetry with respect to time is lost, and a magnetic gap opens in the spectrum of topological states [2]. The topological surface state is localized in the vicinity of the first layer of the crystal, so it is influenced by the magnetic structure near the surface. The magnitude of the energy magnetic gap depends on the component of magnetization perpendicular to the surface of the magnetic topological dielectric [3, 4]. This circumstance stimulates a detailed study of the local magnetic structure of the surface in magnetic topological dielectrics.



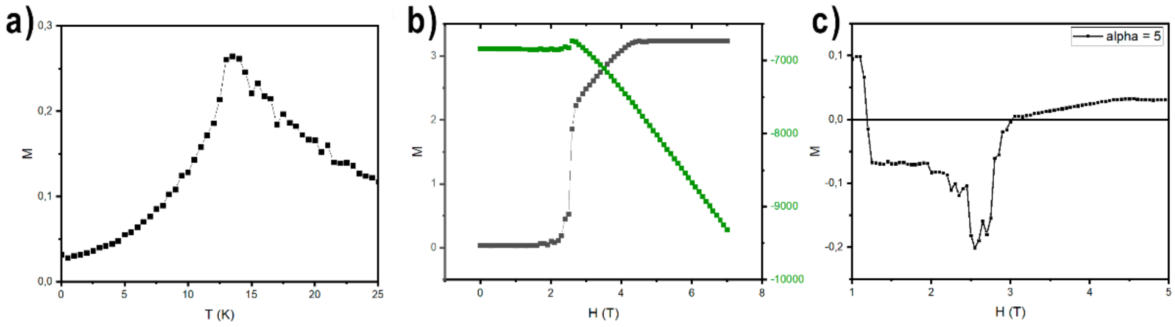
Pic.1 Cristall structure Ge_(x)Mn_(1-x)Bi_2Te_4 (a). Domain contrast as a function of the applied field (b). Magnetic response of the domain wall (c)

The first discovered magnetic topological dielectric with its own crystal site for a magnetic atom is $MnBi_2Te_4$ [5]. It is a layered van der Waals crystal assembled from seven-atom layers (Fig. 1.a). In terms of magnetic properties, it is a uniaxial type A antiferromagnet. The magnetic moments are codirectional within each layer and antiferromagnetically coupled between layers. The easy anisotropy axis is directed along the c axis.

Our object of study is the antiferromagnetic topological insulator Ge_(0.4)Mn_(0.6)Bi_2Te_4. Some of its Mn atoms are replaced by Ge. This leads to a proportional weakening of the magnetic sublattice [5]. We conducted a large-scale study using a cryogenic magnetic force microscope. Maps were taken at various magnetic fields ranging from -6.1 T to 2.025 T, at temperatures ranging from 5 K to 19.1 K. Domain contrast—the difference in magnetic signal in adjacent domains—was obtained (Fig. 1.b). It showed that the surface spin-flop occurred at different fields for different domains: H_(SSFa) = 1.4 T for those in which the magnetic moments of the upper layer are directed antiparallel to the applied field (SSFa), and at H_(SSFp) = 1.9 T for those in which the magnetic moments of the upper layer are directed co-directionally (SSFp). At H_(BSF) = 2.3 T, a bulk spin-flop (BSF) transition is visible. Near the field H_(SSFp), a state with developed magnetic inhomogeneity was detected, as well as the emergence of a vertical domain on the surface. It was discovered that the domain walls have uncompensated magnetization, which motivates a more detailed study of their structure (Fig. 1.c).

To study the magnetic structure of the sample, it was decided to use atomistic micromagnetic modeling with the following Hamiltonian implemented in the Spirit software package [6]:

Above the H_(SSFa) field, the appearance of a horizontal domain wall instead of the corresponding spin-flop transition was detected. This is a consequence of simulations with open boundary conditions along the C axis [7]. Since our crystal exhibits strong nonstoicheometry, it was decided to conduct simulations taking disorder into account. To this end, 40% of the spins in pure $MnBi_2Te_4$ were replaced by vacancies.



Pic.2 Magnetization as a function of temperature during simulation (a). Magnetization as a function of magnetic field during simulation (b). Domain contrast dependence obtained as a result of simulation (c).

This approach yielded a surface spin-flop transition. Figures 2.a and 2.b show the simulation results for M(T) and M(H), respectively. The obtained values are T_(N) = 14K, H_(BSF) = 3T, H_(c) = 4.5T, and H_(SSFa) = 1.5T. Figure 2.c shows the domain contrast as a function of the field corresponding to the SSFa transition. We see that the bulk spin-flop occurs due to the expansion of the surface state throughout the sample, which is reflected in Figure 2.c by a sharp jump in the domain contrast at 2.5T. We also see that an analog of the surface spin-flop transition can spontaneously arise deep within the sample near the transitions, generating a potentially large number of metastable states.

This work was supported by the Russian Science Foundation (grant no. 22-72-10074-P).

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P-24 | Poster session · Wednesday, 23 September 2026

Investigation of the Oxidation Kinetics of $MeBi_2Ch_4$ Crystals by XPS

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Keywords: topological insulator, XPS, oxidation

In modern solid-state physics, one of the most pressing challenges is the creation of stable topological insulators (TIs). Due to their unique properties, TIs represent a promising material platform for advanced quantum technologies. However, upon exposure to the atmosphere, the surface of TIs oxidizes and degrades, the layered structure is disrupted, and an amorphous oxide layer of the constituent elements forms on the surface. This leads to the suppression of topological surface states. A natural question arises: how can this problem be minimized? One solution is the use of chemically more inert materials. Within the consideration of TIs of the same structural type, their stability against oxidation and adsorbates can vary depending on the atomic composition [1]. Thus, by varying the chemical composition through doping, crystals of TIs more resistant to oxidation can be obtained within the same structural family.

In this work, we studied the kinetics and features of the interaction of tetradymite-like van der Waals crystals of the $MeBi_2Ch_4$ family, specifically $GeBi_2Te_4$, $GeBi_2Te_2Se_2$, $SnBi_2Te_4$, and $SnBi_2Te_2Se_2$, with oxygen using X-ray photoelectron spectroscopy (XPS). Based on the analysis of the obtained spectra, we compared the oxidation rates of these crystals and identified the compositions most resistant to this process (Fig.1).

This work was supported by Saint Petersburg University grant No. 125022702939-2.

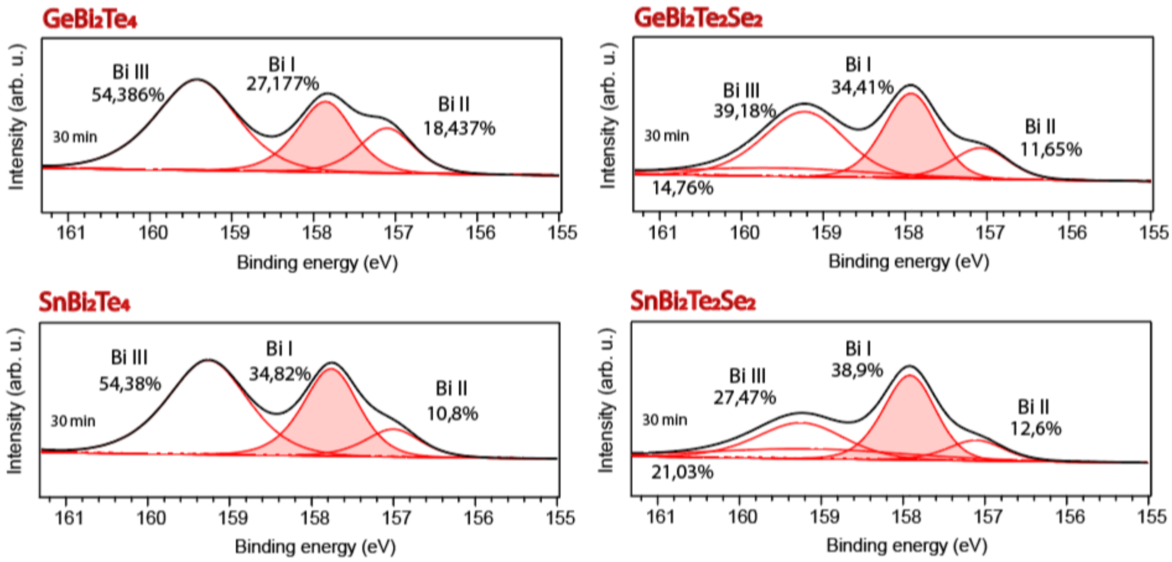

Fig.1 XPS spectra of the Bi 4f_(7/2) level for $GeBi_2Te_4$, $GeBi_2Te_2Se_2$, $SnBi_2Te_4$, and $SnBi_2Te_2Se_2$ compounds after 30 minutes of exposure to oxygen. Bi I – peak of bismuth in the original compound, Bi II – peak of elemental bismuth, Bi III – peak of bismuth oxide. The relative intensities of the components (in percent of the total intensity) are shown on the spectra.

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P-25 | Poster session · Wednesday, 23 September 2026

Microwave single-photon detectors based on superconducting tunnel nanostructures

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Keywords: Josephson threshold detector, RCSJ model, microwave photons

The experimental possibility of detecting signals so weak that they correspond to the energy of photons at a frequency of 5-10 GHz is shown using aluminum superconductor-insulator-superconductor (SIS) junctions at a temperature of 15-700 mK.

The basic scheme illustrating detector operation is shown in Fig. 1, left. Josephson junctions with critical currents from tens of nA to units of μA have been investigated [1, 2]. The switching statistics have been obtained, and it has been shown that the slopes of the switching probability correspond to the registration of one, two, three or more photons. Examples of such statistics are shown in Fig. 1, right. Decreasing the bias current value, we increase the potential barrier height and can change the number of detected photons.

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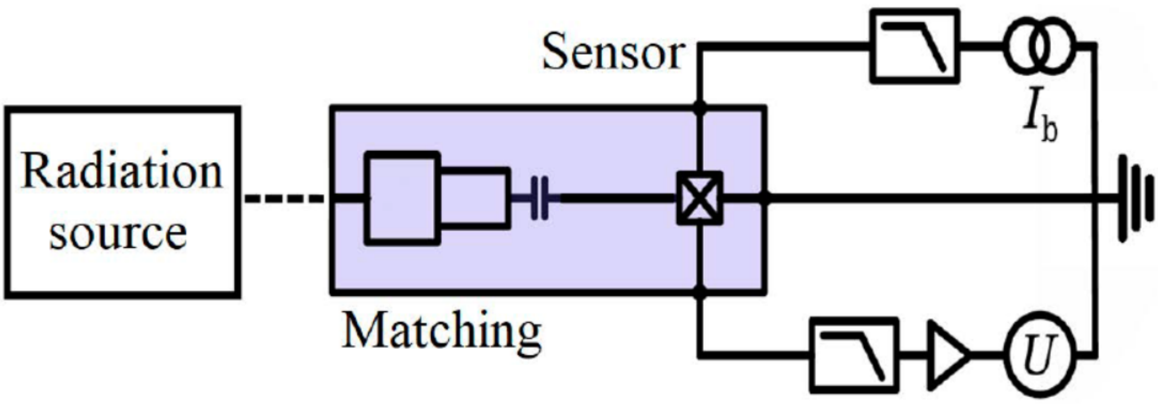
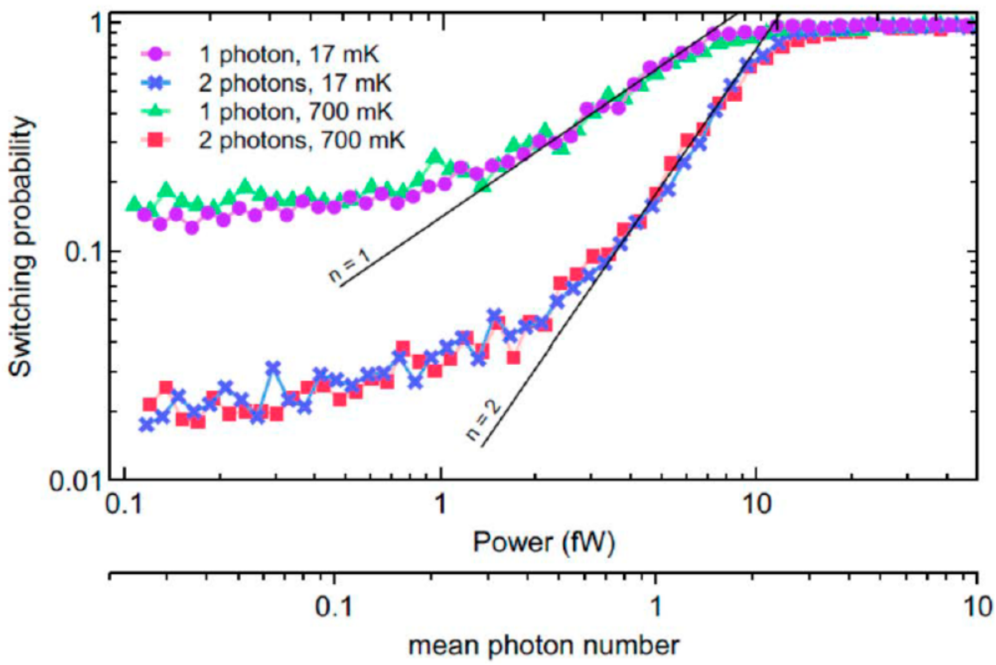


Pic.1 Left - Schematic diagram of a device with a sensor. Right - Switching probability versus normalized ac power of 4.86 GHz single- and double- photon detection at 17 mK and 700 mK.

One can see that the switching probability curves versus power, both at 17 mK and 700 mK, have tilts corresponding to single-photon and double-photon detection (one and two orders of probability to one order of power, respectively). Therefore, for 5 GHz microwave photons, we get about 15 % efficiency of single photon detection even at sub-K temperatures. It should be noted that the dark count rate (nearly constant part of the switching probability curves close to 0.1 level) is almost the same for both 700 mK and 17 mK temperatures.

This work was supported by the Russian Science Foundation, Project 21-79-20227.



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P-26 | Poster session · Wednesday, 23 September 2026

Coexistence of dipolar and quadrupolar higher-order topology

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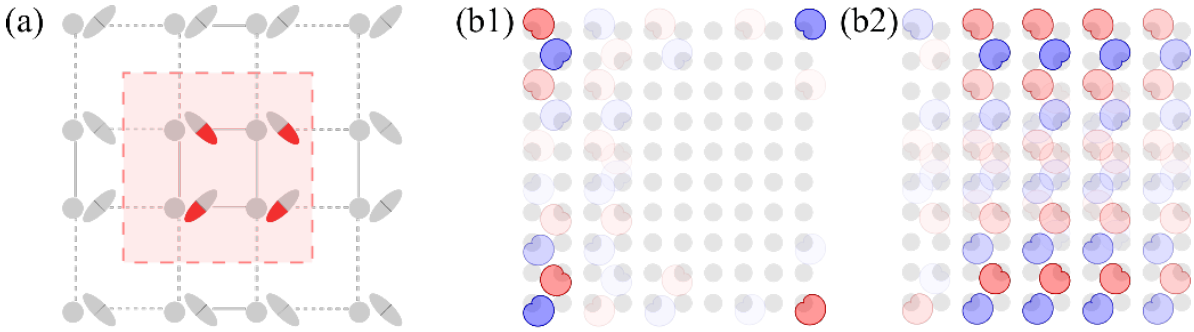
Keywords: HOTI, topology, edge and corner states

In recent years, two fundamental classes of higher-order topology observed in two-dimensional systems have been actively studied: dipole and quadrupole [1] topology. A systematic description of such systems has found wide application in the design of topological lasers, photonic chips, and beam splitters, as well as quantum topological amplifiers [2].

However, similarly to electrostatics, the quadrupole invariant is well defined only in systems with a vanishing dipole moment in the unit cell [3]; otherwise, it is not uniquely defined. Still, one can envision a finite system composed of two non-interacting layers with dipole and quadrupole higher-order topologies, contributing separately to edge and corner states. Thus, the coexistence of dipolar and quadrupolar topology is plausible.

In our work, we propose a systematic approach to determine the topological invariants for mixed dipole-quadrupole topological insulators, where the Wilson loop calculation separates the dipole and quadrupole Wannier subsectors. We show that the position operators projected onto the Wannier subsectors commute (do not commute) for the dipole (quadrupole) Wannier subsector, confirming the separation of these two types of higher-order topology in the Wannier band picture. The invariants computed for each of the Wannier subsectors turn out to be uniquely defined.



Pic.1 (a) Schematic of a lattice consisting of optical two-mode evanescently coupled waveguides. (b1) Corner and (b2) edge states in a finite lattice.

To confirm the possibility of coexistence of dipole and quadrupole topological phases on an optical waveguide platform, we developed the two-orbital model containing both dipole and quadrupole phases. The finite structure possesses both edge states and four corner states, which is consistent with the bulk-boundary correspondence principle.

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P-27 | Poster session · Wednesday, 23 September 2026

Sensitivity analysis of changes in the amplitude and range in spin dynamics

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Keywords: mathematical modeling, molecular dynamics, spin dynamics, LAMMPS, MEAM

Recent advances in nanoscale magnetic technologies, such as spintronics, MRAM, and ultra-high-density recording, require refined mathematical models that consider microparameters like exchange interactions, surface anisotropy, and defect distribution. These models are essential for engineering applications, ensuring manufacturing tolerances, long-term data preservation, and avoiding discrepancies between predicted and actual magnetic behavior due to size variations. Without such detailed analysis, mathematical modeling of magnetic nanostructures is insufficient for reliable industrial use.

The goal of this study is to quantitatively assess the influence of model parameters, particularly the amplitude ε and range δ, on the performance attributes of nanostructures. This endeavor aims to bridge the gap between theoretical mathematical models and the precise physical properties of actual materials.

To determine the coordinates and velocities of the atoms in the system, as well as to consider their magnetic moments, a mathematical model was applied based on the joint solution of the Langevin equation [1] and the Landau–Lifshitz–Hilbert stochastic equation [2]. The modified embedded atom method (MEAM) [3] was used as the interatomic potential. To analyze the sensitivity of the model, were chosen parameters that influence changes in the values of the magnetic energy and the magnetization norm.

The analysis demonstrated that magnetization norm is considerably more sensitive to variations in exchange integral parameters than magnetic energy. This is because magnetization depends on the delicate balance of spins, while energy is a more integrated quantity. A change in the amplitude parameter ε has a more pronounced effect on magnetic energy as it establishes the energy scale of interactions, and this effect intensifies with the percentage of deviation. The range parameter δ exerts a dominant influence on both characteristics. It modulates magnetic energy by scaling the exchange interaction and affects the magnetization norm, particularly in weak (0–0.5 T) and strong (2.5–3 T) fields due to a change in the exchange coupling radius or the «stiffness» of the spin subsystem.

Acknowledgments. The work was carried out within the framework of the state assignment No. FUUE-2025-0001 «Modeling and experimental studies of the structure and magnetic parameters of a Josephson contact from a multilayer nanostructure», state registration No. 125020501412-9.

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P-28 | Poster session · Wednesday, 23 September 2026

Hf/Pd bilayer Transition-Edge Sensors with sub-100 mK critical temperature

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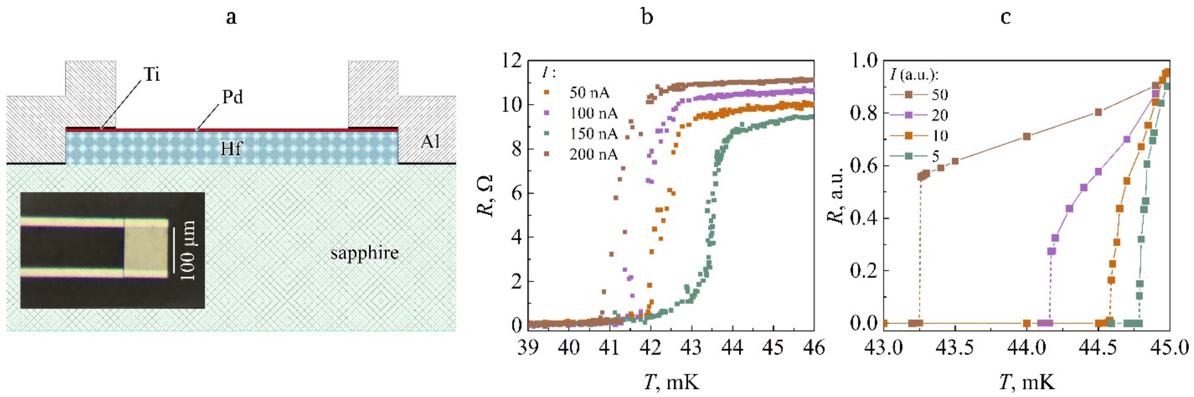
Keywords: TES, hafnium, TDGL model

We report a reproducible fabrication technology for Hf/Pd bilayer Transition-Edge Sensors (TES) [1] engineered for ultra-low operating temperatures and sub-eV energy resolution.

Using electron-beam deposition, a 100 nm Hf superconducting layer [2] is coated with a 5 nm Pd layer (Fig.1, a) to prevent oxidation and suppress its critical temperature.



Pic.1 (a) The detector cross-sectional model. (b) Experimental R(T) at various bias currents. (c) TDGL simulations at various bias currents.

The deposition is performed on a continuously cooled sapphire substrate, which increases defect density and film resistivity, jointly reducing T_(C) to 43-57 mK. Cryogenic measurements (Fig.1, b) demonstrate sharp superconducting transitions with widths of 0.1-3 mK (< 5% of T_(C)) and temperature sensitivity coefficients (α) ranging from 200 to 500.

Generalized time-dependent Ginzburg-Landau (TDGL) [3] simulations accurately reproduce the finite transition width and reversible resistive state without thermal hysteresis (Fig.1, c), confirming the type-I superconducting nature of the films. Intrinsic noise analysis yields a self-noise-limited energy resolution of ~0.03 eV; with a SQUID readout noise of 1 pA/√Hz, the total estimated resolution reaches 0.056 eV.

The proposed Hf/Pd TES technology offers a cost-effective and thermally stable alternative to complex W- or Ir-based sensors, making it highly suitable for advanced quantum sensing applications requiring sub-100 mK operation and an energy resolution below 1 eV.

The research was funded by the scientific program of the National Center for Physics and Mathematics (Section No. 8)

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P-29 | Poster session · Wednesday, 23 September 2026

Quantum enhanced magnetometry on a transmon qutrit based on phase estimation algorithm

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Keywords: quantum sensing, magnetometry, transmon

Phase estimation algorithms are among the most important protocols in quantum information science, offering precise and efficient methods for extracting phase information from quantum states. These protocols are essential for the advancement of quantum sensing technologies, enabling measurement precision that surpasses classical shot-noise limit and approaches the fundamental Heisenberg limit. In this study, we present a thorough comparative analysis of a transmon-based magnetic field quantum sensor utilizing phase estimation algorithms and operated in both qubit and qutrit regimes. Theoretical analysis under ideal, noise-free conditions indicates that both regimes can, in principle, reach the Heisenberg limit; however, operation in the qutrit regime affords a twofold improvement in the measurement precision prefactor compared to the qubit regime. In realistic experimental scenarios, however, external noise sources degrade the achievable precision and can significantly diminish the advantage offered by higher-dimensional regimes.

In this work, we experimentally compare the performance of phase estimation algorithms — Kitaev algorithm, the semiclassical Fourier transform, and LAMA—operating in both qubit and qutrit regimes. Our results demonstrate that three-level (qutrit) sensors outperform two-level (qubit) sensors in magnetic field sensing, even under noise conditions. Moreover, we show that LAMA outperforms both Kitaev's algorithm and the semiclassical Fourier transform in phase estimation efficiency. This superior performance arises from LAMA's use of linearly scaled Ramsey delay intervals, enabling operation at shorter delays while exploiting higher-contrast regions of the interference pattern to enhance phase sensitivity. Additionally, LAMA allows for a greater number of measurement steps within a fixed total measurement time, further improving the overall precision. Collectively, these findings underscore the significant potential of qudit-based sensors and advanced phase estimation protocols for practical quantum metrology applications.

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P-30 | Poster session · Wednesday, 23 September 2026

Reducing of TLS defects by Air-Qubit technological approach

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Keywords: superconducting qubits, fabrication technology, two-level systems, transmon

Superconducting qubits, based on Josephson junctions, is the one of the main candidates for creation of universal quantum computing. And one of the main criteria for such kind of qubits is relatively long coherence times [1]. To reach this criteria, worldwide community solve different problems which we can divide into 2 main challenges: quantum engineering challenges [2] and fabrication technology challenges.

Within the framework of fabrication technology, the main challenge is to minimize defects that occur during the fabrication of topological elements of qubit-based superconducting quantum circuits (resonators, qubits, additional components), as well as the use of low-loss materials.

The main role in losses (all other things being equal) is played by a defect called two-level systems (TLS-defects). This defect is present both in the material and is formed during the fabrication process of the circuit on various interfaces of the circuit. This type of defect forms a connection with the qubit at a resonant frequency and forms an energy dissipation channel, which leads to losses and a decrease in relaxation times and coherence of the qubit [3].

In this paper, we propose an approach to fabrication process of multi-qubit quantum circuits by removing the substrate-qubit and substrate-air interfaces (Fig.1) to minimize the effect of the TLS defect on the characteristics of the resulting qubits and increase the relaxation times and coherence of the finished quantum circuit.

(a)

(b)

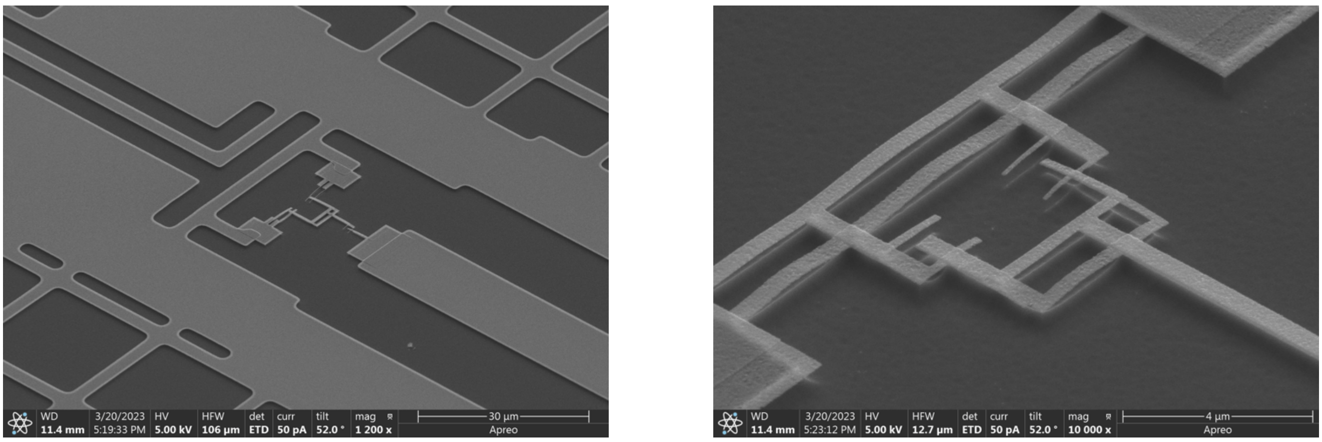

Fig. 1. Transmon qubit fabricated using the air-qubit approach: SEM images before and after interface removal.

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Magnetically Memorable Inductance in Superconducting Multi-layer Resonators

R. Tyumenev [1], * D. S. Kalashnikov[1], B. V. Fradkin[1], A. A. Neilo[2], V. S. Stolyarov[1], A. S. Sidorenko[3], S. V. Bakurskiy[2]

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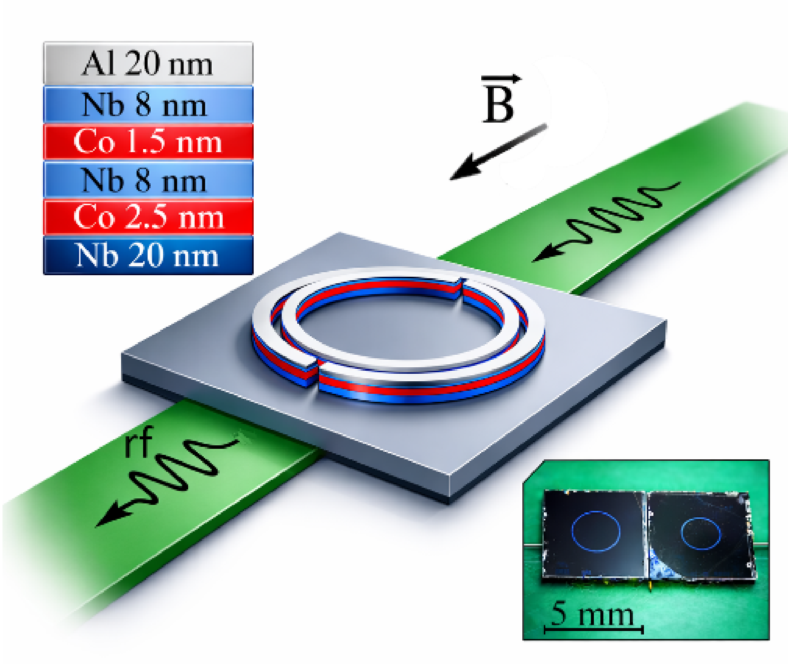
Keywords: functional material, kinetic inductance, spin-valve effect, superconducting resonator, proximity effect, neuromorphic computing

In this paper, a theoretical and experimental study of multilayer ring resonators with a hybrid (superconducting/ferromagnetic) structure has been carried out to create broadband tunable elements with low losses controlled by an external magnetic field. In contrast to traditional multilayer S/F/S/F/S structures, this work examines samples with an additional normal metal layer of aluminum (Al) integrated into the heterostructure. It is assumed that this layer, due to the strong effect of proximity to neighboring layers, can significantly increase the difference in the SRR inductance between the open and closed states, which is due to the high conductivity of Al [1].

As a result of this work, it was experimentally demonstrated that the resonant frequency of the SRR varies depending on the open or closed state of the spin valve. It has been shown that both states can be obtained in a zero magnetic field, which opens up the possibility of using this structure as a memory element. As a result of studying structures with and without a layer of ordinary metal, it was found that the addition of ordinary metal leads to an increase in the desired effect. In addition, a theoretical model has been proposed that successfully describes experimental data [1].

The results were obtained with the financial support of a grant implemented under the Agreement. No. 075-15-2025-010 dated 02/28/2025



Pic.1 The scheme of the experiment for measuring SRR . The layers that make up the SRR are shown in the upper-left corner.

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Temperature Dependence of Ferromagnetic Resonance Parameters in Yttrium Iron Garnet in the Millikelvin Range

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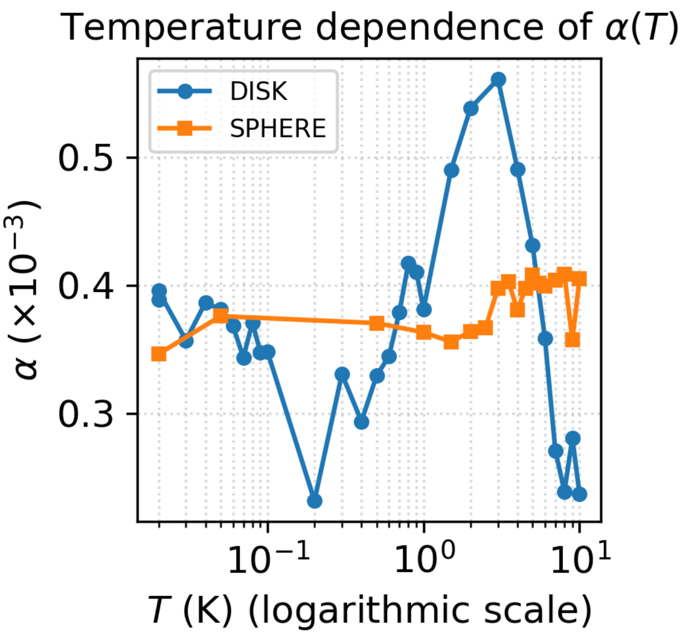
Keywords: yttrium iron garnet (YIG), ferromagnetic resonance (FMR), hybrid quantum systems

In this work, two configurations of YIG samples were compared: a disk grown on substrates of gadolinium gallium garnet ($Gd_3Ga_5O_{12}$) and yttrium–scandium gallium garnet ($Y_3Sc_2Ga_5O_{12}$) [1], and a sphere made from bulk single-crystal YIG (free from substrate influence). FMR spectra were measured in a BlueFors dilution refrigerator over a temperature range from 16 mK to 9 K and in external magnetic fields from 3 to 5 T. Microwave measurements were performed using vector network analysis techniques. The resonance curves were analyzed using a model based on the Landau–Lifshitz–Gilbert (LLG) equation. Numerical modeling of the frequency dependence of the resonance field and FMR linewidth was carried out. The Gilbert damping parameter α was extracted by fitting the experimental data using solutions of the LLG equation [2].

For the disk, with an optimized substrate, a result comparable to that of a bulk single crystal is achieved. Such values of the damping parameter can provide sufficiently long coherence times for quantum systems. The nonlinear behavior observed for the disk is likely associated with the presence of a paramagnetic substrate.



Pic.1 Temperature dependence of the Gilbert damping parameter α for the disk and sphere

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Superconducting Niobium TSV Contacts for Cryoelectronic Devices: Effect of Supercycle Etching on Sidewall Quality and Qubit Fabrication Prospects

Ivan Filippov[1], Aleksandr Anikanov[1], Aleksandr Rykov[1], Alexander Mumlyakov[1], Maksim Shibalov[1], Igor Trofimov[1], Nikolay Porokhov[1], Michael Tarkhov[1]

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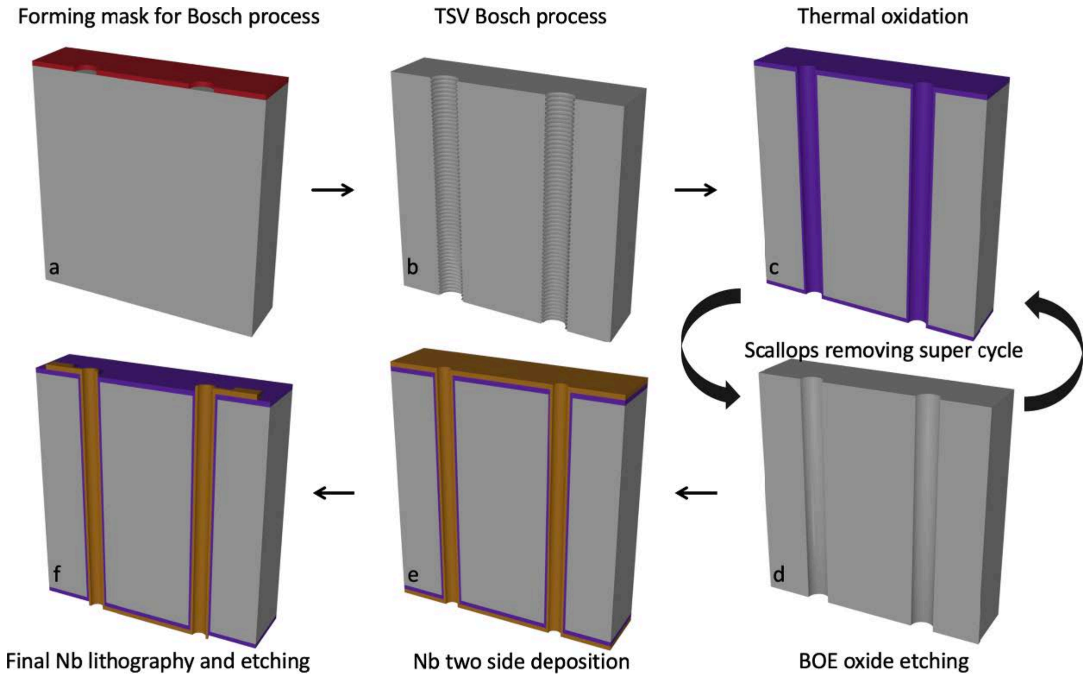
Keywords: superconducting interconnects, sputter deposition, deep reactive ion etching, Bosch process, niobium, cryo-electronics, superconductors

The fabrication of superconducting interconnects using niobium-based through-silicon vias (TSVs) is the focus of this study. The impact of a supercycle—comprising sequential oxidation and chemical etching—on the quality of through-etch sidewalls was investigated. Experimental results demonstrate that incorporating this supercycle substantially improves TSV sidewall quality and eliminates scalloping defects. After twelve repetitions of the supercycle, dissipative electrical coupling is achieved between the superconducting strips on the front and back sides of the sample, with a critical current density of 5×10^4 A cm^{-2}. The critical ratio of substrate thickness to hole diameter required to form such electrical coupling is found to be 3:1. This approach shows promise for application in the fabrication of superconducting qubits.



Pic.1 Graphical presentation of the main steps in the process route for the fabrication of TSV interconnects: (a)—preparing mask for TSV etching, that is the window in SiO2 layer by laser photolithography and plasma etched anisotropic process; (b)—Bosch process 460 μm

deep and removal of top and bottom silicon oxide in BOE solution; (c) and (d)—Re-oxidation and removing of silicon oxide several times from TSV channels; (e)—deposition of 200 nm thick niobium on both sides; (f)—lithography and etching of niobium layers on both sides.

The study was supported by project No. 125020501540-9 of the Ministry of Education and Science of the Russian Federation. Fabrication and technology characterization were carried out at large scale facility complex for heterogeneous integration technologies and silicon+carbon nanotechnologies.

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High-Precision State Discrimination of a Transmon Qutrit Using a Feedforward Neural Network

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Keywords: transmon, qutrit, FNN, readout

Reducing qubit state readout errors is one of the key challenges on the path to realizing quantum computers. As the number of qubits grows, classical readout methods become inefficient and, moreover, are inapplicable to higher-dimensional systems such as qutrits or qudits. In particular, accurate qutrit state readout is critical for quantum magnetometry tasks, where the sensor's precision directly depends on measurement accuracy.

In this work, we propose the use of a feedforward neural network (FNN) for classification of the transmon qutrit state. This approach offers several advantages over other methods, such as support vector machines (SVM) and their nonlinear variants (NSVM). Unlike SVMs, which require full retraining each time the system is recalibrated, FNNs support transfer learning, significantly accelerating the network adaptation process upon system parameter changes. Furthermore, FNNs demonstrate superior performance in classifying multilevel systems like qutrits and exhibit high scalability.

The neural network was implemented and trained using the PyTorch library. The developed FNN takes as input the in-phase and quadrature components (I and Q) of the two-tone signal obtained during qutrit state measurement (I1[n], Q1[n], I2[n], Q2[n]). The network architecture consists of two hidden layers with 16 and 8 nodes respectively, employing the SELU (Scaled Exponential Linear Unit) activation function. The output layer contains three nodes with a softmax activation function, representing the probabilities of the qutrit being in states $|0\rangle$, $|1\rangle$, and $|2\rangle$. Training was performed using the Adam optimizer with a learning rate of 0.0005 and the cross-entropy loss function. The dataset comprised 8000 training and 2000 validation samples. Training lasted for 300 epochs with a batch size of 64.

The training results show that the achieved accuracy of qutrit state discrimination is 90.2%. Additionally, the use of the FNN demonstrates greater robustness to fluctuations in qutrit parameters compared to classical methods. This feature is especially important for quantum magnetometry, where the qutrit is detuned from its ”sweet spot” to enhance sensitivity to magnetic flux, which also causes frequency jitter.

Thus, the proposed approach shows potential for significantly improving measurement accuracy in quantum magnetometry tasks and can be adapted for other applications involving multilevel quantum systems.

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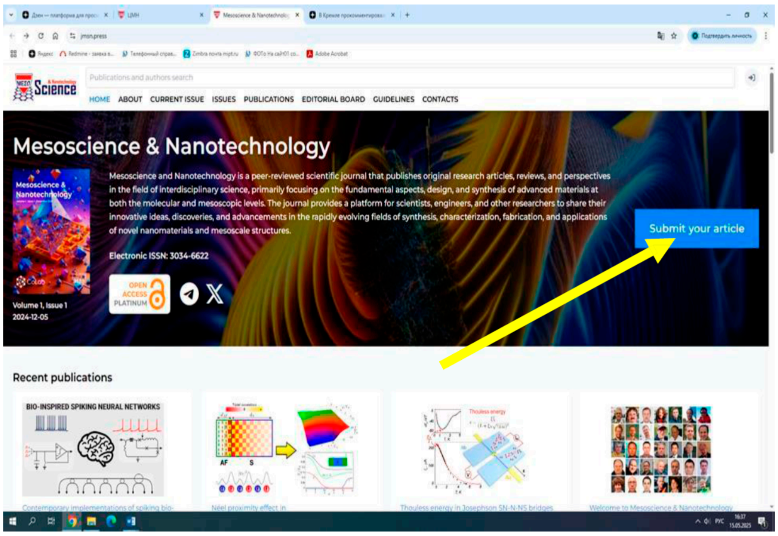

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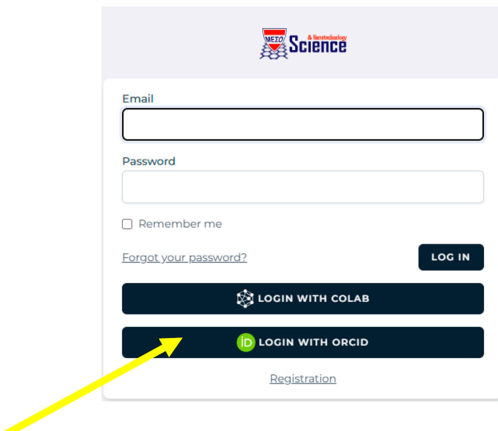

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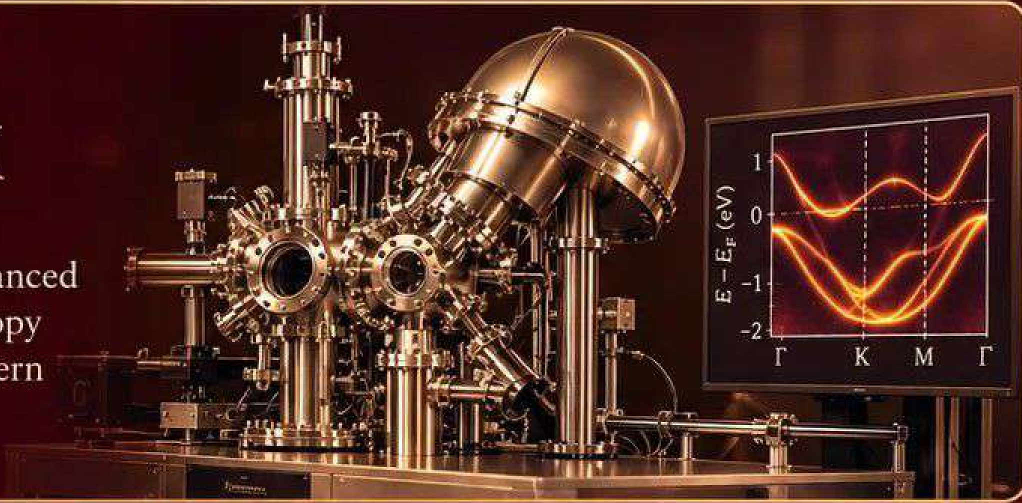

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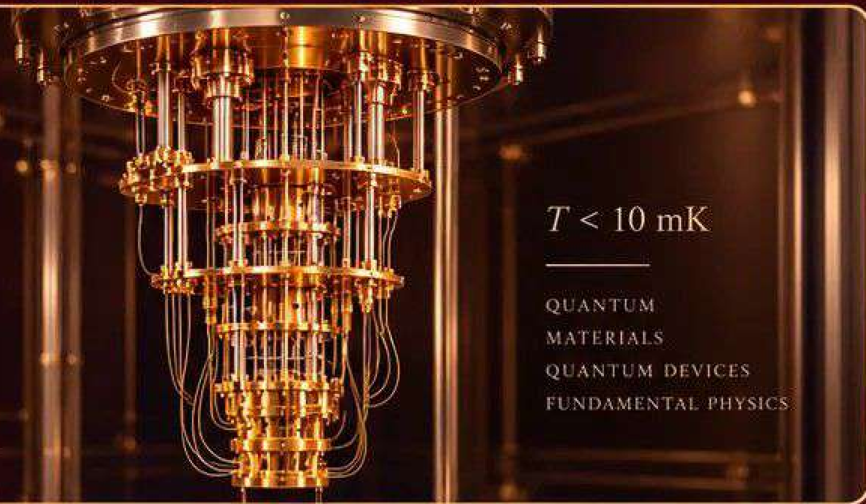

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