Annual DIPC—UPV/EHU Quantum Workshop 2021

UPV/EHU Bilbao

Program

October 8, 2021

organized by UPV/EHU and DIPC

1 Program

9:00h arrival, welcome

9:30h Juanjo Garcia-Ripoll: Distributed quantum gates between quantum computers connected by a quantum link

10:00h Dario Bercioux: Tunable geometric phase in graphene quantum dots with spin-orbit coupling

10:30h Ricardo Dièz Muino and Igor Campillo: Strategic programs on Quantum Technologies

11:00h coffee break

11:30h Deung-Jang Choi: Atomic engineering of spin structures on superconductors

12:00h Mikel Iraola: Towards a Topological Quantum Chemistry description of correlated systems: the case of the Hubbard diamond chain

12:30h Fernando de Juan: Electronic instabilities of two-dimensional metallic dichalcogenides

13:00h lunch break

14:00h Jorge Casanova: Diamond based quantum technologies

14:30h Maxim Ilyn: Magnetic-Semiconductor/Superconductor Heterostructures for Implementation of Topological and Superconducting Spin Qubits

15:00h Jens Siewert: The shape of higher-dimensional state space: Bloch-ball analog for a qutrit

15:30h coffee break

16:00h poster session

2 Venue and Contact Data

Organizers: Enrique Rico, Michele Modugno, Géza Giedke, Roman Orús

Local organizer: Enrique Rico

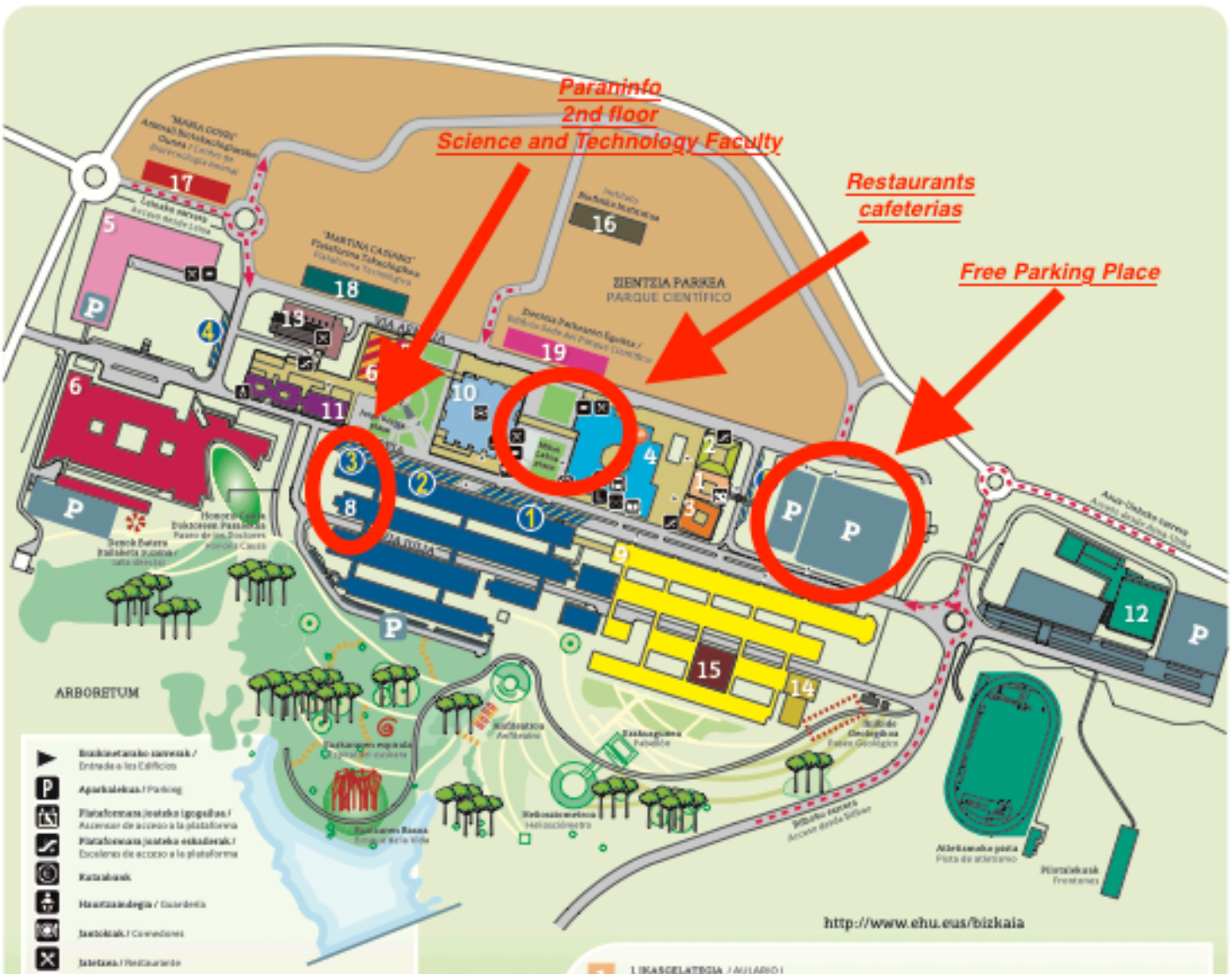
Contact:
enrique.rico.ortega@gmail.com

Website: `http://dipc.ehu.es/giedke/eusqutech21.html`

Venue: Paraninfo of Science and Technology Faculty FCT/ZTF
University of the Basque Country UPV/EHU
Barrio Sarriena, s/n, 48940 Leioa, Biscay

Bizkaiko Campusa
Campus de Bizkaia
Leioa-Erandio

Universidad del País Vasco / Euskal Herriko Unibertsitatea



AUTOBUS GELTOKIAK / PARADAS DE AUTOBÚS

1. MIKEL LABOA PLAZA
   - A3161 UPV/EHU - Bizkaia Dulia / Puente Colgante
   - A3510 UPV/EHU - Termibus
   - A3604 UPV/EHU - Uraondoa/Cruces - Ibaiondoa
2. BIBLIOTEKA
   - A3501 UPV/EHU - Santutxu
   - A3506 UPV/EHU - Bilbokoi
   - A3630 UPV/EHU - Galdakao
   - A3631 UPV/EHU - Ugao Miraballes
3. JORGE OTEIZA PLAZA
   - A3505 UPV/EHU - Santutxu
   - A3506 UPV/EHU - Sarrao
   - A3506 UPV/EHU - Basauldo
4. ERREKTORDEGIA - RECTORADO
   - A3505 UPV/EHU - Gernika
   - A3508 UPV/EHU - Bermeo-Mungia-Orozko
   - A3904 UPV/EHU - Ermua
   - A3151 Azoeta - Larrabetzu
5. IRAKASLEAPEGIAK - AULARIOS
   - A3163 UPV/EHU - Andraonatzi / Santa María de Getxo (Algortako Etorbidetik / por Algorta)
   - A3163 UPV/EHU - Erandio
   - A3164 UPV/EHU - Getxo (Makuleta Etorbidetik / por Av. Chopera)
   - A3501 UPV/EHU - Bilbao-Erandio-Astrabudua
   - A3151 Azoeta - Larrabetzu
   - A3166 UPV/EHU - Uribe Kosta

Erakinetarako sarrerak / Entrada a los Edificios
Aparkalekua / Parking
Plataformara jaisteko igogailua / Ascensor de acceso a la plataforma
Plataformara jaisteko eskailerak / Escalera de acceso a la plataforma
Kutxabank
Haurtzaindegia / Guardería
Jantokiak / Comedores
Jatetxea / Restaurante
Kafetegia / Cafetería
Liburu denda - Paper denda / Librería - Papelería
Supermerkatua / Supermercado
Autozerbitzua / Autoservicio
Hizkuntza Laborategia / Laboratorio de Lenguas
Optika / Óptica
Ikasleentzako Zerbitzuak (IAE, Ikasle kanseilua...) / Servicios para el Alumnado (SOIL Consejo de Estudiantes...)
Bizkaiko Garraio Publikoaren Bulegoa / Oficina del Transporte Público de Bizkaia

BUS from intermodal where Donostia bus arrives

1. IRAKASGELATEGIA / AULARIO I
   — Ikasleen Atala / Sección de alumnado
2. BIZKAIKO CAMPUSEKO ERREKTOREORDEKETZA / VICERRECTORADO DE CAMPUS DE BIZKAIA
   ZUZENDEKETA FAKULTATEA-BIZKAIA / FACULTAD DE DERECHO-BIZKAIA
3. LAN HARREMAN ETA GIZARTE LAN ZIENTZIA FAKULTATEA / FACULTAD DE RELACIONES LABORALES Y TRABAJO SOCIAL
4. GIZARTE ETA KOMUNIKAZIO ZIENTZIEN FAKULTATEA / FACULTAD DE CIENCIAS SOCIALES Y DE LA COMUNICACIÓN
5. BILBOKO HEZKUNTZA FAKULTATEA / FACULTAD DE EDUCACIÓN DE BILBAO
6. ARTE EDERREN FAKULTATEA / FACULTAD DE BELLAS ARTES
7. ARETO NAGUSIA / AULA MAGNA
   Arte Ederren Fakultatea / Facultad de Bellas Artes - 2. Eraikina / Edificio 2
8. ZIENTZIA ETA TEKNOLOGIA FAKULTATEA / FACULTAD DE CIENCIA Y TECNOLOGÍA
9. MEDIKUNTZA ETA ERIZAINTZA FAKULTATEA / FACULTAD DE MEDICINA Y ENFERMERÍA
   — Klinika Odontologikoa / Clínica Odontológica
10. BIBLIOTEKA NAGUSIA / BIBLIOTECA CENTRAL
    — Argitalpen Zerbitzua / Servicio Editorial
11. ERREKTORDEGIA / RECTORADO
    — ZITEK (Enpresa-sustapena / Vivero de empresas)
12. KIROLGINTZA / POLIDEPORTIVO
    — Kirol Zerbitzua / Servicio de Deportes
13. LHII-OSTALARITZA ESKOLA / HTP-ESCUELA DE HOSTELERÍA
14. ABELTEGIA / ANIMALARIO
15. TITIAN / TITIÁN

ZIENTZIA PARKEA / PARQUE CIENTÍFICO

16. BIOFISIKA INSTITUTUA / INSTITUTO BIOFÍSICA
17. "MARIA GOYRI" ANIMALI BIOTERMOLOGIARAKO GUNEA / CENTRO DE BIOTECNOLOGÍA ANIMAL
18. "MARTINA CASANO" PLATAFORMA TEKNOLOGIKOA / PLATAFORMA TECNOLÓGICA
19. ZIENTZIA PARKEAREN EGOITZA / EDIFICIO SEDE DEL PARQUE CIENTÍFICO

3 Invited Talks and Poster Contributions

1. Bercioux, Dario (DIPC & Ikerbasque, Donostia)
   Tunable geometric phase in graphene quantum dots with spin-orbit coupling

2. Casanova, Jorge (UPV/EHU & Ikerbasque, Bilbao)
   Diamond based quantum technologies

3. Choi, Deung-Jang (DIPC, CFM & Ikerbasque, Donostia)
   Atomic engineering of spin structures on superconductors

4. de Juan, Fernando (DIPC & Ikerbasque, Donostia)
   Electronic instabilities of two-dimensional metallic dichalcogenides

5. Dièz Muino, Ricardo (DIPC & CFM, Donostia)
   Strategic programs on Quantum Technologies

6. García-Ripoll, Juan José (CSIC IFF, Madrid)
   Distributed quantum gates between quantum computers connected by a quantum link

7. Ilyn, Maxim (CFM, Donostia)
   Magnetic-Semiconductor/Superconductor Heterostructures for Implementation of Topological and Superconducting Spin Qubits

8. Iraola, Mikel (DIPC, Donostia)
   Towards a Topological Quantum Chemistry description of correlated systems: the case of the Hubbard diamond chain

9. Siewert, Jens (UPV/EHU & Ikerbasque, Bilbao)
   The shape of higher-dimensional state space: Bloch-ball analog for a qutrit

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1. Alaña, Aitor (UPV/EHU, Bilbao)
   Superfluid-Supersolid Phase Transition in a Dipolar BEC

2. D'Emidio, Jonathan (DIPC, Donostia)
   Entanglement Entropy from Nonequilibrium work

3. Englbrecht, Matthias (U Innsbruck, DIPC)
   Party-local Clifford transformations of stabilizer states

4. Garcia de Andoin, Mikel (UPV/EHU, Bilbao)
   Digitized Quantum Annealing for Logistic Network Design Problems

5. Gatti, Giancarlo (UPV/EHU, Bilbao)
   Random Access Codes via Quantum Contextual Redundancy

6. Gonzalez Conde, Javier (UPV/EHU, Bilbao)
   Efficient loading of density functions into a quantum computer

7. Huang, Tangyou (UPV/EHU, Bilbao)
   Shortcuts to Adiabaticity for Interacting Trapped Bose Gases

8. Ibarrondo, Rubén (UPV/EHU, Bilbao)
   Quantum Genetic Algorithm

9. Jimenez, Miguel Angel (CFM, Donostia)
   On the origin of the corner modes of the breathing kagome lattice

10. Jyoti, Divya (CFM, Donostia)
    Superconducting gap engineering

11. Mier, Cristina (CFM, Donostia)
    Spin chains in a superconductor towards to topological superconductivity

12. Munoz Segovia, Daniel (DIPC, Donostia)
    Superconducting Collective Modes in Single-layer NbSe2

13. Munuera Javaloy, Carlos (UPV/EHU, Bilbao)
    Robust Detection of High-Frequency Signals at the Nanoscale

14. Reichert, Maximilian (UPV/EHU, Bilbao)
    Quantum-enhanced Doppler radar for velocity estimation

15. Sanz, Sofia (DIPC, Donostia)
    N-terminal Graphene-based Nanostructures for Electron Quantum Optical setups

Tunable geometric phase in graphene quantum dots with spin-orbit coupling

Dario Bercioux

DIPC, Ikerbasque, Donostia

We show that the confined states at a circular pn junction in graphene with strong proximitized spin-orbit coupling and in a perpendicular magnetic field are analogous to the states of a semiconducting quantum ring. We derive the effective one-dimensional Hamiltonian governing the spin dynamics of the zero-mode and calculate the associated geometric phase. We find that for a given polarity of the junction, there exists a special point in parameter space where the spin is fully polarized in the radial direction in the plane. Additionally, we propose a circuit in a quantum Hall framework mimicking a semiconductor quantum ring with spin-orbit coupling.

Diamond based quantum technologies

Jorge Casanova

UPV/EHU, Ikerbasque, Bilbao

Quantum Sensing with nitrogen-vacancy (NV) centers in diamond promise to revolutionize detection and imaging techniques. Via the adequate application of radiation patterns over the NV sensor, one can increase spectral resolution up to a level that allows us to detect and position individual nucleus in a target sample such as a large biomolecule. In this talk I will comment on quantum control protocols based on dynamical decoupling techniques to increase accuracy in detection and control of large nuclear ensembles for important technological applications such as quantum information storage and processing, as well as for imaging purposes.

Atomic engineering of spin structures on superconductors

Deung-Jang, Choi[1,2,3]

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Scanning tunneling microscopy (STM) has proved to be a mature technique for the study of magnetic impurities on different substrates. Additionally, the STM allows us to manipulate atoms and assemble magnetic structures of atomic dimensions that are going to behave differently depending on their geometrical and chemical environment. We have applied our techniques to the study of magnetic spectra on atomic spin structures not only on metallic system [1] but also on superconducting surfaces [2-4] revealing the topological properties [5,6]. Recently, the introduction of impurity states in the superconducting gap has received a lot of attention. Indeed, the search of a new superconducting state called topological superconductivity is strongly based in the combination of doping classical (s-wave) superconductors with magnetic impurities that arrange spins in a chiral fashion. We present the first results of controlled single-atom manipulation to assemble a chain of Cr atoms on a Bi_2Pd superconductor. Such magnetic impurities on different substrates allow us to explore many-body effects and exotic phenomena in different experimental spin systems giving an understanding on the parameters on each system.

References

[1] Choi D.-J., et al. Building Complex Kondo Impurities by Manipulating Entangled Spin Chains, Nano Lett., **17** (10), pp 6203–6209 (2017).

[2] Choi D.-J., et al. Mapping the orbital structure of impurity bound states in a superconductor. Nat. Commun. **8**, 15175 (2017).

[3] Choi D.-J., et al. Influence of Magnetic Ordering between Cr Adatoms on the Yu-Shiba-Rusinov States of the β-Bi2Pd superconductor, Phys. Rev. Lett., **120**(16), 167001 (2018).

[4] Mier C., Verlhac B., Garnier L., Robles R., Limot L., Lorente N., and Choi D.-J., Superconducting Scanning Tunneling Microscope Tip to Reveal Sub-millielectronvolt Magnetic Energy Variations on Surfaces, The Journal of Physical Chemistry Letters **12** (11), 2983-2989 (2021).

[5] Mier C., Hwang J., Kim J., Bae Y., Nabeshima F., Imai Y., Maeda A., Lorente N., Heinrich A. and Choi D.-J., Atomic Manipulation of In-gap States on the β-Bi2Pd Superconductors, Physical Review B 104 (4), 045406 (2021).

[6] Cristina Mier, Deung-Jang Choi, Nicolás Lorente, arXiv:2108.11146

Electronic instabilities of two-dimensional metallic dichalcogenides

Fernando de Juan

DIPC, Ikerbasque, Donostia

Transition metal dichalcogenides like NbSe2 are metals with simple, large Fermi surfaces and well known charge density wave and superconducting instabilities. In this talk I will review their salient features in their bulk form, and then discuss recent experiments with single layers which display striking features at odds with the common lore: a breaking of threefold symmetry in transport and the emergence of collective bosonic modes in tunneling. I will then discuss how most evidence suggests that a competing order parameter, likely of f-wave symmetry, might become important in monolayers, and address how this can reconcile the experimental puzzles.

Strategic programs on Quantum Technologies

Ricardo Diez Muino and Igor Campillo

(1) DIPC, CFM, Donostia (2) Euskampus

Distributed quantum gates between quantum computers connected by a quantum link

Juan José García-Ripoll

CSIC IFF, Madrid

In this talk I will discuss the design and optimization of quantum protocols between coupled quantum computers made of transmon qubits, cavities and a long transmission waveguide that connects both devices. I will discuss the operation of this device under realistic assumptions of finite separation, finite bandwiths, finite qubit lifetime and limited couplings. We will see the how the parameters of the device can be optimized for implementing both transfer of information as well as delocalized universal two-qubit gates, and how multiplexing can aid in increasing both the bandwidth and the effective connectivity of the device. This work has been supported by H2020 FET-Open Project SuperQuLAN (https://www.superqulan.eu)

Magnetic-Semiconductor/Superconductor Heterostructures for Implementation of Topological and Superconducting Spin Qubits

Maxim Ilyn

CFM, Donostia

Interfacing magnetic semiconductors with superconductors allows for generation of the spin-split density of states in the superconductors that can be used for manipulation of superconducting spin qubits. In addition, in the presence of materials with strong spin-orbit interactions, these heterostructures can be pivotal in developing of topological qubits based on Majorana fermions. In this talk, we present our recent experimental results on magnetic and electronic properties of Al/EuS and $NiBr_2/NbSe_2$ heterostructures and the development of the first devices, based on these materials.

Towards a Topological Quantum Chemistry description of correlated systems: the case of the Hubbard diamond chain

Mikel Iraola

DIPC, Donostia

The recently introduced topological quantum chemistry (TQC) framework has provided a description of universal topological properties of all possible band insulators in all space groups based on crystalline unitary symmetries and time reversal. While this formalism filled the gap between the mathematical classification and the practical diagnosis of topological materials, an obvious limitation is that it only applies to weakly interacting systems. It is an open question to which extent this formalism can be generalized to correlated systems that can exhibit symmetry protected topological phases which are not adiabatically connected to any band insulator. In this work we address the many facettes of this question by considering the specific example of an extended version of a Hubbard diamond chain. This model features different insulating phases, including a Mott phase. First, we discuss the nature of these phases and determine the phase diagram and topology of the interacting model with infinite density matrix renormalization group calculations, variational Monte Carlo simulations and with many-body topological invariants. We then proceed by considering a generalization of the TQC formalism to Green's functions combined with the concept of topological Hamiltonian to identify the topological nature of the phases. The results are benchmarked with the above determined phase diagram and we discuss the applicability and limitations of the approach.

The shape of higher-dimensional state space: Bloch-ball analog for a qutrit

Jens Siewert

UPV/EHU & Ikerbasque, Bilbao

Geometric intuition is a crucial tool to obtain deeper insight into many concepts of physics. A paradigmatic example is the Bloch ball, the geometrical representation for the state space of the simplest possible quantum system, a two-level system (or qubit). However, already for a three-level system (qutrit) the state space has eight dimensions, so that its complexity exceeds the grasp of our three-dimensional space of experience. This is unfortunate, given that the geometric object describing the state space of a qutrit has a much richer structure and is in many ways more representative for a general quantum system than a qubit. In this work we demonstrate that, based on the Bloch representation of quantum states, it is possible to construct a three-dimensional model for the qutrit state space that captures most of the essential geometric features of the latter. Besides being of indisputable theoretical value, this opens the door to a new type of representation, thus extending our geometric intuition beyond the simplest quantum systems.

Superfluid-Supersolid Phase Transition in a Dipolar BEC

Aitor Alaña

UPV/EHU, Bilbao

We investigate the nature of the quantum phase transition between superfluid and supersolid phases of a dipolar BEC (162Dy) by performing numerical simulations for both the ground state and the dynamical crossing of the transition. The project has been carried out in a very close collaboration with a recent experiment in the group of G. Modugno in Pisa. By changing the trapping frequencies we are able to createquasi-2D and quasi-1D transitions, which show relevant differences.

Entanglement Entropy from Nonequilibrium work

Jonathan D'Emidio

DIPC, Donostia

The R?nyi entanglement entropy in quantum many-body systems can be viewed as the difference in free energy between partition functions with different trace topologies. We introduce an external field λ that controls the partition function topology, allowing us to define a notion of nonequilibrium work as λ is varied smoothly. Nonequilibrium fluctuation theorems of the work provide us with statistically exact estimates of the R?nyi entanglement entropy. We apply this framework in the context of Monte Carlo simulations of quantum spin systems, allowing for entropy calculations of unprecedented size.

Reference: Phys. Rev. Lett. 124, 110602

Party-local Clifford transformations of stabilizer states

Matthias Englbrecht

U Innsbruck, DIPC

Graph states are important for various tasks in quantum information theory. We study how these states transform under party-local Clifford transformations (PLC). Such transformations arise, for instance, in quantum networks where local operations are complemented by shared entanglement between spatially close nodes of the network, a setting that becomes relevant as experimental techniques advance. For the 3-partite case, the problem of PLC equivalence of graph states has been solved in [1] via the introduction of an entanglement generating set (EGS), a finite set of states into a collection of which every graph state decomposes uniquely under PLC. We show that the EGS is infinite for more than 3 parties and that finding states in the EGS is equivalent to a classification problem of tuples of alternating matrices. Moreover, we generalize the notion of local complementation, which describes the action of local Clifford transformations on graph states.

[1] Sergey Bravyi, David Fattal, and Daniel Gottesman. *GHZ extraction yield for multipartite stabilizer states*. Journal of Mathematical Physics 47.6 (2006): 062106.

Digitized Quantum Annealing for Logistic Network Design Problems

Mikel Garcia de Andoin

UPV/EHU, Bilbao

We propose a digitized quantum annealing algorithm to solve logistic network design problems, which consists of finding the configuration of factories delivering goods to a set of clients through a series of supply lines under the condition of minimum cost. Our algorithm employs improved heuristics for the selection of the parameters of the Hamiltonian encoding the problem. We also propose an evolution scheme which allows us to reach high fidelities with a circuit depth that grows linearly with the number of factories J, clients I, and the number of discretization steps n_T in an ideal quantum computer, i.e. $\mathcal{O}(2n_T(I+J))$. We present an alternative evolution scheme based on digital quantum computation, which can be implemented in a realistic quantum computer with a limited connectivity among qubits. Remarkably, numerical simulations show that our algorithm succeeds in obtaining a high fidelity for a predictable selection of n_T and total annealing times T. Finally, we introduce the tools required to implement this algorithm in both digital and digital-analog paradigms.

Random Access Codes via Quantum Contextual Redundancy

Giancarlo Gatti

UPV/EHU, Bilbao

We propose a protocol to encode bits in the measurement statistics of parity observables with overlapping contexts. The intrinsic information redundancy of quantum contexts allows for a compressed encoding and efficient retrieval when large entangled states ($>$ 18 qubits) perform the encoding. Applications of this protocol include algorithms involving storage of large amounts of data but requiring only partial retrieval of the information, as is the case of decision trees. In particular, we showcase quantum advantage over state-of-the-art information storage capacity for more than 44 qubits, and prove that systems above 100 qubits would suffice to encode a brute force solution for games of chess-like complexity.

Efficient loading of density functions into a quantum computer

Javier Gonzalez Conde

UPV/EHU, Bilbao

The loading of classical data into a quantum computer represents an essential requirement for the implementation of many promising quantum algorithms, especially in the field of quantum machine learning. Thus, the lack of an efficient universal protocol for quantum state preparation means a major bottleneck for their applicability. In this article, we introduce a quantum state preparation method that addresses this issue and partially solves the loading of density functions. Based on the Grover-Rudolph algorithm and assuming an acceptable error, ϵ, measured in terms of the fidelity, our proposed protocol reduces the complexity from $\mathcal{O}(2^n)$ to $\mathcal{O}(2^{k_0(\epsilon)})$ by clustering angles, where n is the number of qubits and $k_0(\epsilon)$ is asymptotically independent of n. Our result guarantees a dramatic reduction in the number of two-qubit gates required for the loading discretized density functions. Therefore, the presented algorithm serves as a stepping stone for new applications in quantum machine learning, and in quantum computation in general. Additionally, we present an ansatz for variational models, inspired by our protocol, that is capable of loading functions containing zeros, and thus do not satisfy the necessary conditions of our procedure.

Shortcuts to Adiabaticity for Interacting Trapped Bose Gases

Tangyou Huang

UPV/EHU, Bilbao

Frictionless quantum control of atomic interacting Bose gases is difficult to achieve due to the absence of invariant and scaling law. In this regard, we constructed shortcut-to-adiabaticity protocols for the expansion of the effectively one-dimensional Bose-Einstein condensate (BEC) loaded in the time-dependent harmonic trap using an auxiliary equation produced by variational approximation for week interaction and the effective scaling approach for arbitrary values of interactions. Taking into account the BEC's intrinsic nonlinearity, results are reported for the minimal transfer time, excitation energy (which measures deviation from the effective adiabaticity), and stability of control strategies for interactions between the noninteracting and the Thomas-Fermi limits. These results are not only useful for the realization of fast frictionless cooling, but also help us to address fundamental problems of the quantum speed limit and thermodynamics.

Quantum Genetic Algorithm

Rubén Ibarrondo

UPV/EHU, Bilbao

Genetic Algorithms (GAs) are extremely successful bioinspired optimisation algorithms, which emulate the natural selection process. Merging GAs with quantum computation is an old ambition which has been considered as a potential source of new heuristic optimisation methods. However, only restricted results have been achieved up to now due to the limitations imposed by quantum mechanics for cloning or erasing information. Here, we develop a fully quantum genetic algorithm (QGA) and study different subroutines for cloning or breeding by means of both a thorough numerical analysis and quantum-channel techniques. This approach paves the way for a new type of optimisation quantum algorithm which, additionally, can be straightforwardly parallelized among different quantum processors.

On the origin of the corner modes of the breathing kagome lattice

Miguel Angel Jimenez

Superconducting gap engineering

Divya Jyoti[1,2], Cristian Mier[1], Deung-Jang, Choi[1,2,3]and Nicolas Lorente[1,2]

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[3]Ikerbasque, Basque Foundation for Science, 48013 Bilbao, Spain

Superconducting behavior is strongly affected when a single impurity or chains of magnetic atoms are placed on a superconducting surface. The superconducting gap (Δ) is modified on each atomic site throughout the lattice structure in the presence of the magnetic impurities. Here, we will present the results for the observation in one dimension. We use an analogy between Bogoliubov-de-Gennes (BdG) set of equations and Abrikosov-Gorkov theory in a lattice model giving rise to equations of motion for the Green's functions. This allows us to express the effect of the magnetic impurity via a self-energy that contains scattering off the impurity via its potential part (non-magnetic) and its exchange part (magnetic). From our work, we can envisage to craft superconducting and non-superconducting patterns on a material by creating structures of magnetic impurities on top of the superconductor. This will create materials that can be spatially modified, leading to an engineering of the superconducting gap.

Spin chains in a superconductor towards to topological superconductivity

Cristian Mier[1], Nicolas Lorente[1,2] and Deung-Jang, Choi[1,2,3]

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[2]Donostia International Physics Center (DIPC), Paseo Manuel de Lardizabal 4, 20018 Donostia-San Sebastian

[3]Ikerbasque, Basque Foundation for Science, 48013 Bilbao, Spain

The search for Majorana bound states (MBS) in solid-state platforms has motivated an increasing number experiments, in particular, the realization of spin chains using STM in a superconducting surface is of special interest due to the high degree of precision that this technique allows. We use Green's function formalism to simulate a 2D superconductor with a chain of magnetic atoms on its surface. The calculations obtained with this method show a great agreement with experimental results on atomic Cr chains on the β-Bi_2Pd supercoductor [1,2]. We study two types of magnetic chains with different distance between the atomic impurities and orientation with respect to the surface. The calculations allow us to distinguish different topological character between the two, showing that one of the studied chains is in a non-trivial topological phase, and thus, we expect the emergence of MBS in this system [1,3].

[1] C. Mier, J. Hwang, J. Kim, Y. Bae, F. Nabeshima, Y. Imai, A. Maeda, N. Lorente, A. Heinrich, and D.-J. Choi, Phys. Rev. B **104**, 045406

[2] D.-J. Choi, C. G. Fernández, E. Herrera, C. Rubio-Verdú, M. M. Ugeda, I. Guillamón, H. Suderow, J. I. Pascual, and N. Lorente, Phys. Rev. Lett. **120**, 167001

[3] Cristina Mier, Deung-Jang Choi, Nicolás Lorente, arXiv:2108.11146

Superconducting Collective Modes in Single-layer NbSe2

Daniel Muñoz Segovia

DIPC, Donostia

Single-layer niobium diselenide ($NbSe_2$) has attracted considerable attention during the last years due to the combination of the lack of inversion symmetry and the so-called Ising spin-orbit coupling, which confer interesting properties to its superconducting ground state. In particular, they result in the so-called singlet-triplet mixing, i.e., the superconductivity has a symmetry-allowed triplet contribution even if the dominant pairing interaction would be in the singlet channel. Moreover, recent experiments observing nematic superconductivity under an applied in-plane magnetic field point to the fact that the triplet has a condensation energy close to the singlet [1,2], which is also consistent with the ab-initio calculations showing proximity to a ferromagnetic state [3]. Now, we report STM measurements showing signatures of a bosonic mode intrinsic to the superconducting state [4]. We propose that this mode corresponds to a Leggett-like superconducting collective mode associated to the nearby triplet pairing. In this poster, I will present our theoretical calculation of the Leggett mode energy using a simplified continuum model of $NbSe_2$, and discuss how our result compares to the experimental observations.

References:

[1] A. Hamill, et al., Nat. Phys. 17, 949-954 (2021).
[2] C.-W. Cho, et al., arXiv:2003.12467 (2020).
[3] D. Wickramaratne, et al., Phys. Rev. X 10, 041003 (2020).
[4] W. Wan, et al., arXiv:2101.04050 (2021).

Robust Detection of High-Frequency Signals at the Nanoscale

Carlos Munuera Javaloy

UPV/EHU, Bilbao

We present a method relying on shortcuts to adiabaticity to achieve quantum detection of high-frequency signals at the nanoscale in a robust manner. Our protocol delivers tailored amplitudes and frequencies for control fields that, firstly, enable the coupling of the sensor with high-frequency signals and, secondly, minimize errors that would otherwise spoil the detection process. To exemplify the method, we particularize to detection of signals emitted by fast rotating nuclear spins with nitrogen-vacancy (NV) center quantum sensors.

Quantum-enhanced Doppler radar for velocity estimation

Maximilian Reichert

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We propose a quantum-enhanced protocol for the estimation of the radial-velocity v of a moving target, which is modelled as a perfectly reflecting mirror. A frequency-entangled twin-beam multimode squeezed vacuum state is used as the probe state. After the signal beam is reflected by the moving target and its center frequency ω_0 is shifted due to the Doppler effect to ω_0/λ, with $\lambda = (1-v)/(1+v)$, a joint measurement is performed on the both the signal and the idler beam. By calculating the quantum Fisher informations J_q, of the reflected twin-beam state with respect to λ, and J_c, of a classical protocol using a coherent state, we show that $J_q/J_c > 1$ for certain parameter configurations, which proves a quantum-enhancement. In particular, we show that frequency-entanglement is a necessary condition for a quantum advantage. The quantum-enhanced protocol beats the standard quantum limit in the high-gain regime and asymptotically reaches the Heisenberg-limit in the case of high entanglement. Finally, we provide the analytic expression for an optimal observable which allows us to achieve this advantage.

POSTER REQUEST

N-terminal Graphene-based Nanostructures for Electron Quantum Optical setups

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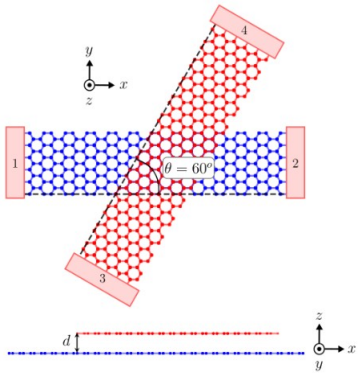
Graphene exhibits many exceptional mechanical and electronic properties that make it attractive for the fabrication of electronic devices at the nanoscale [1], but its gapless spectrum is a major obstacle for carbon-based electronic applications, since the absence of an electronic gap makes it a poor candidate to build logic electronic devices, e.g. field-effect transistor [2]. A gap can be however induced in different ways, among others, via lateral quantum confinement of the electrons, e.g., as it occurs in one-dimensional (1D) graphene nanoribbons (GNRs). On the other hand these GNRs can be produced [3] and manipulated [4, 5] with atomistic precision.

Here we analyze the effect of placing two GNRs one on top of the other interacting via the van-der-Waals interaction (4-terminal device, see Fig.). Previous work based on DFT and Non-equilibrium Green's functions (NEGF) formalism [6] showed that electrons injected from one terminal can be split into two outgoing waves with a tunable ratio that strongly depends on the intersection angle between the ribbons. In this work we complement this by adopting a simple and numerically efficient tight-binding description that captures the essential physics [7]. In addition to the intersection angle, the precise stacking of the device results in a powerful tool to control the direction and intensity of the electron beam [8]. Here we study the electron transport properties in terms of the Scattering matrix, which can be easily computed in the NEGF formalism by means of the generalized Fisher-Lee relations [9], of the different highly-symmetric configurations of crossed GNRs of varying width and edge chiralities, and their possible applications for electron quantum optical setups [10, 11].



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