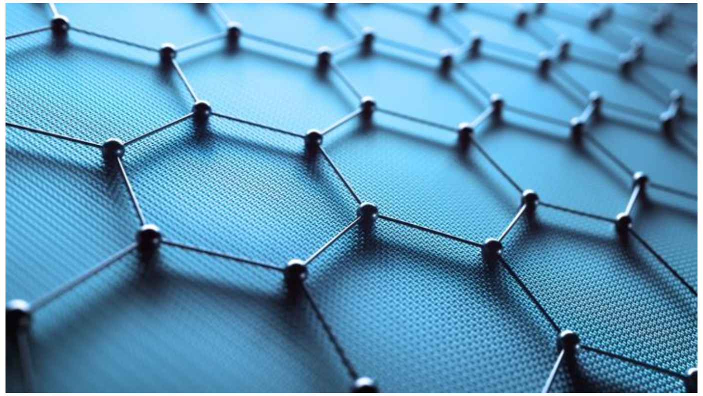
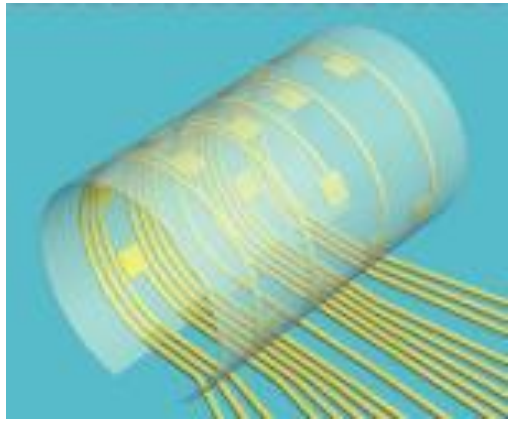
QUANTEP
QUANtum Technologies Experimental Platform

Call type: Thematic
Title: QUANTEP - QUANtum Technologies Experimental Platform
Research Field: Quantum Technologies
Research Units: INFN LNL, MI, PG, PI, PV, RM2, SA, TO

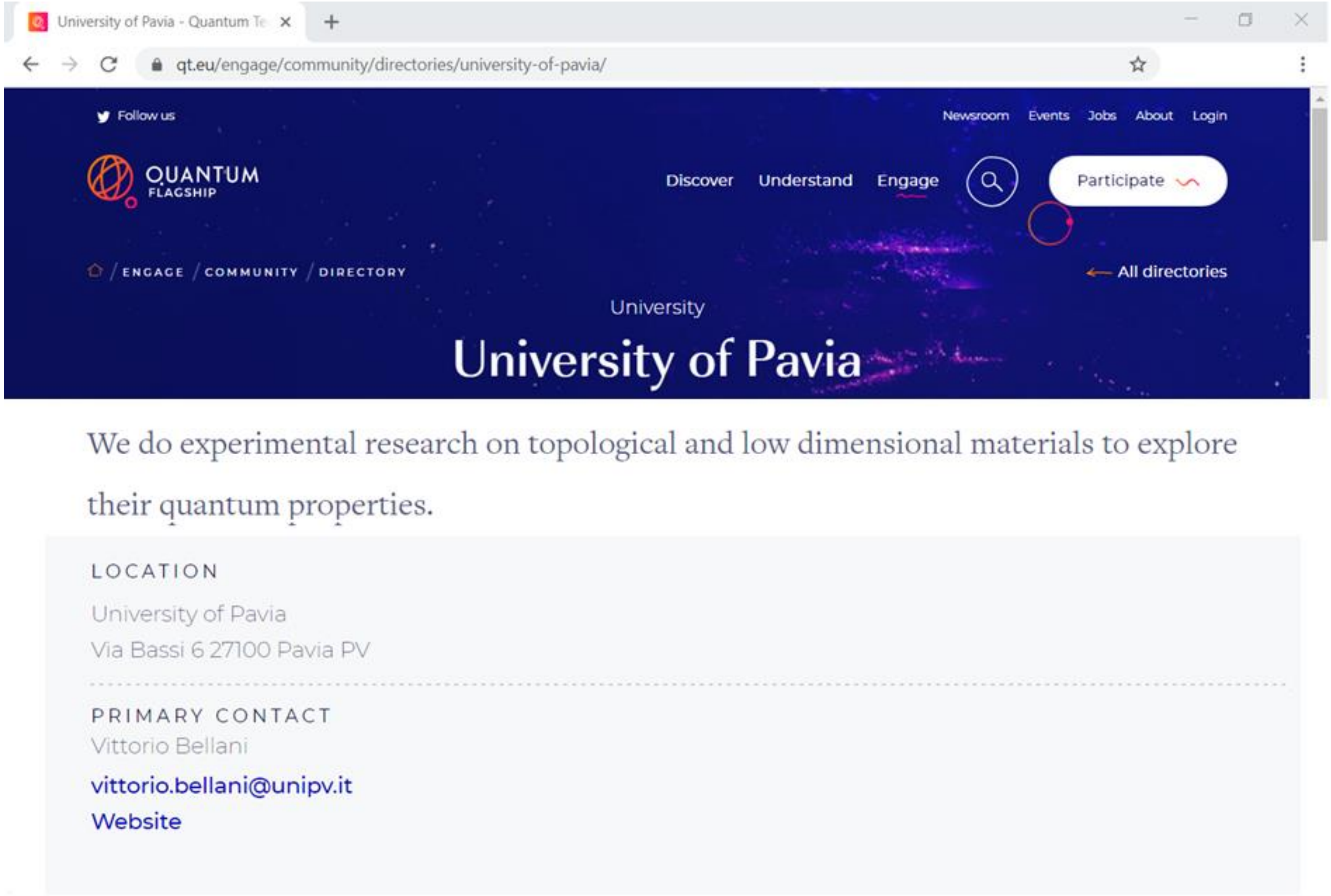
The QUANTEP project aims at the development and implementation of quantum technologies. The potential of novel quantum materials, realized by using as building blocks one and two dimensional materials





Tecnologie Quantistiche: Nota del MIUR sul Piano Triennale 2019 -2021

Con riferimento al ricco e prezioso bagaglio di know-how nell'ambito delle architetture di calcolo, e delle tecnologie associate, si incita l'INFN ad avere un ruolo significativo nelle attività di ricerca e sviluppo del settore, non tralasciando la nuova sfida connessa con le Tecnologie Quantistiche che la UE ha lanciato con una nuova Flagship ad esse dedicata.



By Cade Metz

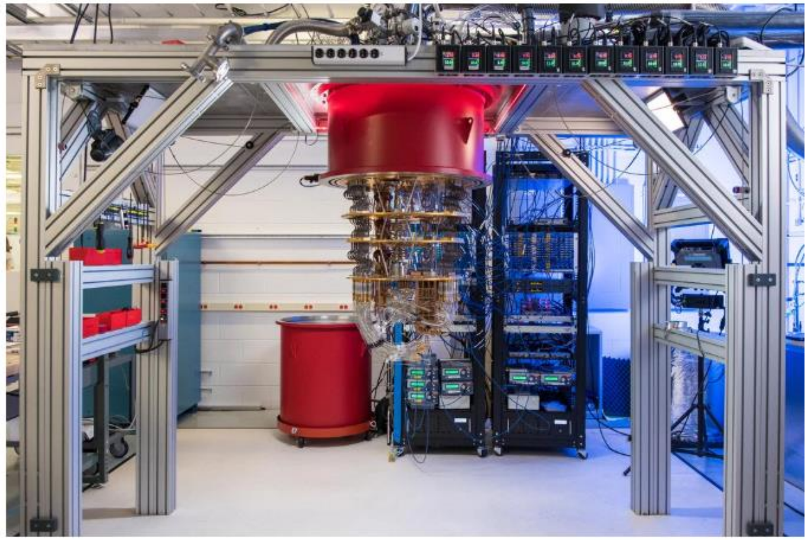
Oct. 23, 2019

The New York Times

Google Claims a Quantum Breakthrough That Could Change Computing

SANTA BARBARA, Calif. — Google said on Wednesday that it had achieved a long-sought breakthrough called "quantum supremacy," which could allow new kinds of computers to do calculations at speeds that are inconceivable with today's technology.

The Silicon Valley giant's research lab in Santa Barbara, Calif., reached a milestone that scientists had been working toward since the 1980s: Its quantum computer performed a task that isn't possible with traditional computers, according to a paper published in the science journal Nature.



Google's quantum computer. The company said in a paper published on Wednesday that the machine needed only a few minutes to perform a task that would take a supercomputer at least 10,000 years. Google

nature

Article | Published: 23 October 2019

Quantum supremacy using a programmable superconducting processor

Frank Arute, Kunal Arya, [...] John M. Martinis

Nature **574**, 505–510(2019) | Cite this article

Here we report the use of a processor with programmable superconducting qubits to create quantum states on 53 qubits. Our Sycamore processor takes about 200 seconds to sample one instance of a quantum circuit a million times—our benchmarks currently indicate that the equivalent task for a state-of-the-art classical supercomputer would take approximately 10,000 years.

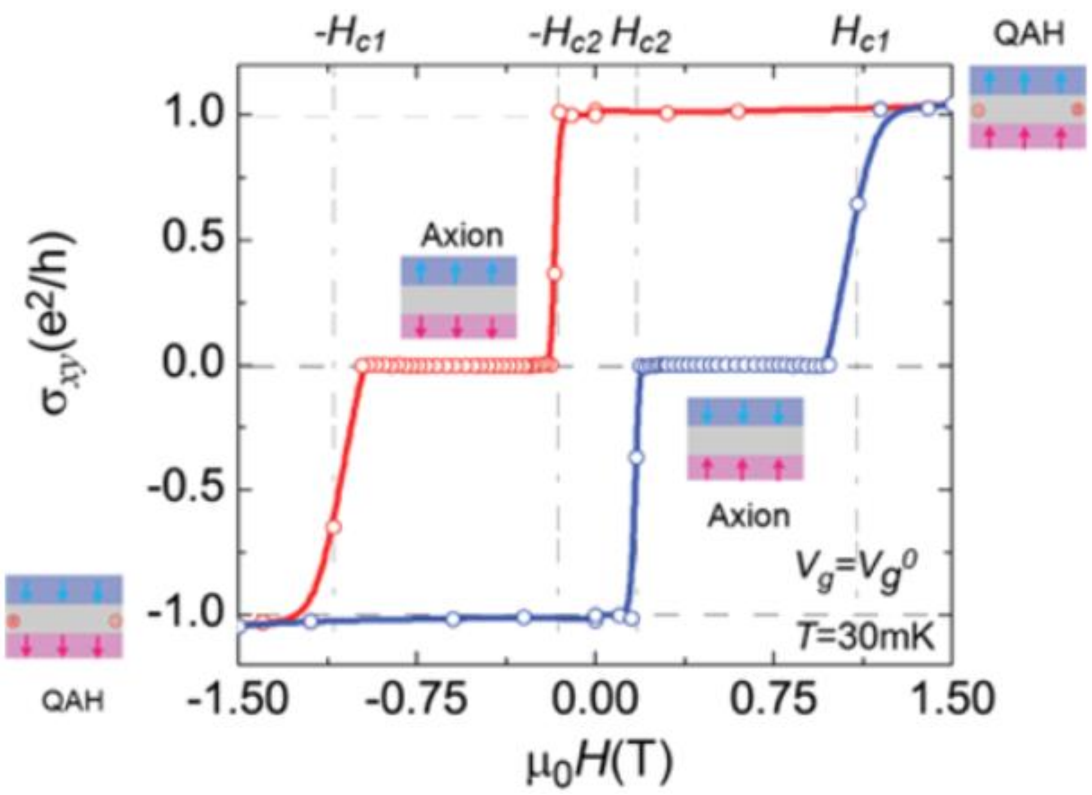
PHYSICAL REVIEW LETTERS

Open Access

Proposal to Detect Dark Matter using Axionic Topological Antiferromagnets

David J. E. Marsh, Kin Chung Fong, Erik W. Lentz, Libor Šmejkal, and Mazhar N. Ali

Phys. Rev. Lett. **123**, 121601 – Published 17 September 2019



Science Advances

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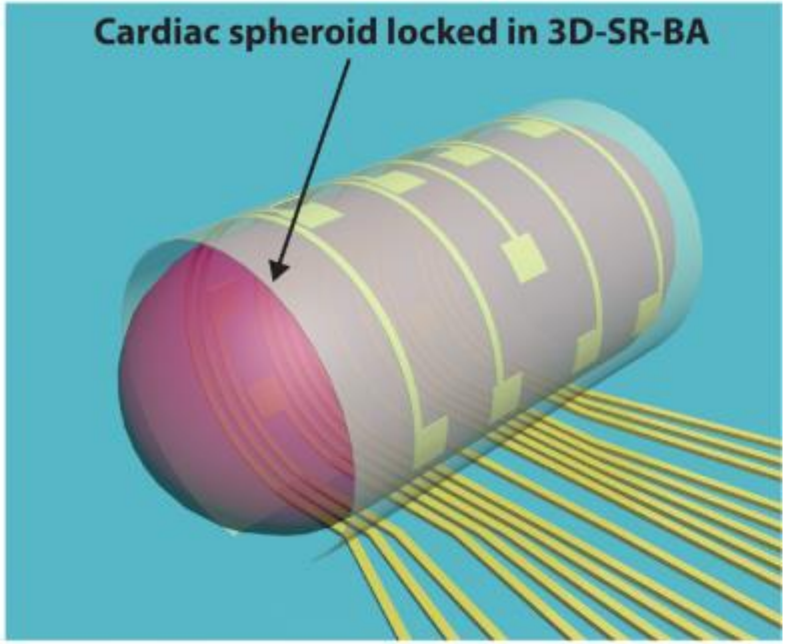
RESEARCH ARTICLE | APPLIED SCIENCES AND ENGINEERING

Organ-on-e-chip: Three-dimensional self-rolled biosensor array for electrical interrogations of human electrogenic spheroids

Anna Kalmykov[1], Changjin Huang[2,3], Jacqueline Bliley[1], Daniel Shiwarski[1], Joshua Tas...
+ See all authors and affiliations

Science Advances 23 Aug 2019:
Vol. 5, no. 8, eaax0729
DOI: 10.1126/sciadv.aax0729



The Nobel Prize in Physics 2010

Andre Geim
Konstantin Novoselov

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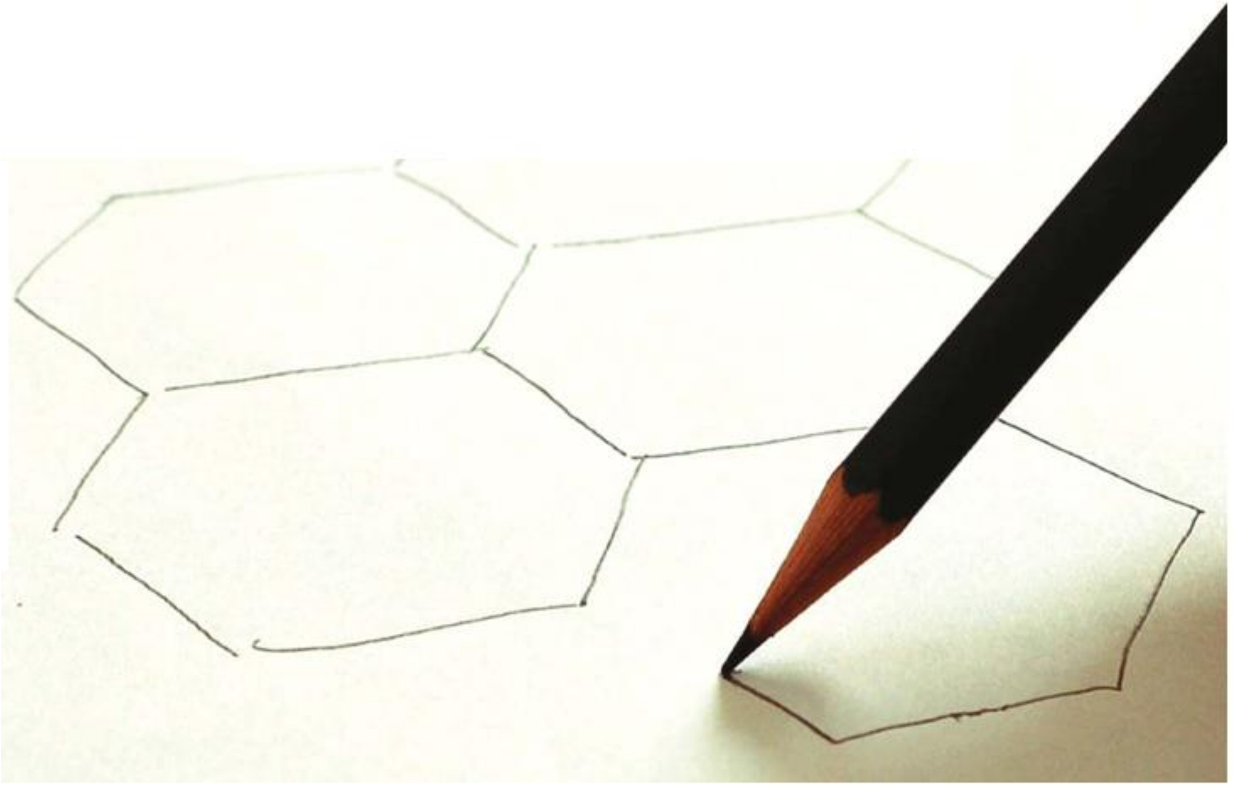
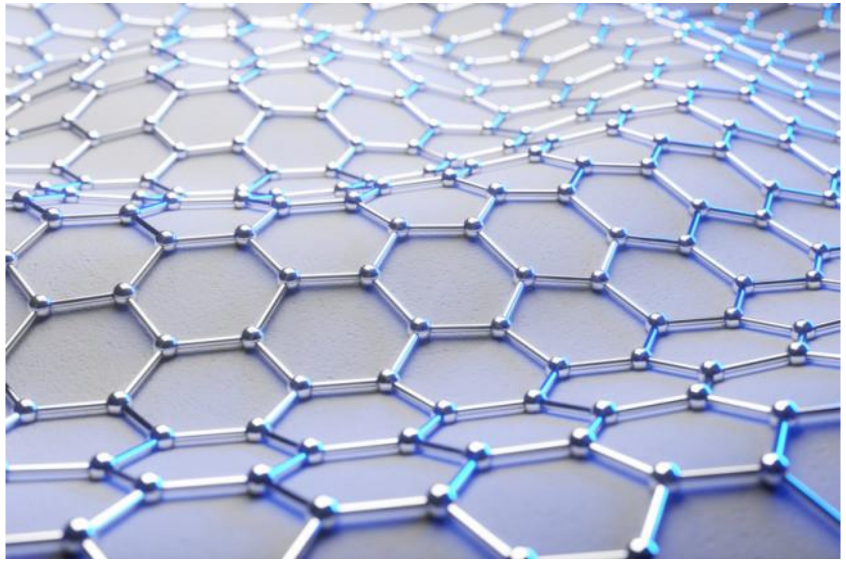
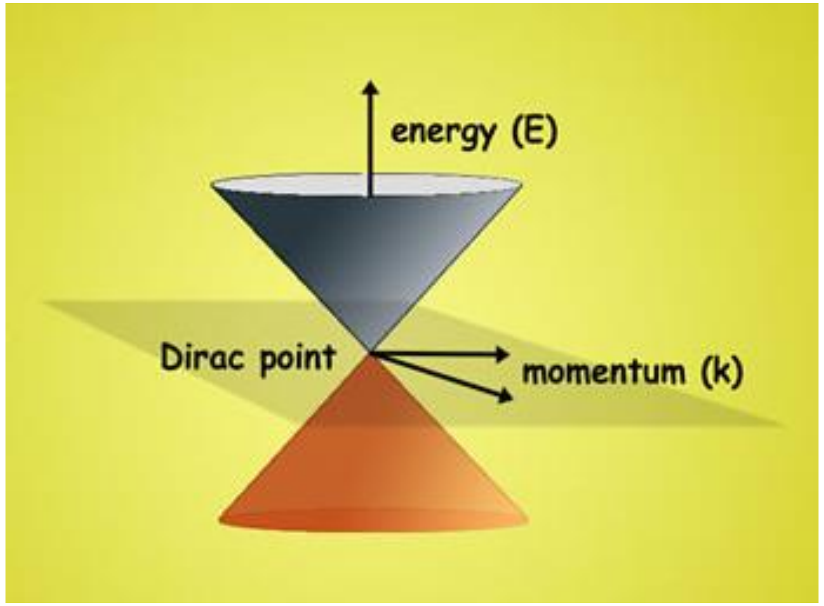
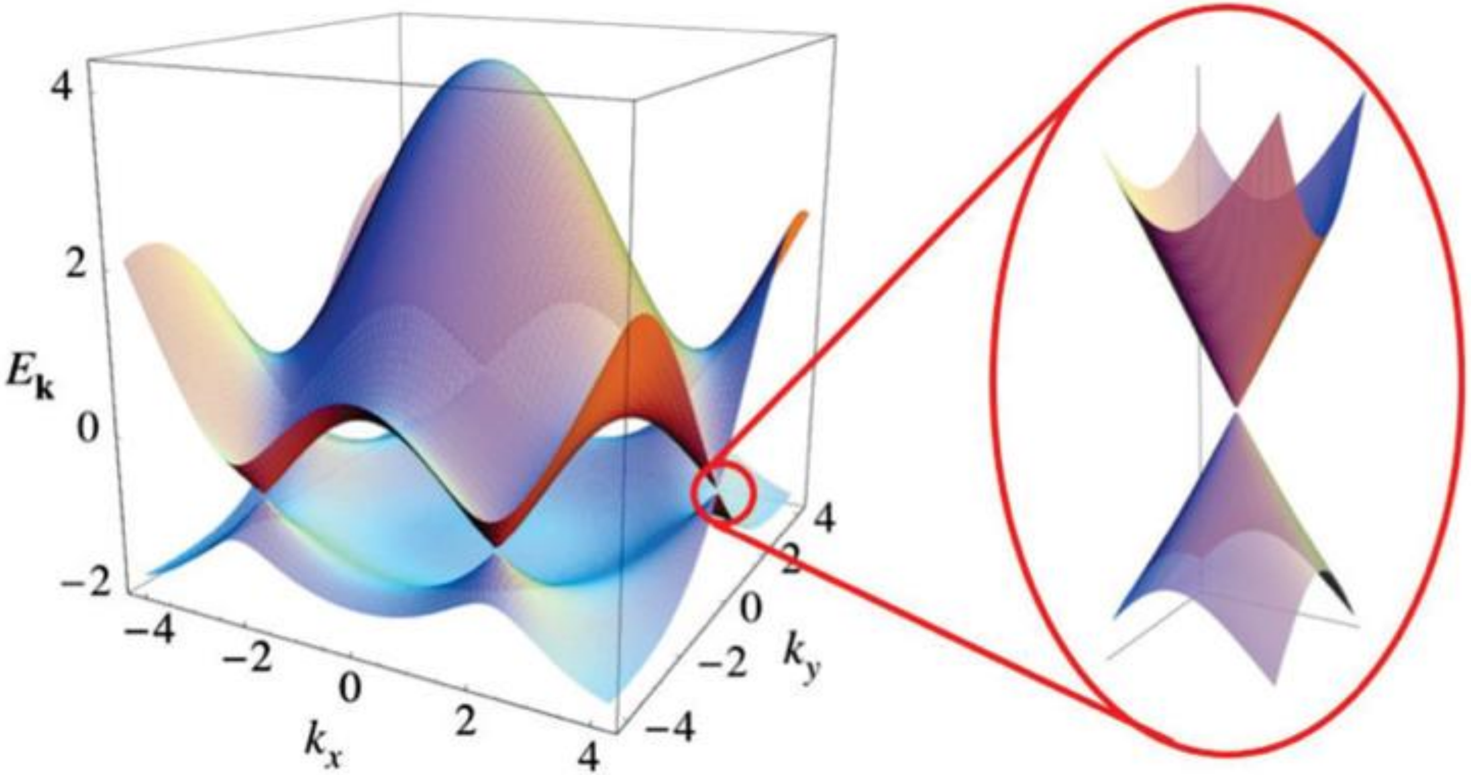
The Nobel Prize in Physics 2010 was awarded jointly to Andre Geim and Konstantin Novoselov "for groundbreaking experiments regarding the two-dimensional material graphene."



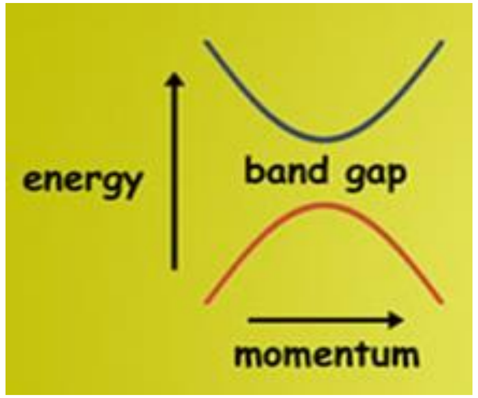


Electron become Dirac Fermions





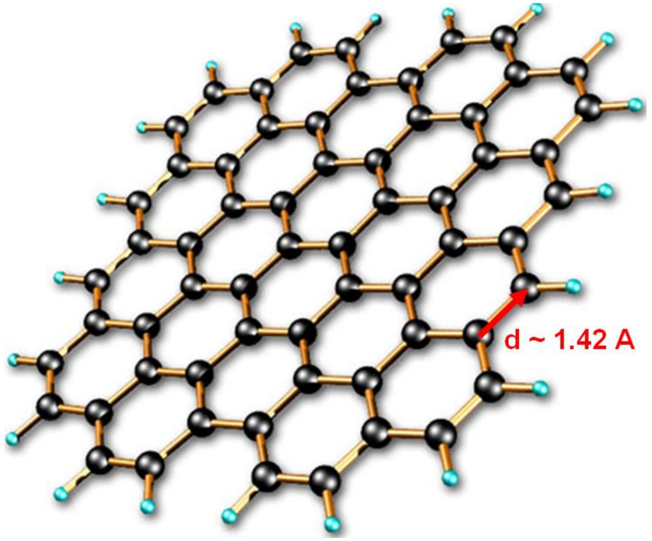
Traditional material

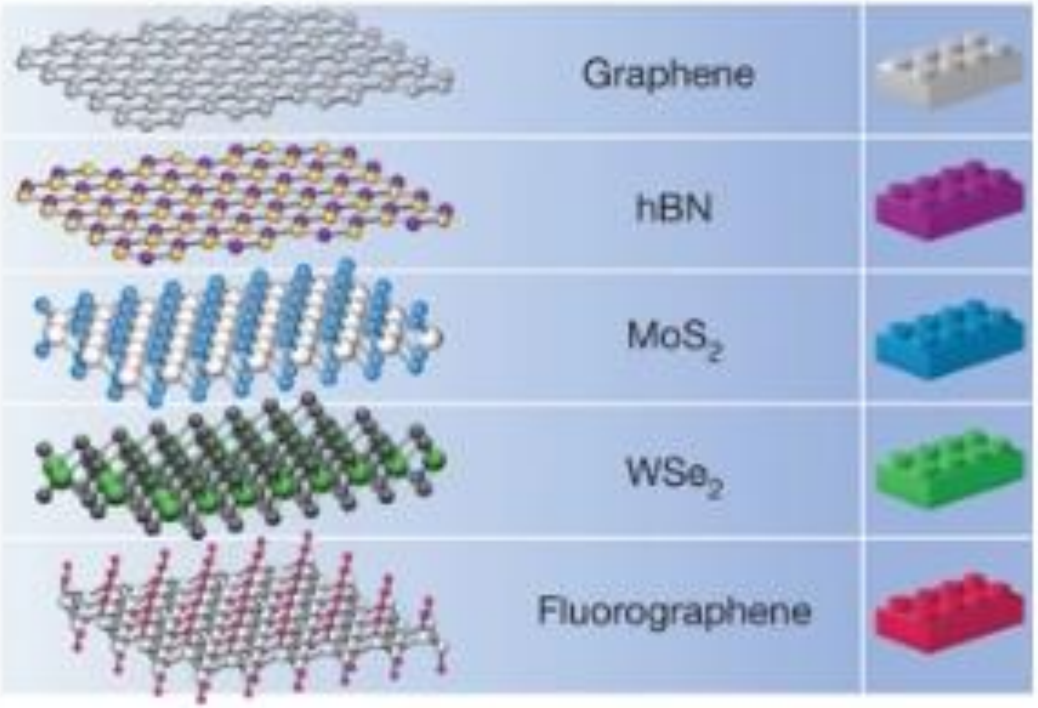


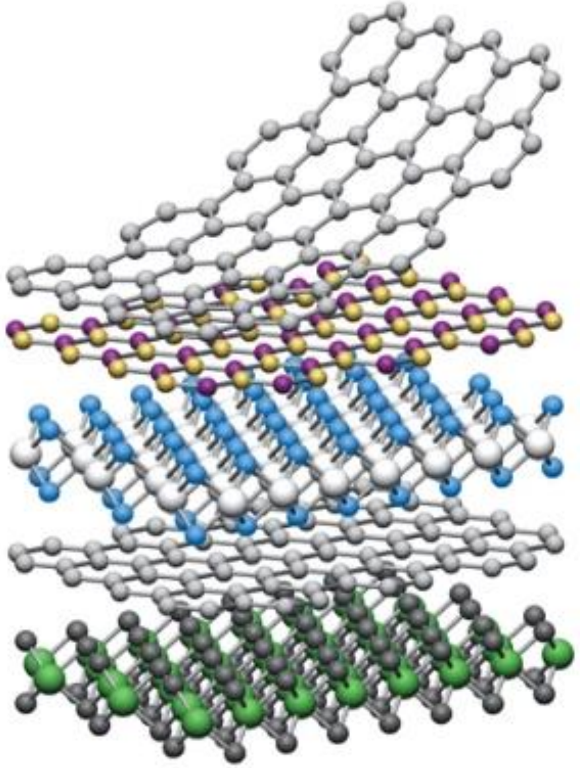
Atomic-scale Lego

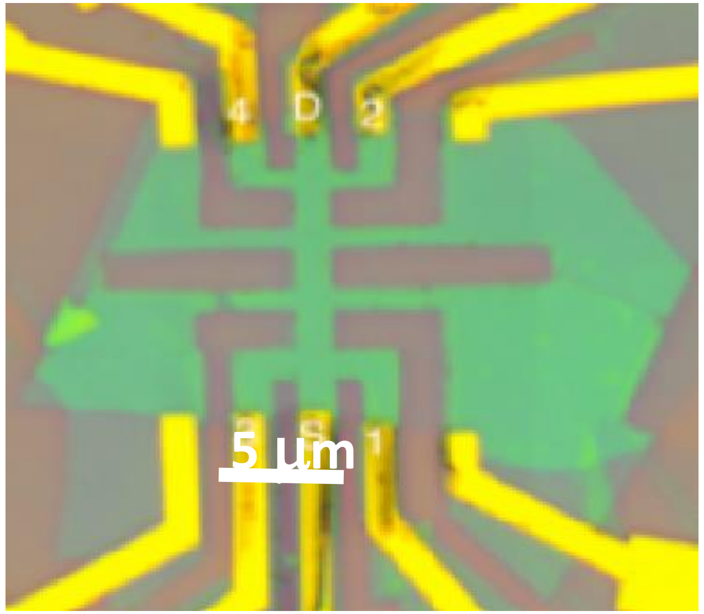
2D and 1D crystals are like *Lego* : we can construc of a huge variety of layered structures.

Thils Lego structure have phycal properties not present in the *traditional crystals*





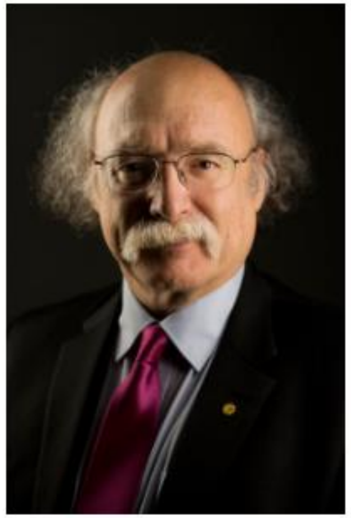




The one layer material can have topological properties (with topological quantum numbers)

The Nobel Prize in Physics 2016

David J. Thouless



F. Duncan M.

J. Michael Kosterlitz

The Nobel Prize in Physics 2016 was divided, one half awarded to David J. Thouless, the other half jointly to F. Duncan M. Haldane and J. Michael Kosterlitz "for theoretical discoveries of topological phase transitions and topological phases of matter."

British scientists win Nobel prize in physics for work so baffling it had to be described using bagels

Thors Hans Hansson attempts to explain topological phase transitions using bagels

The Abdus Salam International Centre for Theoretical Physics

IAEA

Topology Explained

2016 Nobel Physics Prize puts focus on field of growing interest to researchers

07/10/2016 - Trieste

The 2016 Nobel Prize in Physics was awarded "for theoretical discoveries of topological phase transitions and topological phases of matter." What does that mean?

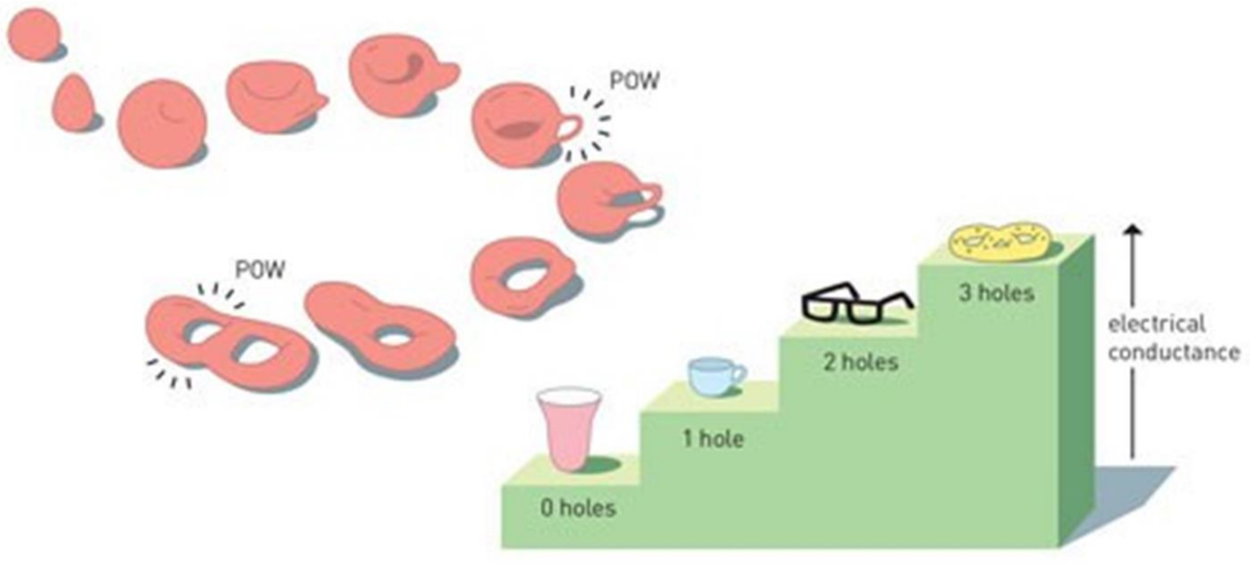
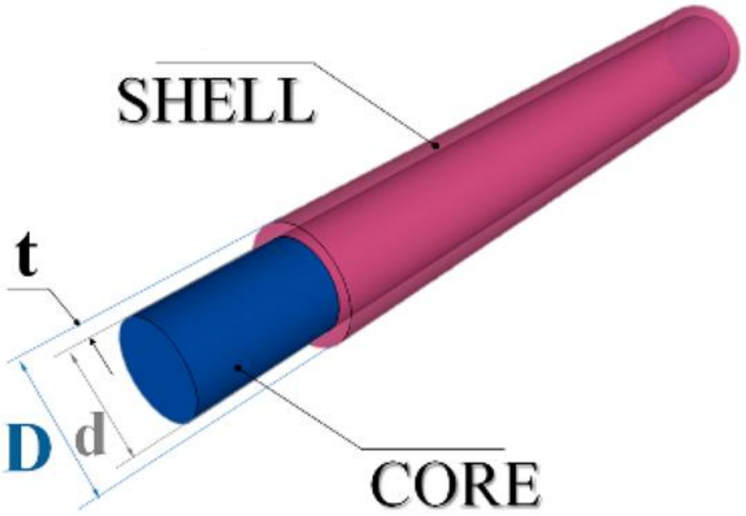


Illustration: ©Johan Jarnestad/The Royal Swedish Academy of Sciences

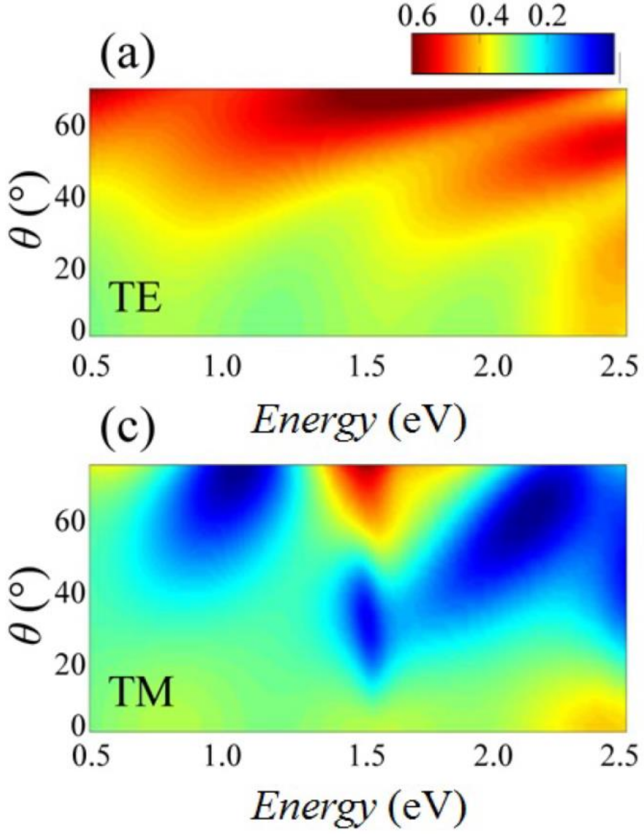
Topology, simply defined, is a field of study that describes step-like changes in a property. For example, to borrow an analogy presented during the announcement of the Nobel Prize in Physics, a pastry cannot have half a hole. It can have none and be a cinnamon bun, or it can have one and be a donut. If you bend that donut without breaking it, it is still a donut with one hole, even if it doesn't look the same. Certain properties of the donut have been maintained. These are known as topological properties, and their study has given rise to some fascinating physics.

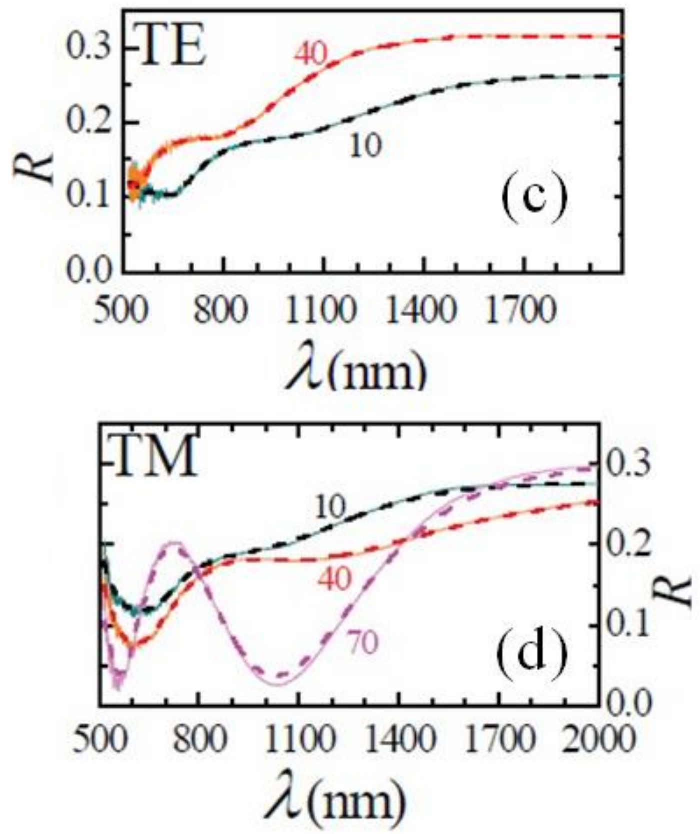
The one layer (or very thin) material can be rolled around another material

Core shell nano-wire



Polarization response





nanomaterials

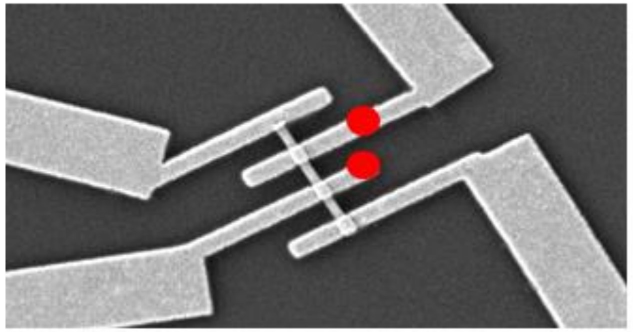
MDPI

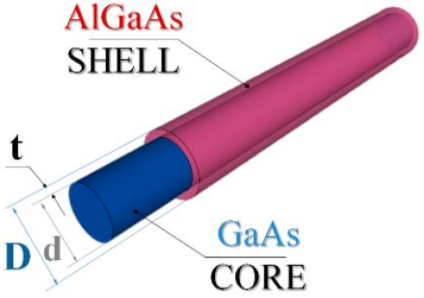
Materials **2019**, *12*(21), 3572; https://doi.org/10.3390/ma12213572

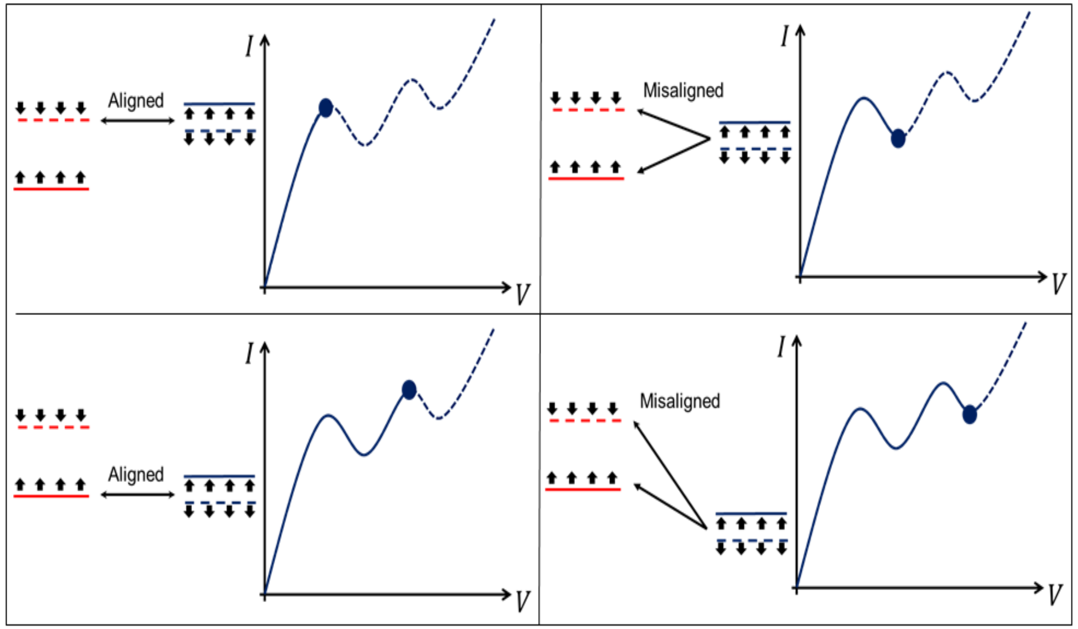
Article

Francesco Floris [1], Lucia Fornasari [1], Andrea Marini [2], Vittorio Bellani [1], Francesco Banfi [3], Stefano Roddaro [4], Daniele Ercolani [4], Mirko Rocci [4], Fabio Beltram [4], Marco Cecchini [4], Lucia Sorba [4] and Francesco Rossella [4,*]

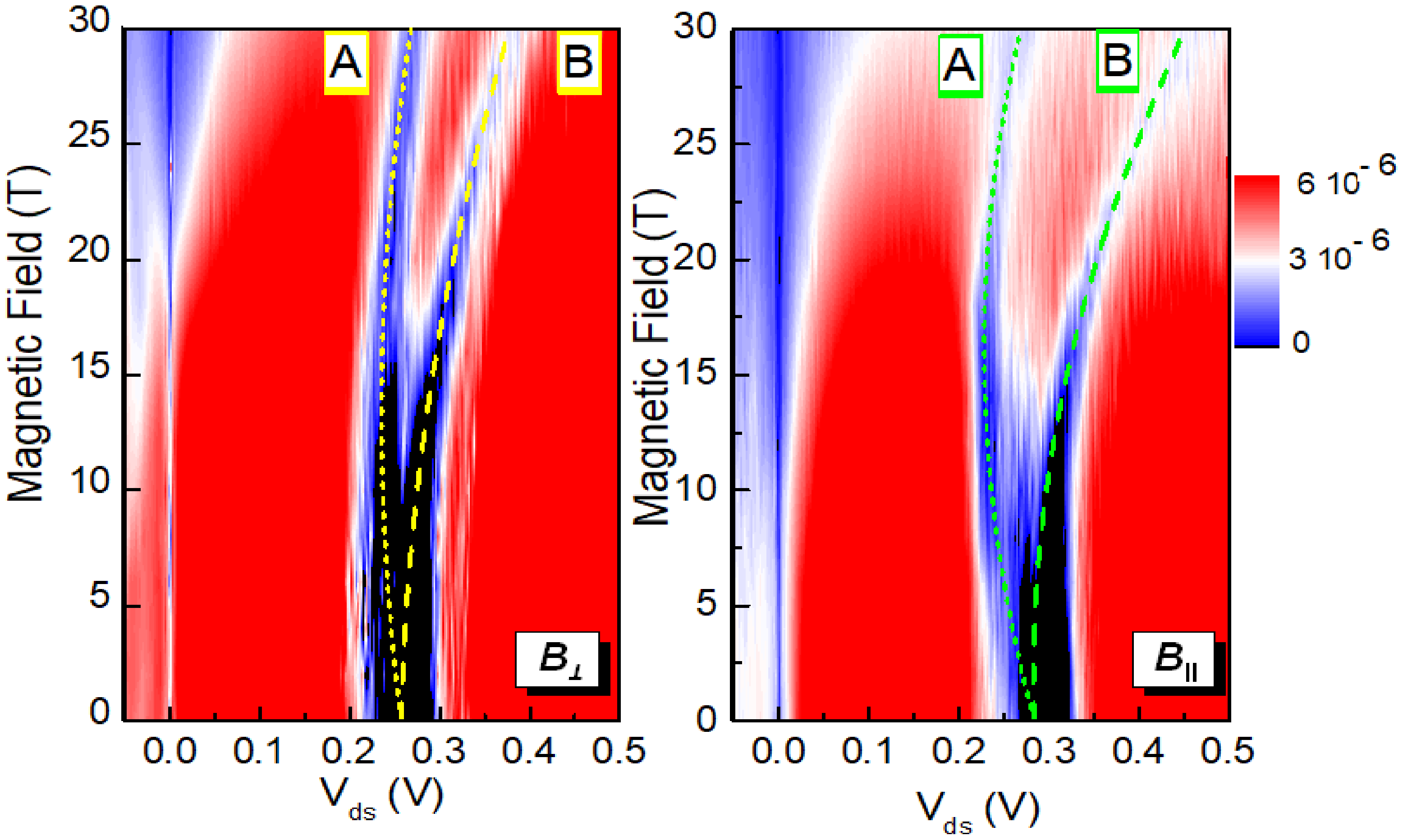
This gives rise to unexpected new physics







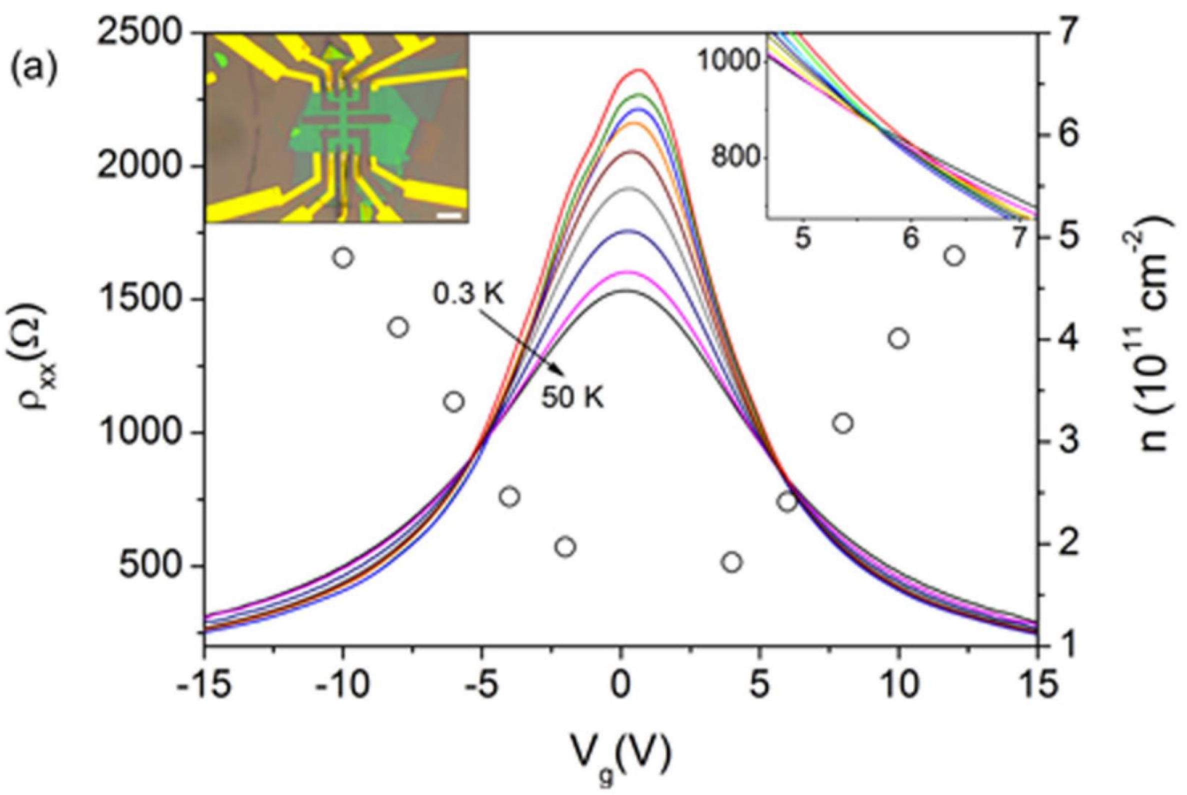
Schematic description of the evolution of the *I/V* characteristics, and of the corresponding spin split *e* and *h* levels alignment, with the magnetic field; in this figure the *e* and *h* spin alignment in the split levels.



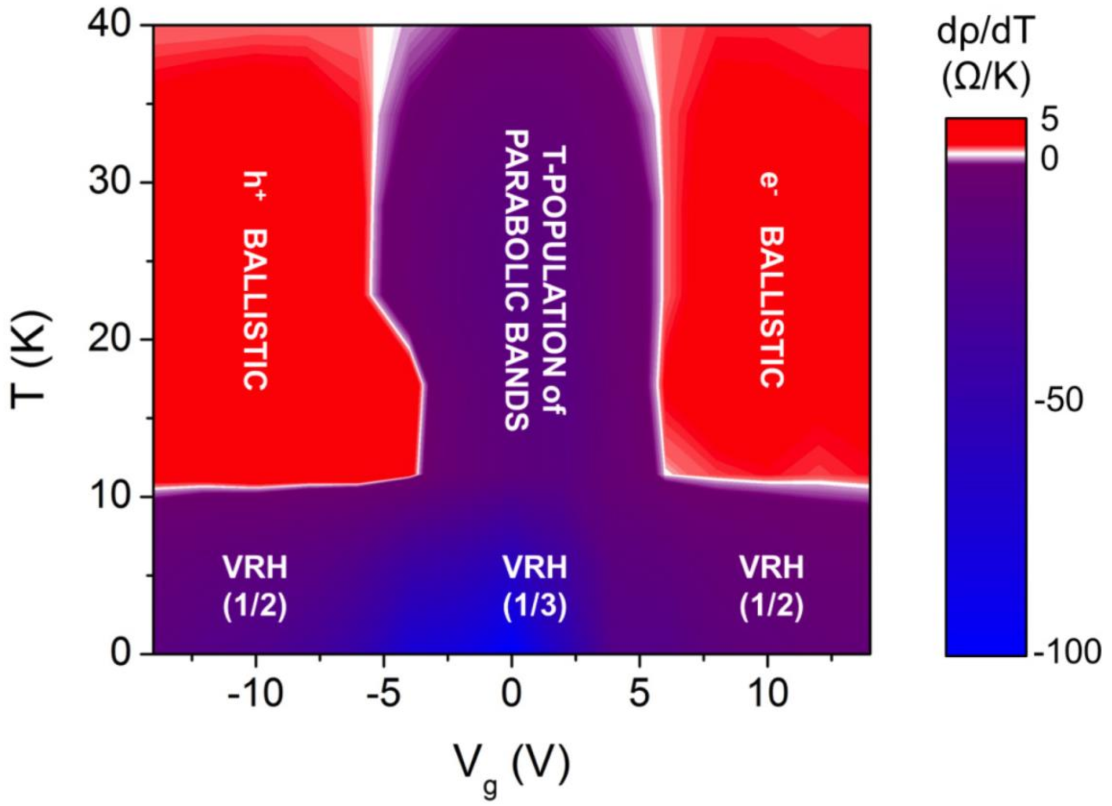
dI/dV versus V_{db} and B, for magnetic field applied perpendicularly and parallel to the NWs. Measurement of the anisotropic transport to be exploited in the control of polarization of nanowires on Silicon waveguide device, using electro-optical effects.

INFN Pavia unit, 2020, to be published.

One layer material show Dirac Fermions and topological states. They are used in quantum devices: quantized transparency, chiral electrical flow



Measurement of the Dirac Fermions in graphene.



Exploration of the electrical transport regimes.

Temperature- and density-dependent transport regimes in a h-BN/bilayer graphene/h-BN heterostructure

C. Cobaleda, S. Pezzini, E. Diez, and V. Bellani

Phys. Rev. B **89**, 121404(R) – Published 10 March 2014

New J. Phys. **20** (2018) 053062 https://doi.org/10.1088/1367-2630/aac595

New Journal of Physics

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IOP Institute of Physics

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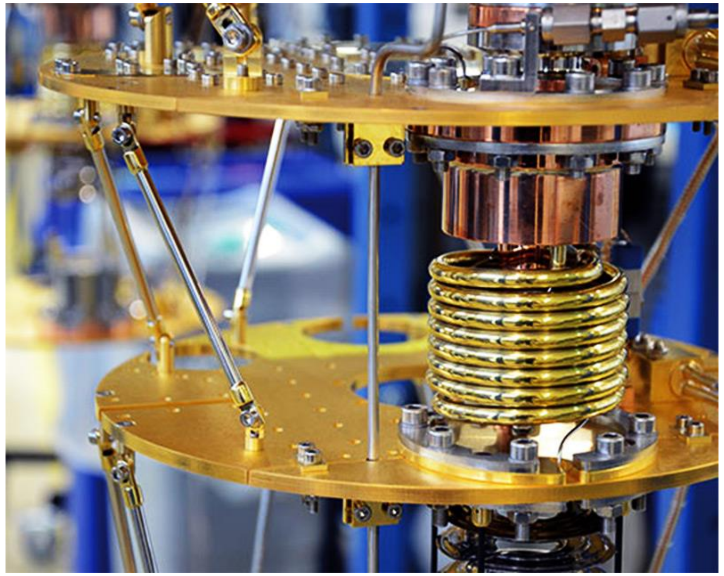
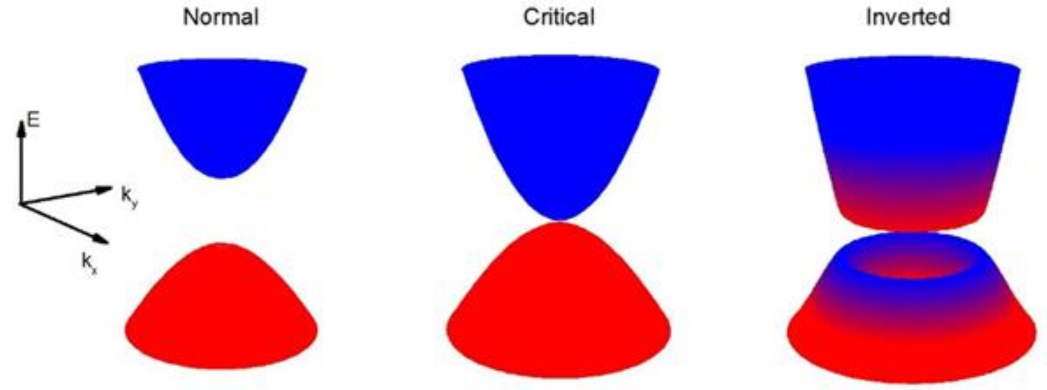
PAPER

Anomalously large resistance at the charge neutrality point in a zero-gap InAs/GaSb bilayer

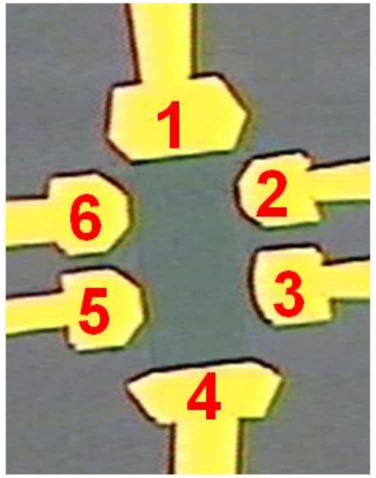
W Yu[1], V Clericò[2], C Hernández Fuentevilla[2], X Shi[1,11], Y Jiang[3], D Saha[4], W K Lou[5], K Chang[5], D H Huang[6], G Gumbs[7], D Smirnov[8], C J Stanton[4], Z Jiang[3], V Bellani[9,10], Y Meziani[2], E Diez[2,12], W Pan[1,12], S D Hawkins[1] and J F Klem[1]



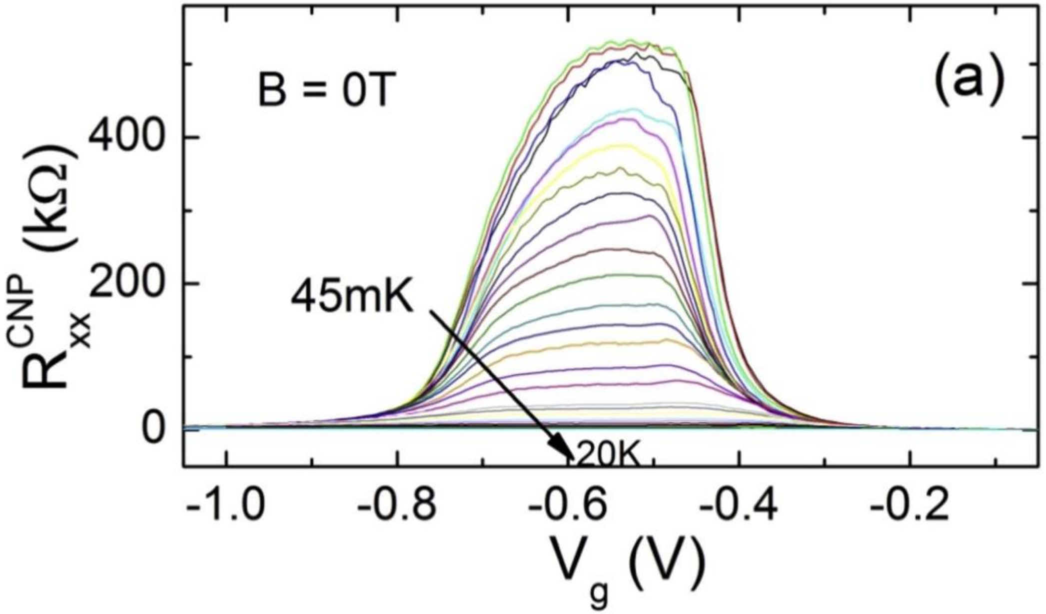
Dilution refrigerator with base temperature 45 mK



Band structures of the InAs/GaSb DQWs calculated using the eight-band k·p method



The 6 contact measurement configuration



Longitudinal resistance as a function of gate voltage for increasing temperatures

Table 1.3.1: FTE for each Research Unit normalized to 11 months/year per person.

Research Unit	FTE without AdR requests			FTE with AdR requests		
	2021	**2022**	**2023**	**2021**	**2022**	**2023**
LNL	1.0	1.3	0.9	1.0	2.3	0.9
Milano	2.2	2.2	2.2	2.7	2.7	2.2
Perugia	1.3	1.3	1.3	2.3	1.3	1.3
Pisa	1.8	1.8	1.8	1.8	2.8	1.8
Pavia	2	2	2	2	3	3
Roma TV	4.7	4.7	4.6	4.7	4.7	4.6
Salerno	0.6	0.6	0.3	0.6	0.6	0.3
Torino	3.4	3.4	2.1	4.4	3.4	2.1
TOTAL	**17**	**17.3**	**15.2**	**19.5**	**20.8**	**16.2**

- **Pavia:** The Pavia group will work on the demonstration that chiral states and polarised spins in nanowires and 2D materials allow to control polarization in the waveguides through proximity effects. This will allow connecting silicon optoelectronics with spintronics accessible through nanowires, graphene and 2D materials. The new nano-devices implementing optoelectronics and spintronics will have positive impact at industrial levels, with the opportunity of patents, developing new materials and device fabrication processes, and will give the opportunity to create spin-offs and start-ups to place the new products on the market.

- **Torino, Legnaro**: The Torino and Legnaro groups will acquire new expertise in deterministic implantation and develop new world-class facilities. This will have significant impact well beyond QUANTEP conclusion. Furthermore, opening a new line of research on solid-state SPS and telecommunication wavelengths will have a significant scientific output in terms of integration of new devices, and migration of the most recent results in the field of quantum technologies towards silicon platforms.

- **Perugia**: The Perugia group will work on the implementation of an integrated unit in one chip that can execute a quantum algorithm. This would have a significant impact in the field of metrology and not decryptable data transmission and would extend the application of Machine Learning techniques by reducing the processing time of large datasets.

- **Milano, Pisa, Tor Vergata**: The Milano, Pisa and Tor Vergata groups will develop new and advanced expertise on silicon photonics that will have very significant impact on INFN for the development of new data acquisition systems for HEP experiments, and on the telecommunication industry.

Res. Unit Local Resp.	WP	Roles and Tasks	Competences	Infrastructures	Collaborations
Pavia	**6**	III-V nanowires, Graphene and 2D materials	Epitaxy, Transport, Fabrication, Light scattering/reflection	CBE, Lithography, Transport, Raman/Rayleigh scattering	EMFL, MagLab, NEST, Berkeley

WP6 man power		**Dedicated months/person**			Activity
People	Unit	2021	2022	2023	
F. Bellani	PV	4	4	4	WP leader, T11, T12, T13, T17, T26. T27, T28, T32
F. Boffelli	PV	2	2	2	T12, T13,T17, T27,T28,T32
V. Demontis	PV	2	2	2	T11, T12, T13, T17, T26, T27, T28, T32
A. Fontana	PV	2	4	4	T11,T13, T26,T28,T32
E. Giroletti	PV	7	5	8	T12, T13,T17,T27,T32
F. Rossella	PV	2	2	2	T11, T12, T13, T17, T26, T27, T28, T32
E. Vittone	TO	3	3	0	T13,T28
AdR	PV	0	11	11	T11, T12, T13, T17, T26. T27, T28, T32
Total		22	33	33	

WP6 Activity: Design, nanofabrication and testing of novel quantum device concepts, based on III-V semiconductor nanowires and graphene, as potential candidates for enabling unprecedented functionalities in the control over light-matter interaction mechanisms, such as polarization modulation, in silicon photonic systems.

WP6 Tasks:
T11. Design of PC Prototypes (based on nanowires and 2D material based) [M3-M4]
T12. Production of PC Prototypes (epitaxy and nanofabrication) [M5-M7]
T13. Test and Characterization of PC Prototypes (electrical and optical measurements) [M8-M13]
T17. Production, test and characterization of PCs integrated with IC1 (nano-fabrication and electro-optical measurements) [M14-M16]
T26. Design of final PCs [M17-M17]
T27. Production of final PCs (epixaty and nanofabrication) [M18-M20]
T28. Test and Characterization of final PCs (electro-optical measurements) [M21-M25]
T32. Production, test and characterization of PCs integrated with IC2 (epitaxy, nanofabrication, electro-optical measurement) [M26-29]

WP6 Milestones:
Study of III-V nanowires and 2D material candidates for PC devices [M13];
Fabrication and characterization of PC hetero-structured devices on Si [M25];
Measurement of the polarization in hetero-strucutured devices. [M29].

WP6 Deliverables:
Electrical and optical charaterization of nanowires and 2D materials on Si [M12];
Measurement of the chiral response and polarization properties of the nano-structures on Si [M16];
Electrical and optical response of the nanowire and 2D material based PC devices [M22].

Table 2.2.1: List of 3 years total funding requests (kEuros) per spending chapter

Chapter	2021	2022	2023	Total
Travel expenses	28	29	25	**82**
Consumables	174	180	35.5	**389.5**
Equipments	319	15	0	**334**
SPServices	150	0	0	**150**
SW licenses	20.5	22	0	**42.5**
TOTAL	**691.5**	**246**	**60.5**	**998**

PV	6	Human resources (AdR)	25			SPServices
	6	Crygenic liquids	4	5	4	Consumables
	6	Materials for chemical beam epitaxy and nano-lithography	10	10	8	Consumables
	6	Rotating sample holder	15			Equipments
	6	Optical material (objectives, polarizers and waverplates)	9			Equipments
	6	Gaussmeter	8			Equipments
	6	Travels	6	6	6	Travels
		Total PV	77	21	18	