Nanowires quantum detector

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Quantum Technologies within INFN: status and perspectives

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Proposal to Detect Dark Matter using Axionic Topological Antiferromagnets

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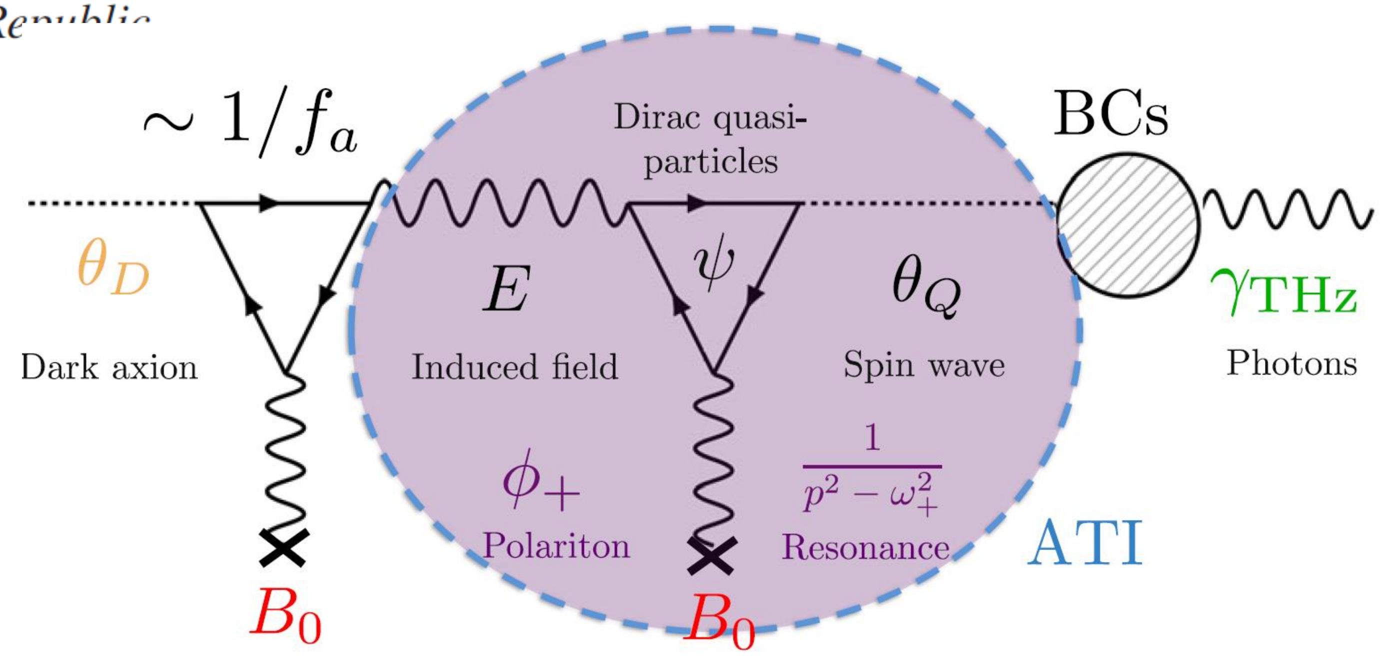
Antiferromagnetically doped topological insulators (ATI) are among the candidates to host dynamical axion fields and axion polaritons, weakly interacting quasiparticles that are analogous to the dark axion, a long sought after candidate dark matter particle. Here we demonstrate that using the axion quasiparticle antiferromagnetic resonance in ATIs in conjunction with low-noise methods of detecting THz photons presents a viable route to detect axion dark matter with a mass of 0.7 to 3.5 meV, a range currently inaccessible to other dark matter detection experiments and proposals. The benefits of this method at high frequency are the tunability of the resonance with applied magnetic field, and the use of ATI samples with volumes much larger than 1 mm^3.

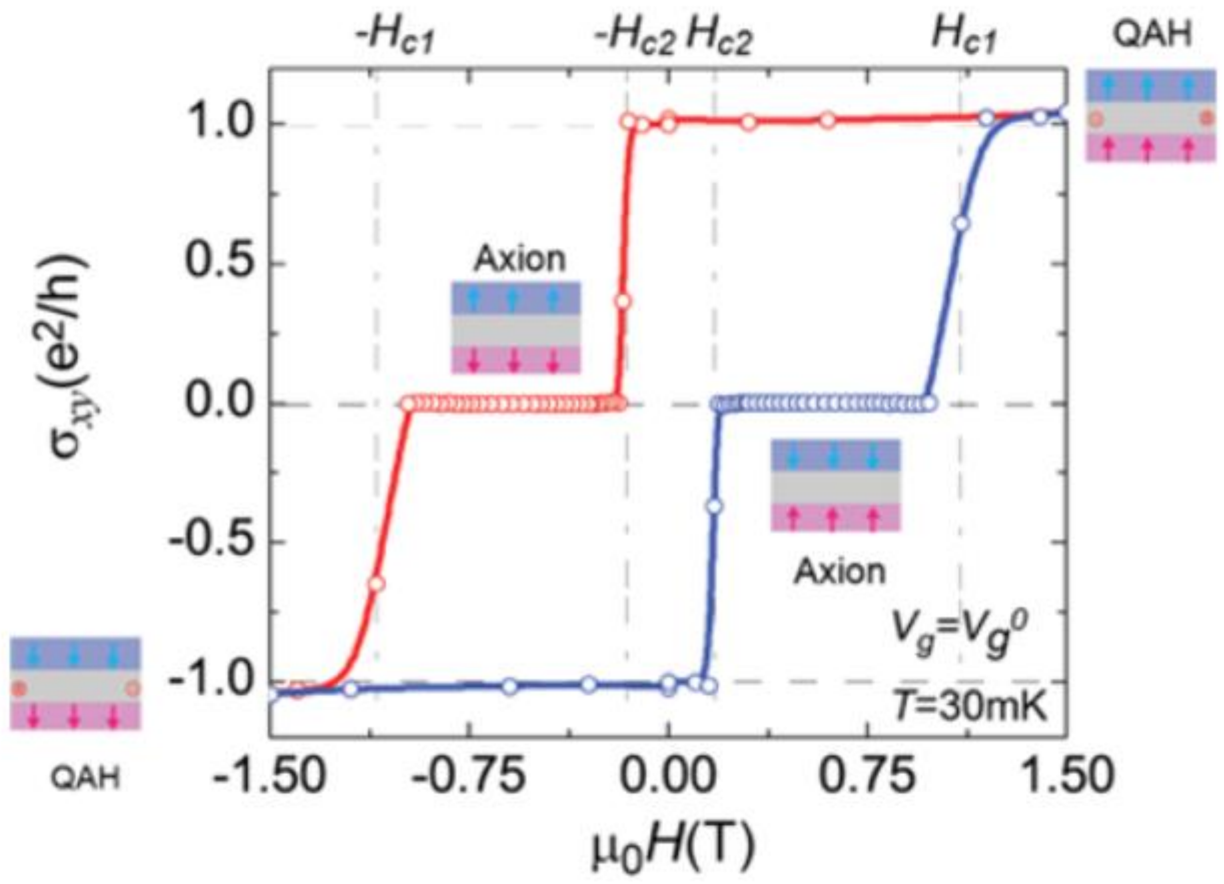


(b) Resonant enhancement of DA-photon conversion. Colored text refers to Fig. 3. Inside the ATI, the DA couples to the mixed states $\phi_\pm$ shown in the shaded circle. Conversion is resonantly enhanced when $p^2 = \omega_a^2 = \omega_+(k, B_0)^2$, represented by the polariton propagator. At the ATI dielectric boundary, polaritons convert to propagating photons, due to boundary conditions (BCs) [44] represented here by the vertex. (c) The axion-polariton dispersion relation for $\omega_\pm(k, B_0)$ [45]. Scanning the applied B_0 field tunes $\omega_+(k=0)$ in the range 0.7 to 3.5 meV and scans the resonance.

Observation Of Axion Physics In Condensed Matter

What Has Been Achieved

The strongly spin-momentum coupled electronic states in topological insulators (TI) are created by a combination of spin-orbit coupling and time-reversal symmetry. The surface conductance associated with these states is expected to be quantized and has a mathematical description identical to that used for fundamental particles known as 'axions'. The axion description can be robustly proven by interfacing the two opposite surfaces of a TI thin film with magnetic moments that can be independently reoriented with respect to each other. We have used this property to demonstrate axion physics by measuring the Hall effect and electric resistance of such a TI heterostructure. When the magnetization on the opposite surfaces is in the same direction, the Hall conductance is quantized to e^2/h, where e is electron charge and h is Planck's constant, while the electrical conductivity is zero. This is known as the quantum anomalous Hall (QAH) insulator. When the magnetizations are oppositely oriented, the Hall and electrical conductivity both vanish. This is the 'axion insulator.'



Importance of Achievement

Our results provide a robust model system for studying fundamental concepts in physics that cut across subfields, including condensed matter, field theory and particle physics.

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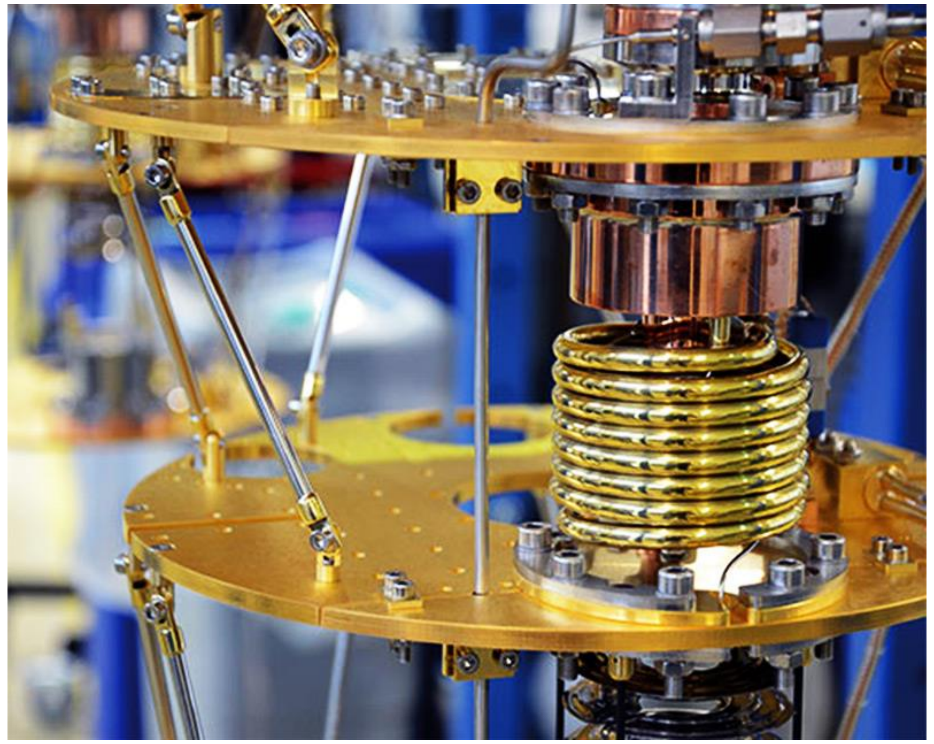
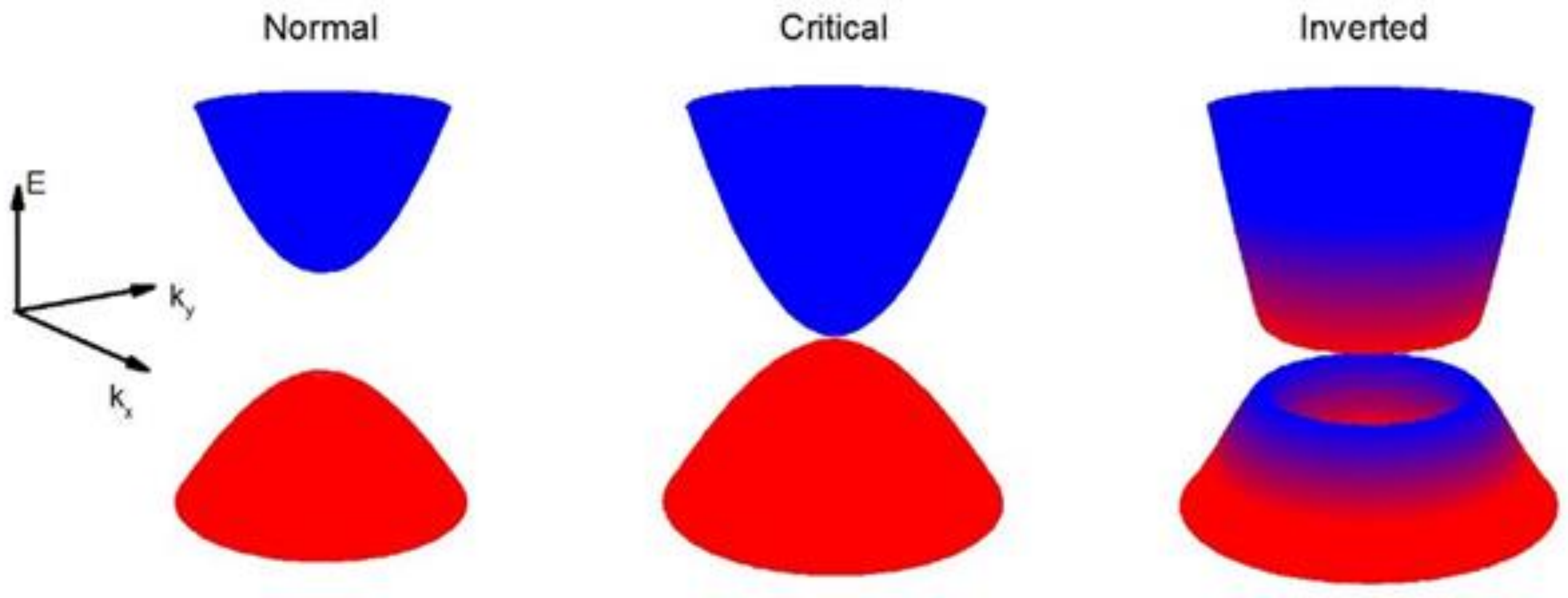


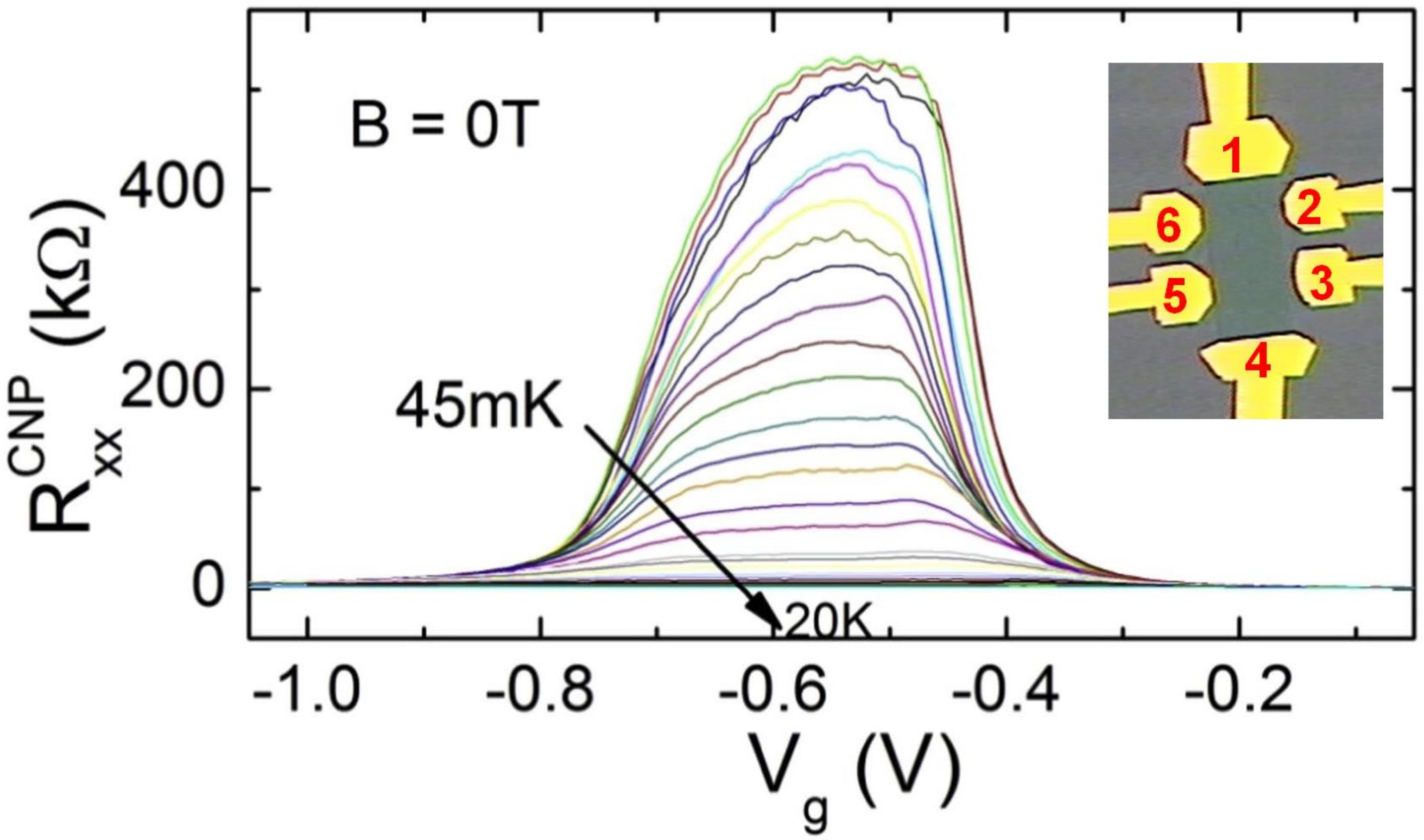
PAPER

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]



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



Longitudinal resistance Rxx as a function of gate voltage Vg for increasing Temperatures.

The Nobel Prize in Physics 2016 More

The Nobel Prize in Physics 2016

David J. Thouless
F. Duncan M. Haldane
J. Michael Kosterlitz

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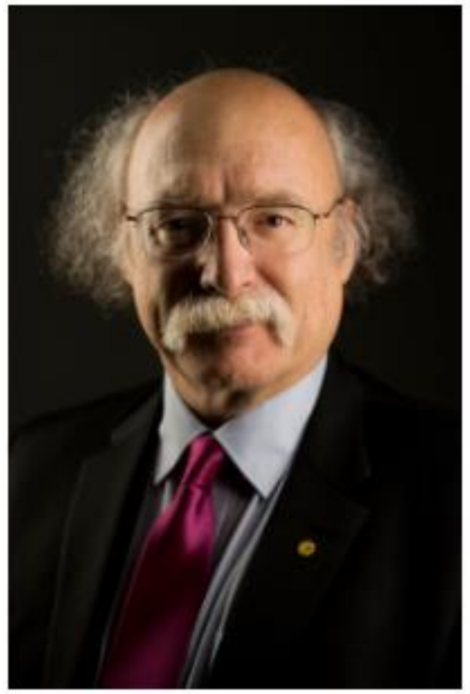
David J. Thouless



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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."

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Premium

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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

Topology Explained

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

07/10/2016 - Trieste

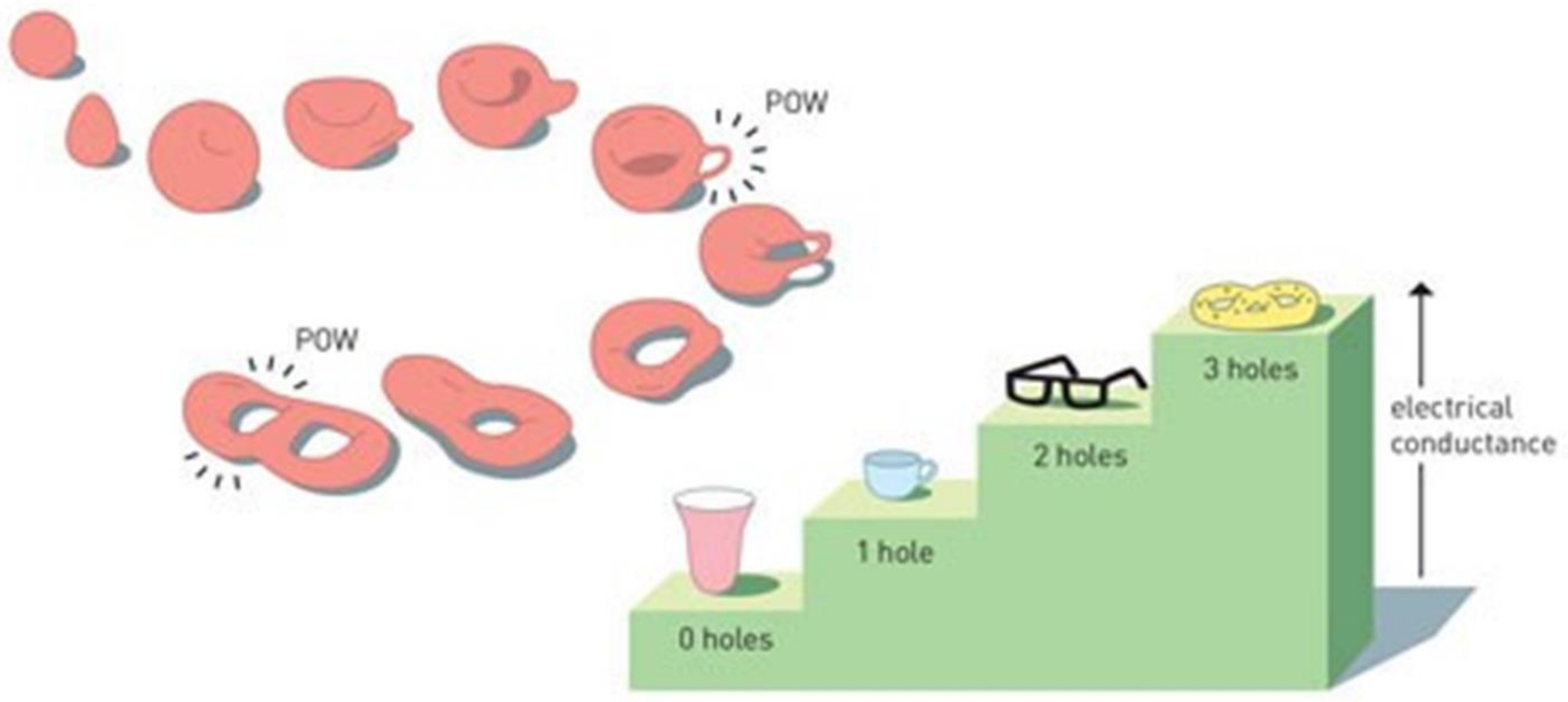
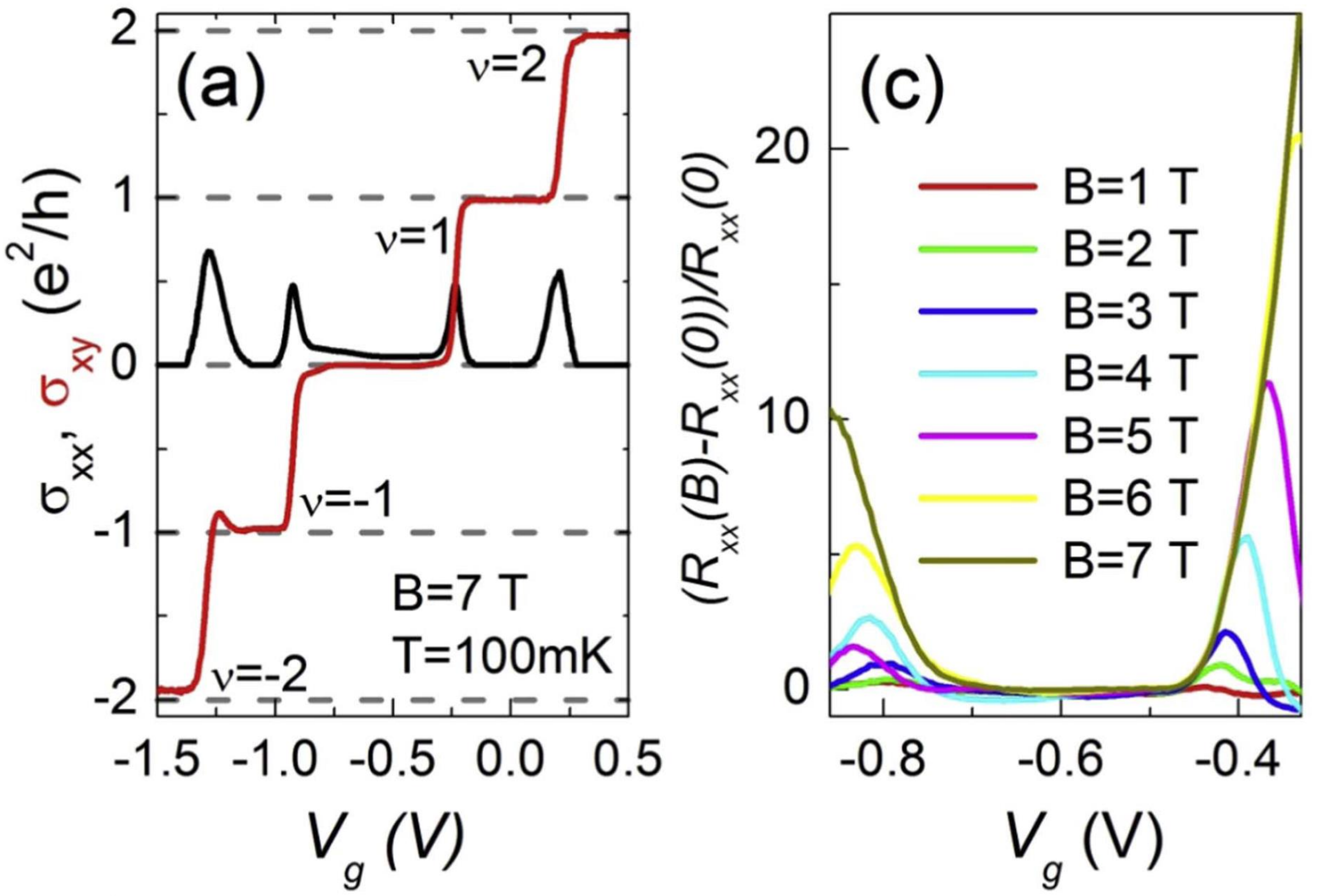


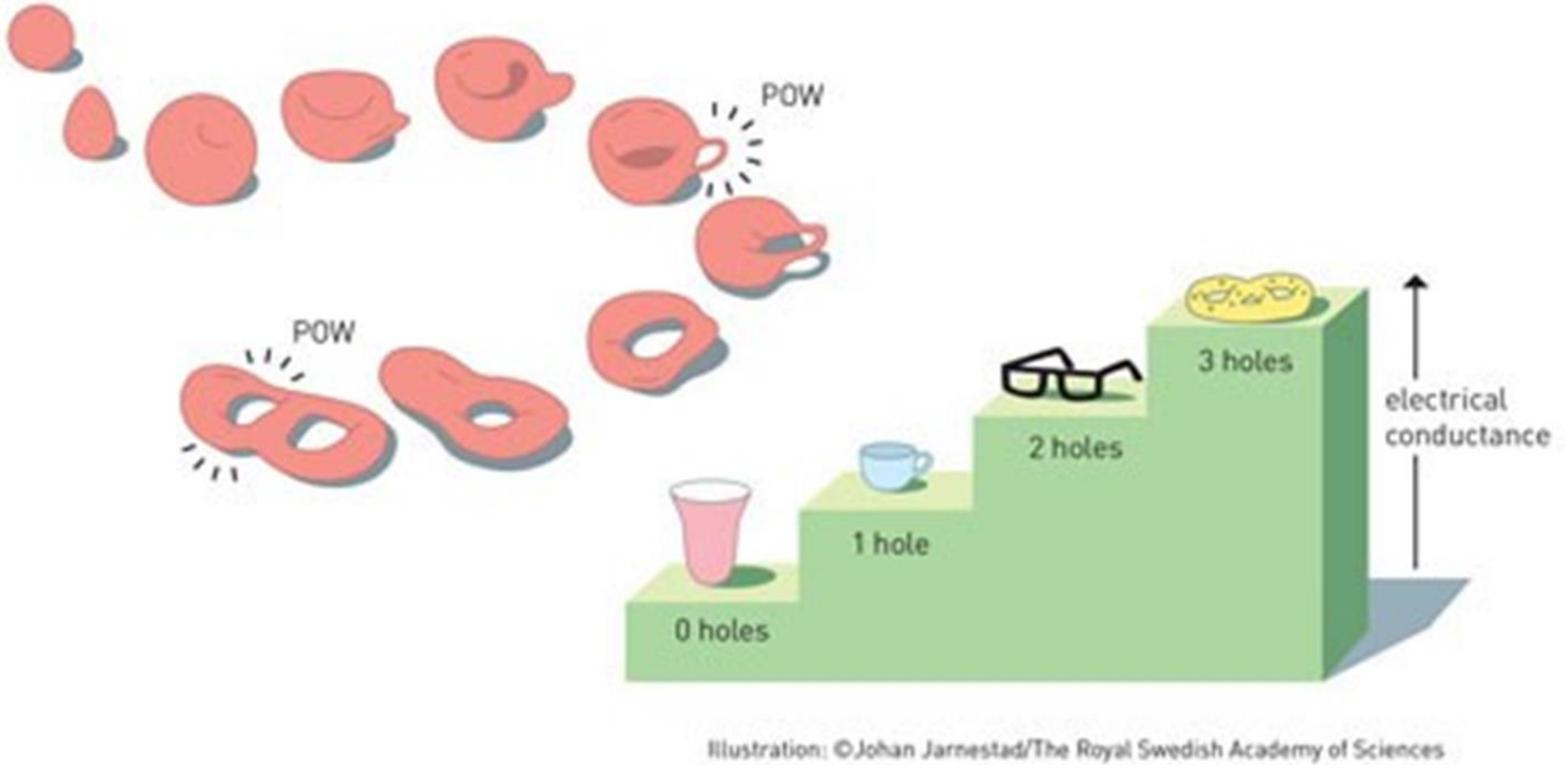
Illustration: ©Johan Jarnestad/The Royal Swedish Academy of Sciences

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

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.



Magnetotransport properties of the critical sample. (a) Longitudinal (s_{xx}) and Hall (s_{xy}) conductivities as a function of V_g, measured at $B = 7$ T. (c) Normalized magnetoresistance $(R_{xx}(B) - R_{xx}(0))/R_{xx}(0)$ in the charge neutrality point, for increasing magnetic fields.

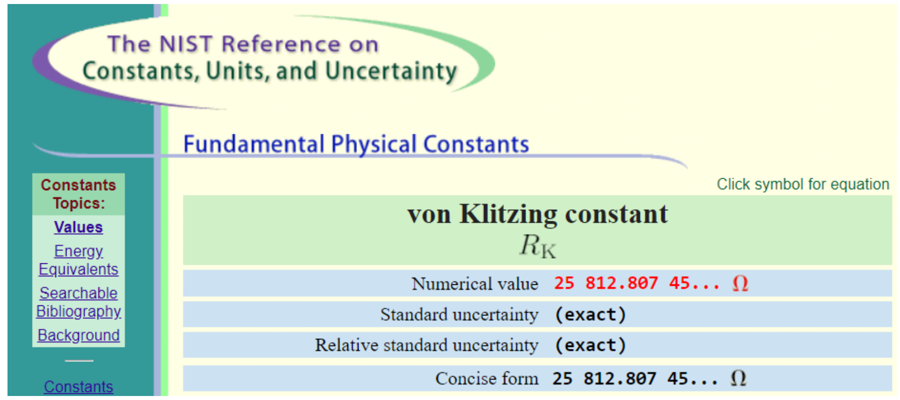


The Nobel Prize in Physics 1985

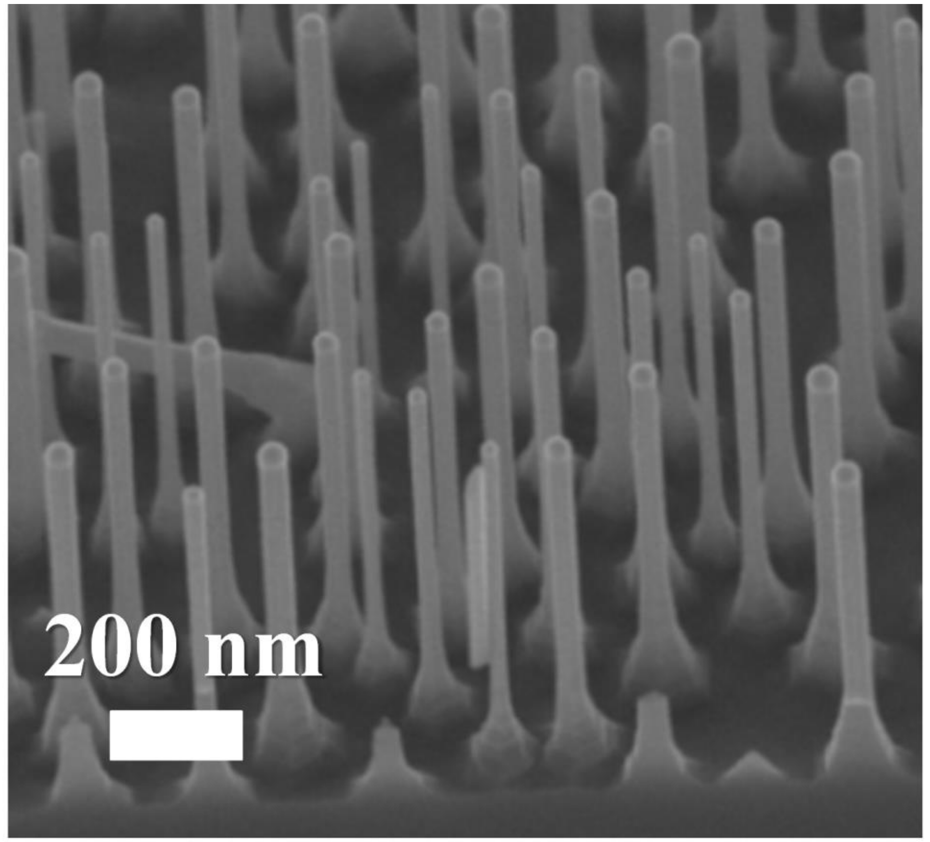
Photo from the Nobel Foundation archive.

Klaus von Klitzing

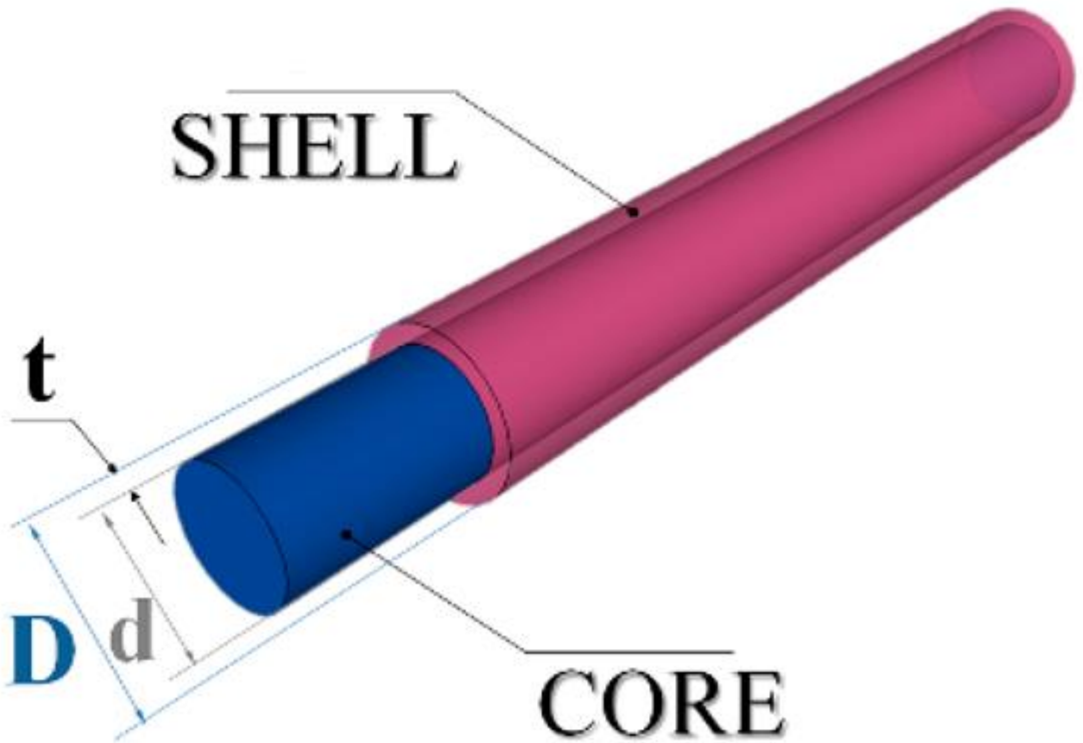
Prize share: 1/1



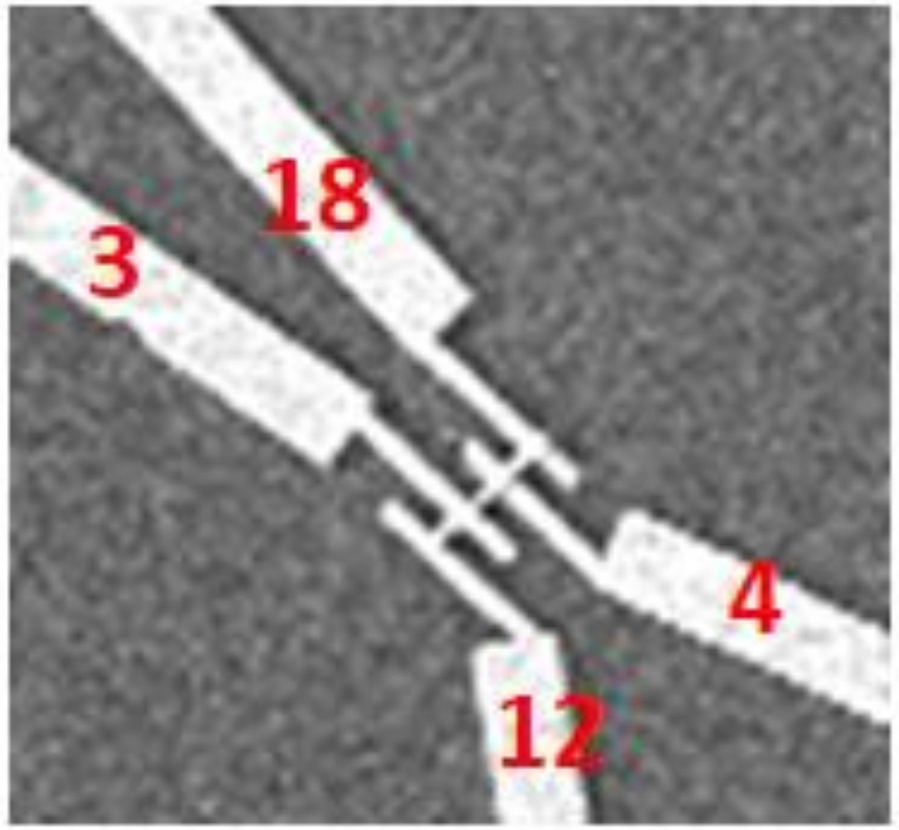
The Nobel Prize in Physics 1985 was awarded to Klaus von Klitzing "for the discovery of the quantized Hall effect."



SEM of a core–shell nanowires array.



Schematic structure of the single NW



materials

MDPI

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

Francesco Floris [1,*], Lucia Fornasari [2], Vittorio Bellani [2], Andrea Marini [3], Francesco Banfi [4], Franco Marabelli [2], Fabio Beltram [5], Daniele Ercolani [5], Sergio Battiato [5], Lucia Sorba [5] and Francesco Rossella [5,*]

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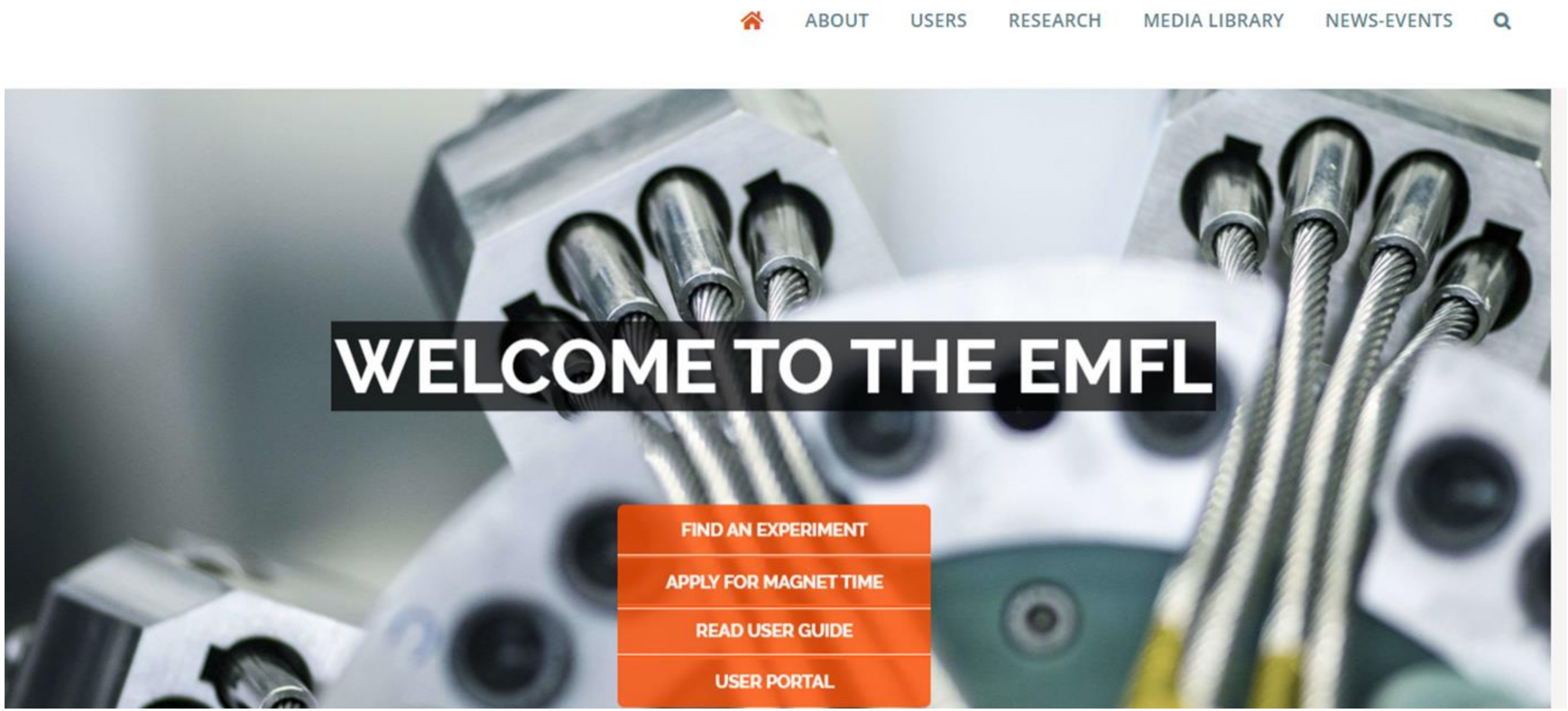
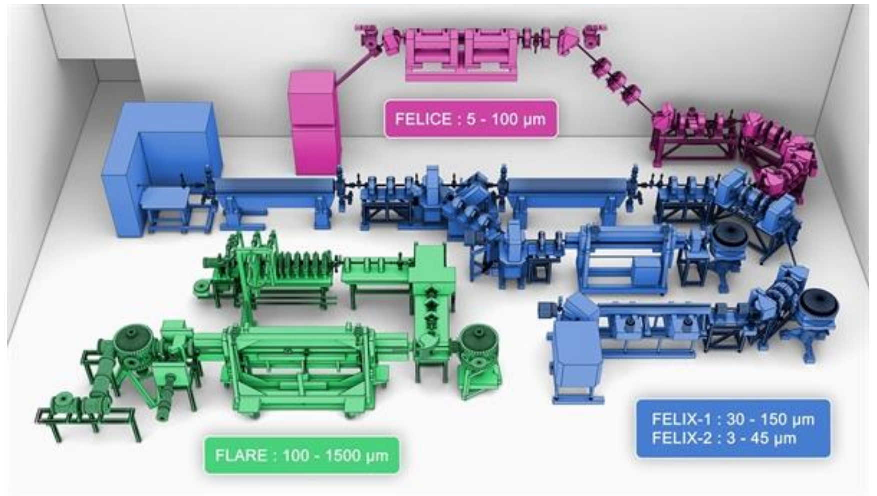
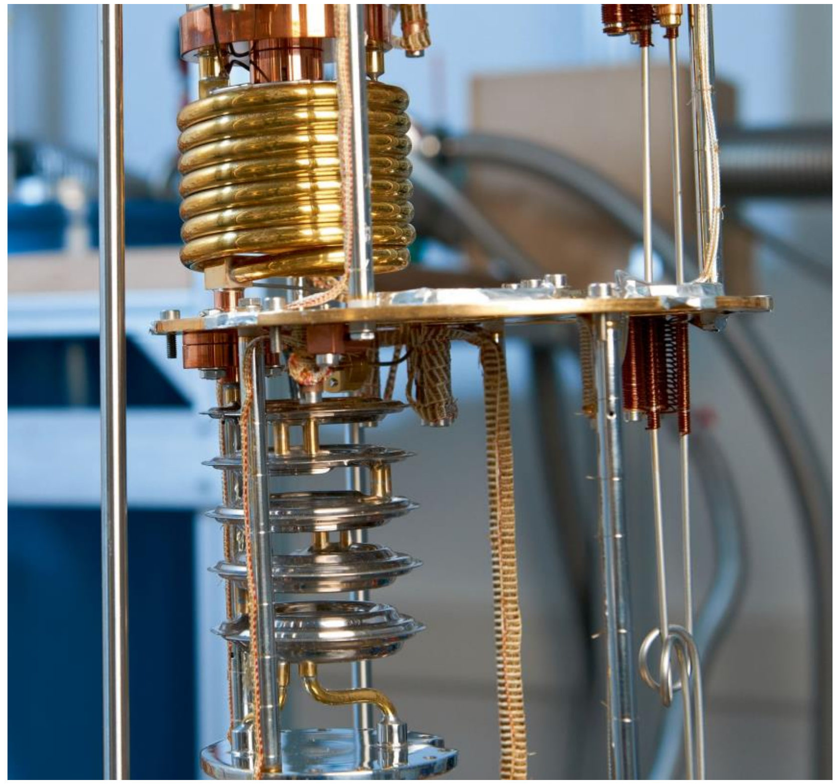
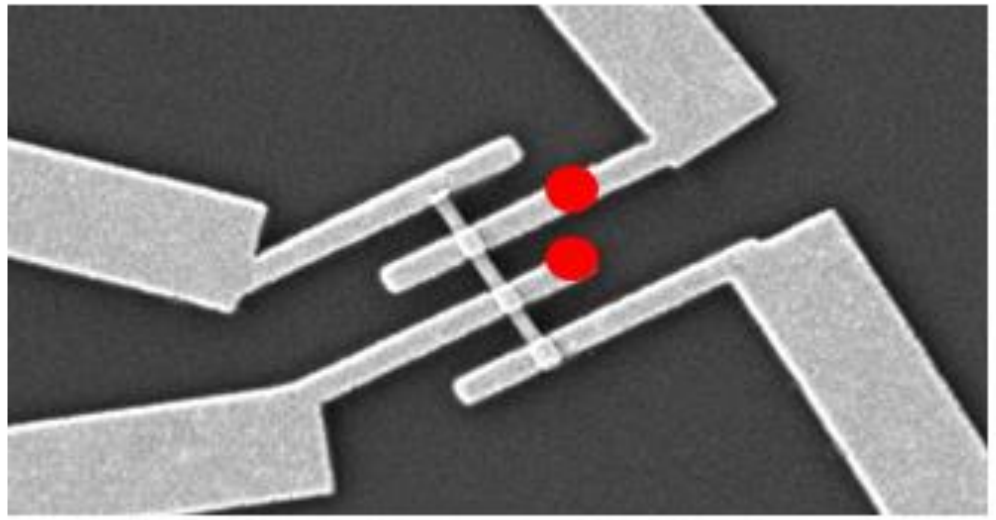
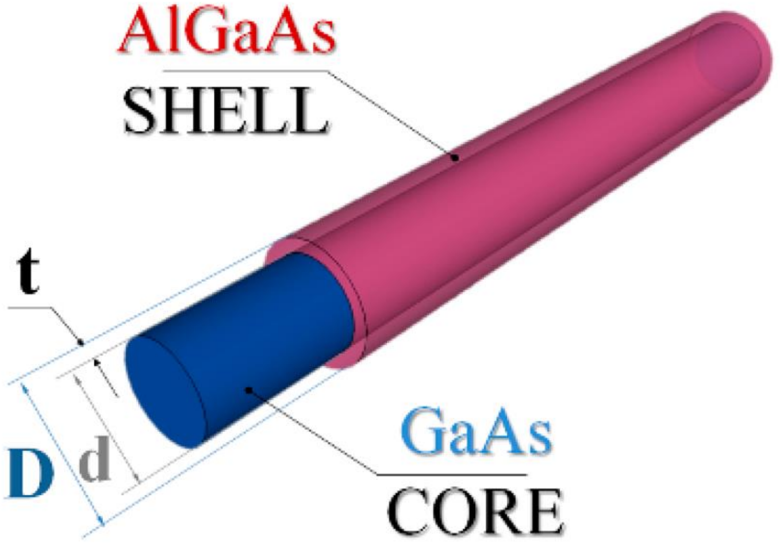
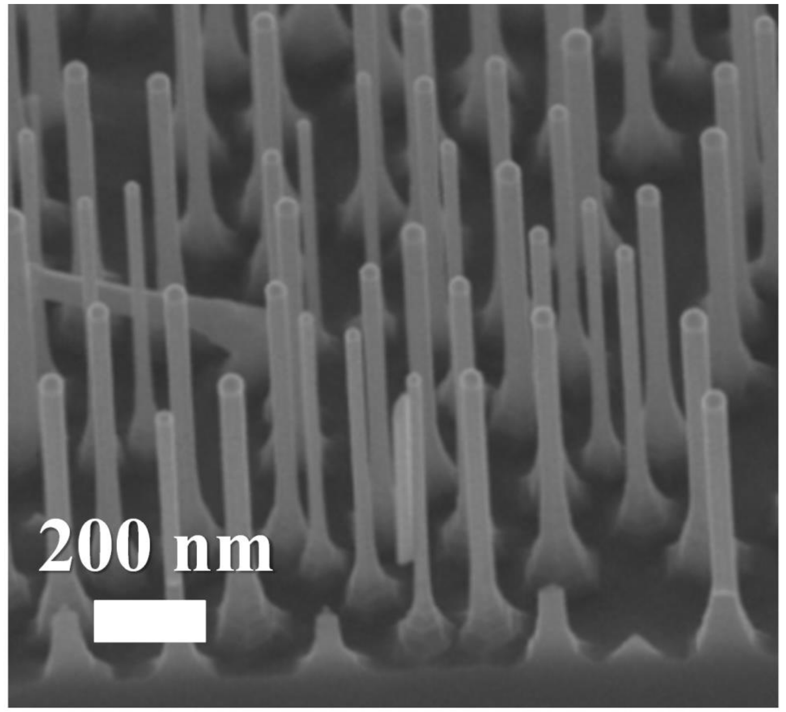


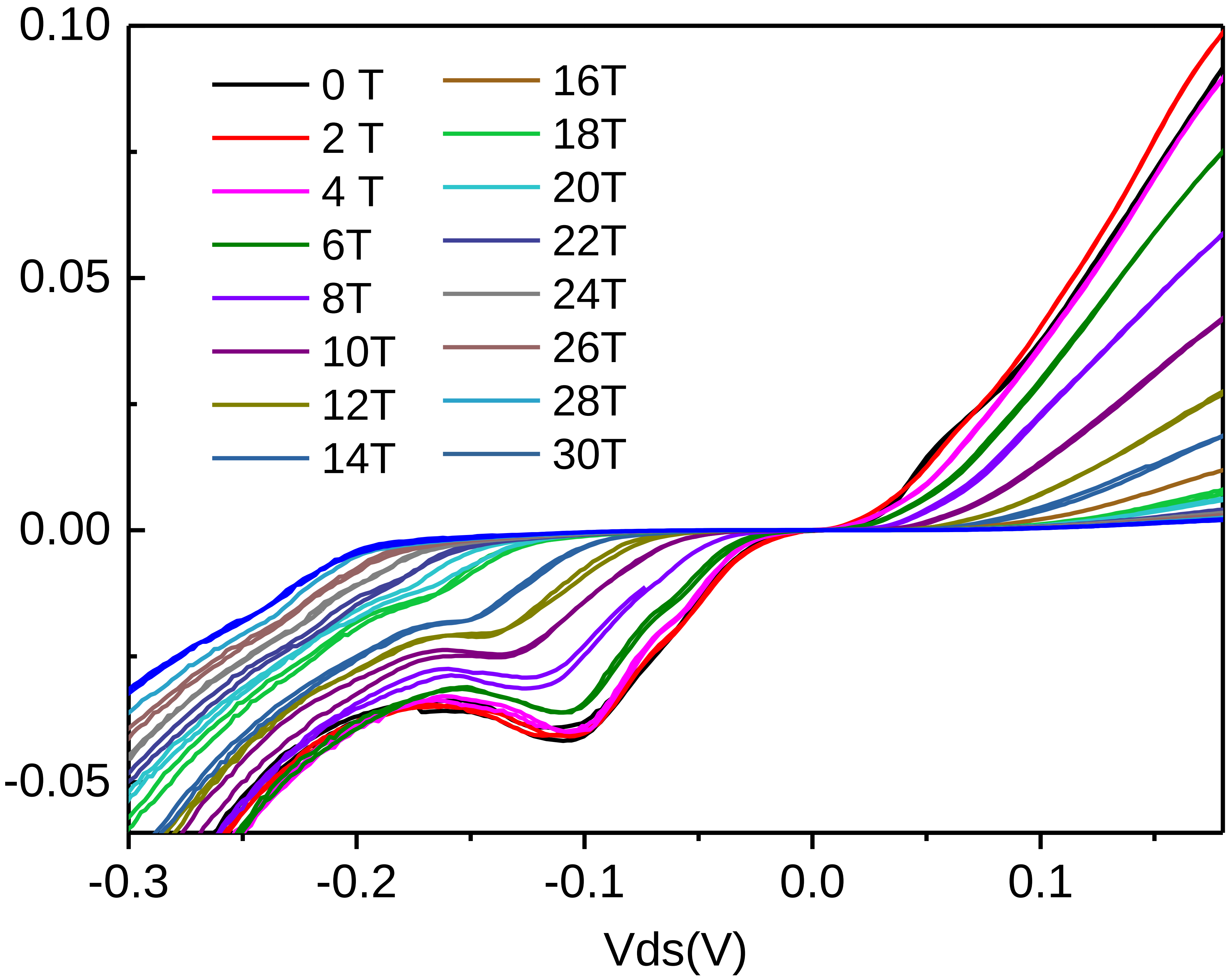




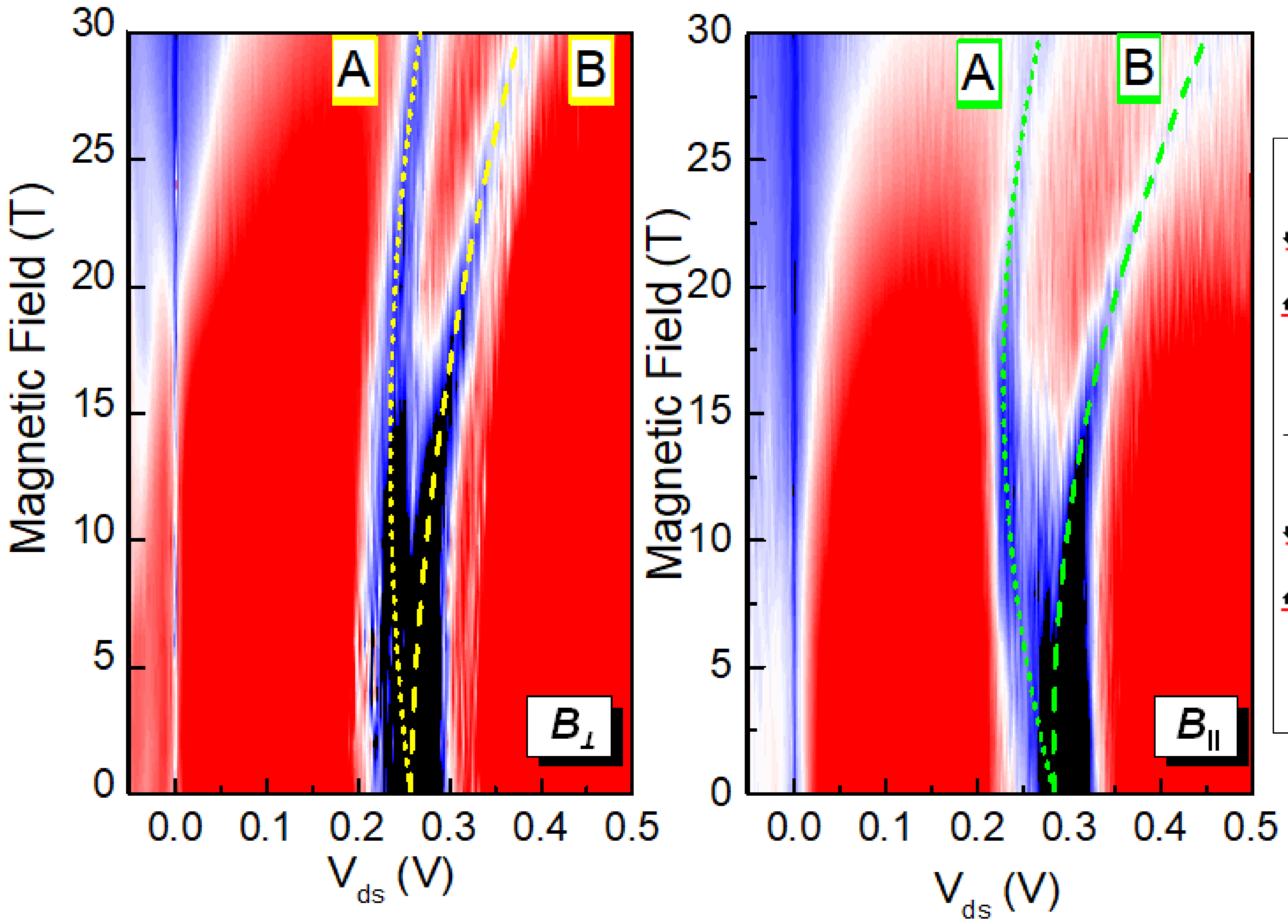




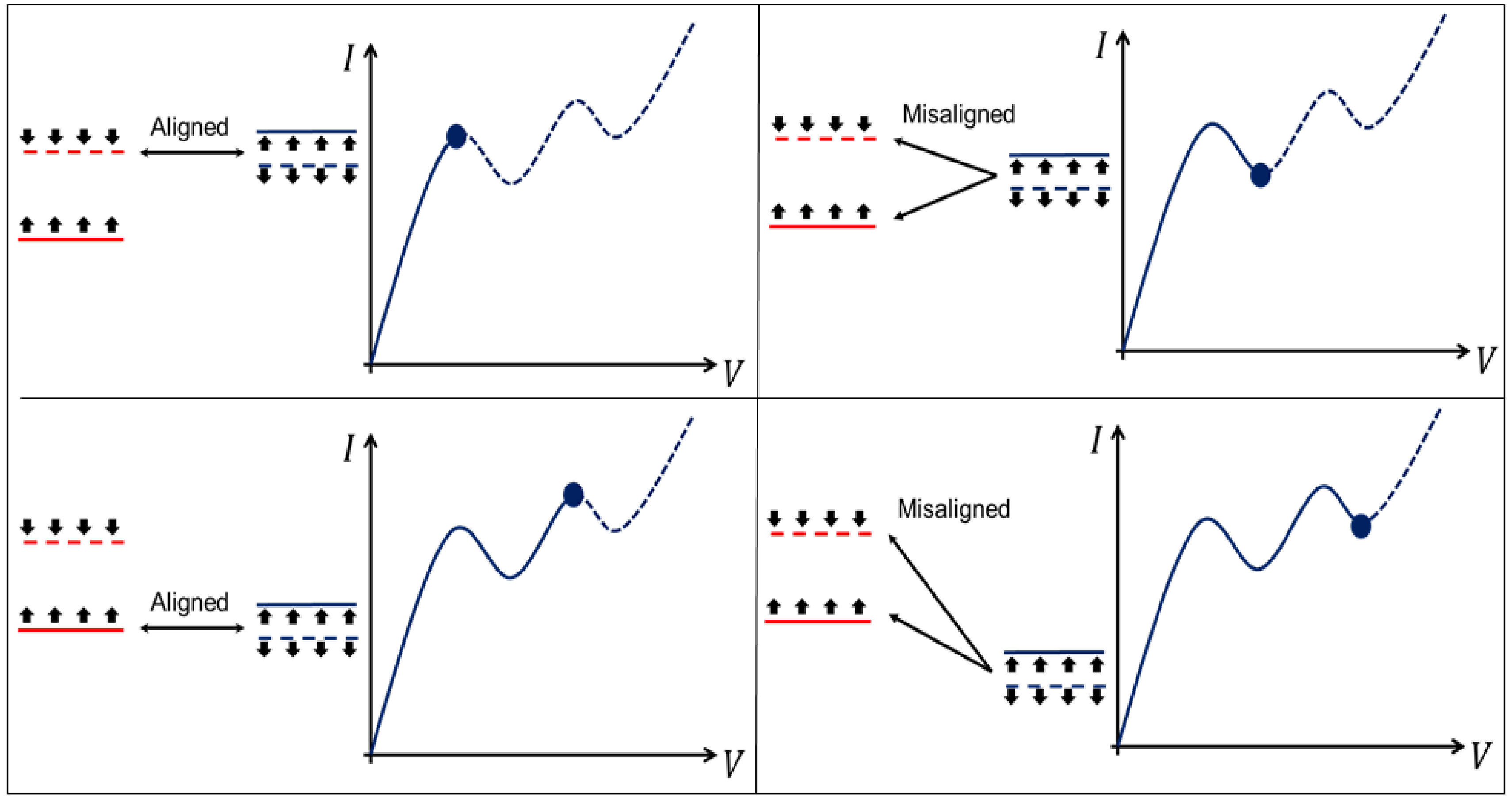




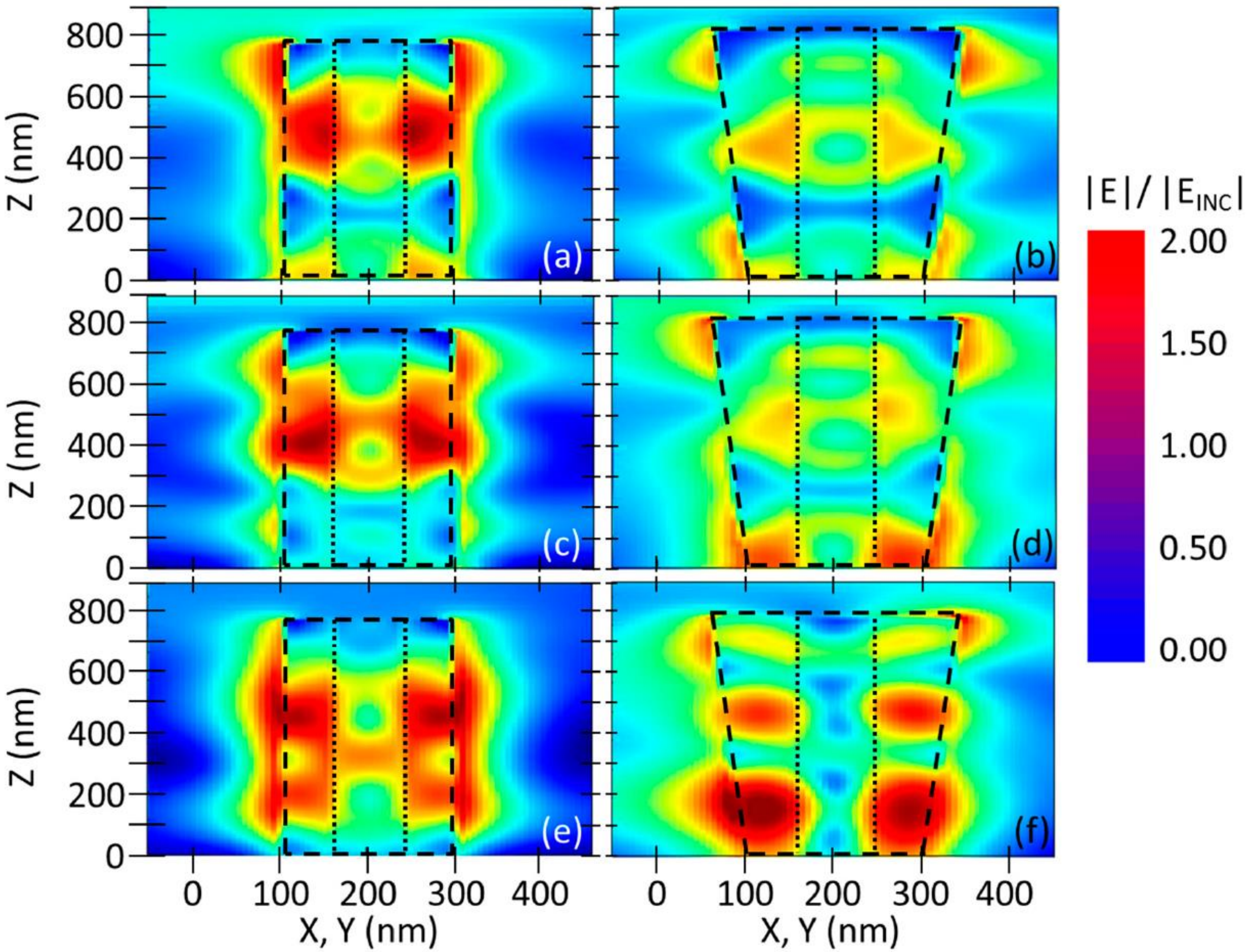
I-V charateristics of the NW detector versus magnetic field at T = 2 K.



dI/dV versus V_{db} and *B*, for magnetic field applied perpendicularly and parallel to the NWs. The NDC simultaneously hand linear landau shift, Zeeman splitting and quadratic diamagnetic shift.



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.



Longitudinal electric field distribution around a NW. Near-field normalized electric field expansion for the non-tapered C–S geometry, (**a**) θ = 0 ° , λ = 925 nm; (**c**) θ = 40° , λ = 800 nm and (**e**) θ = 70, λ = 735 nm. Near-field normalized electric field expansion for the tapered C–S geometry, (**b**) θ = 0 ° and a λ = 925 nm, (**d**) θ = 40 and a λ 820 nm (**f**) θ = 70° , λ = 690 nm.

F. Floris et al., Materials 12, 3572 (2019).

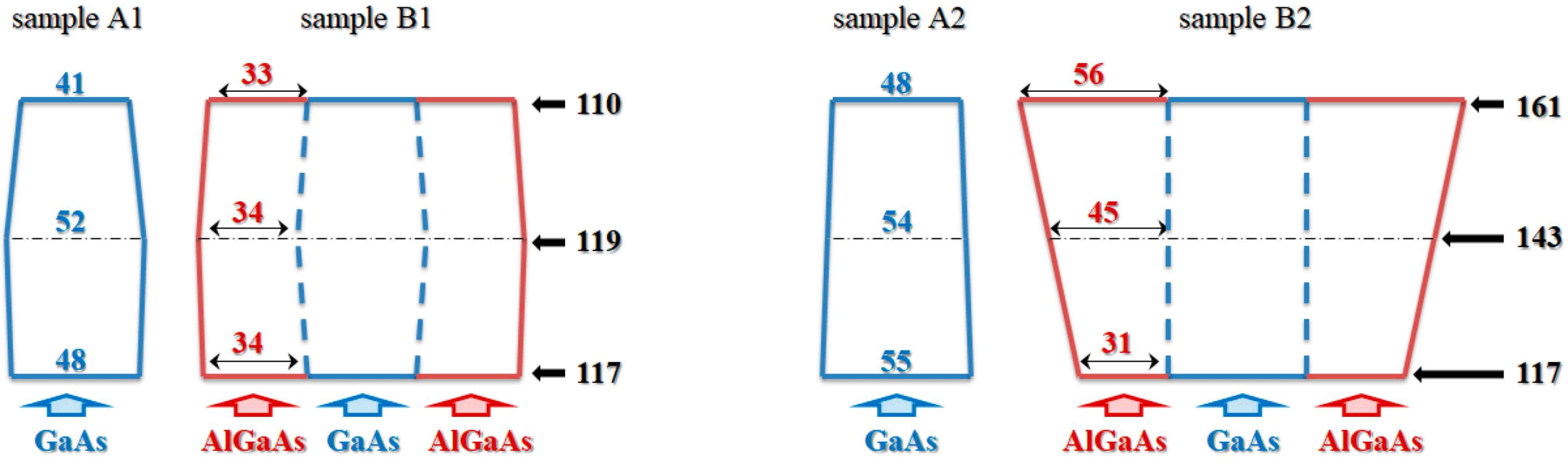
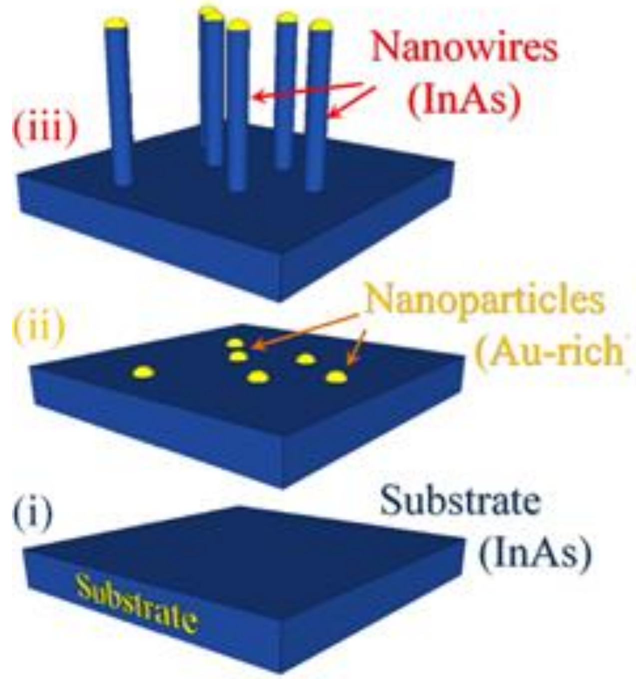
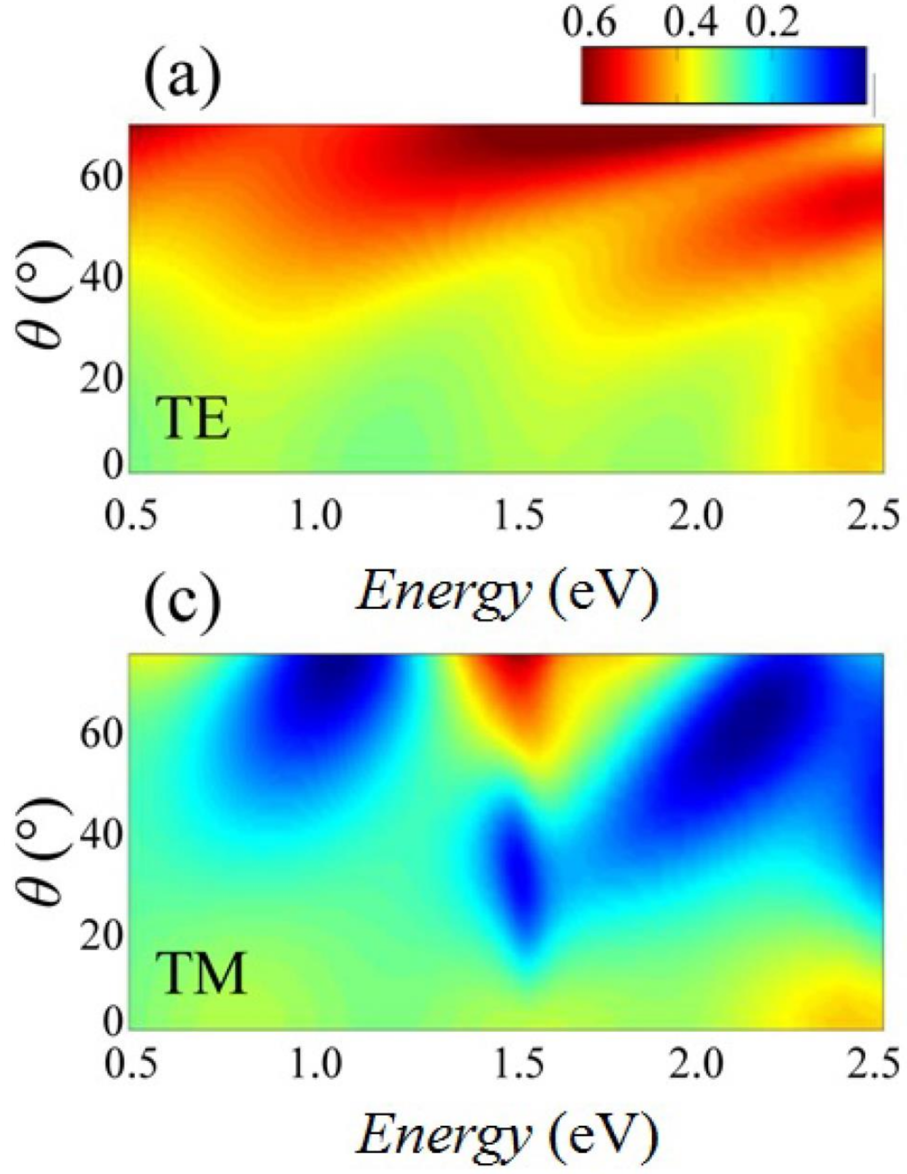


Figure 2. Schematic of the geometrical features of the four types of NW samples investigated in this work: not-tapered homogeneous GaAs NWs (samples A1 and A2), not-tapered core–shell GaAs–AlGaAs NWs (sample B1), and tapered core–shell GaAs–AlGaAs NWs (B2). Label numbers are expressed in nm and indicate: diameter of GaAs samples A1 and A2 (blue colored); thickness of AlGaAs shell in samples B1 and B2 (red colored); outer diameter of samples B1 and B2 (black colored).

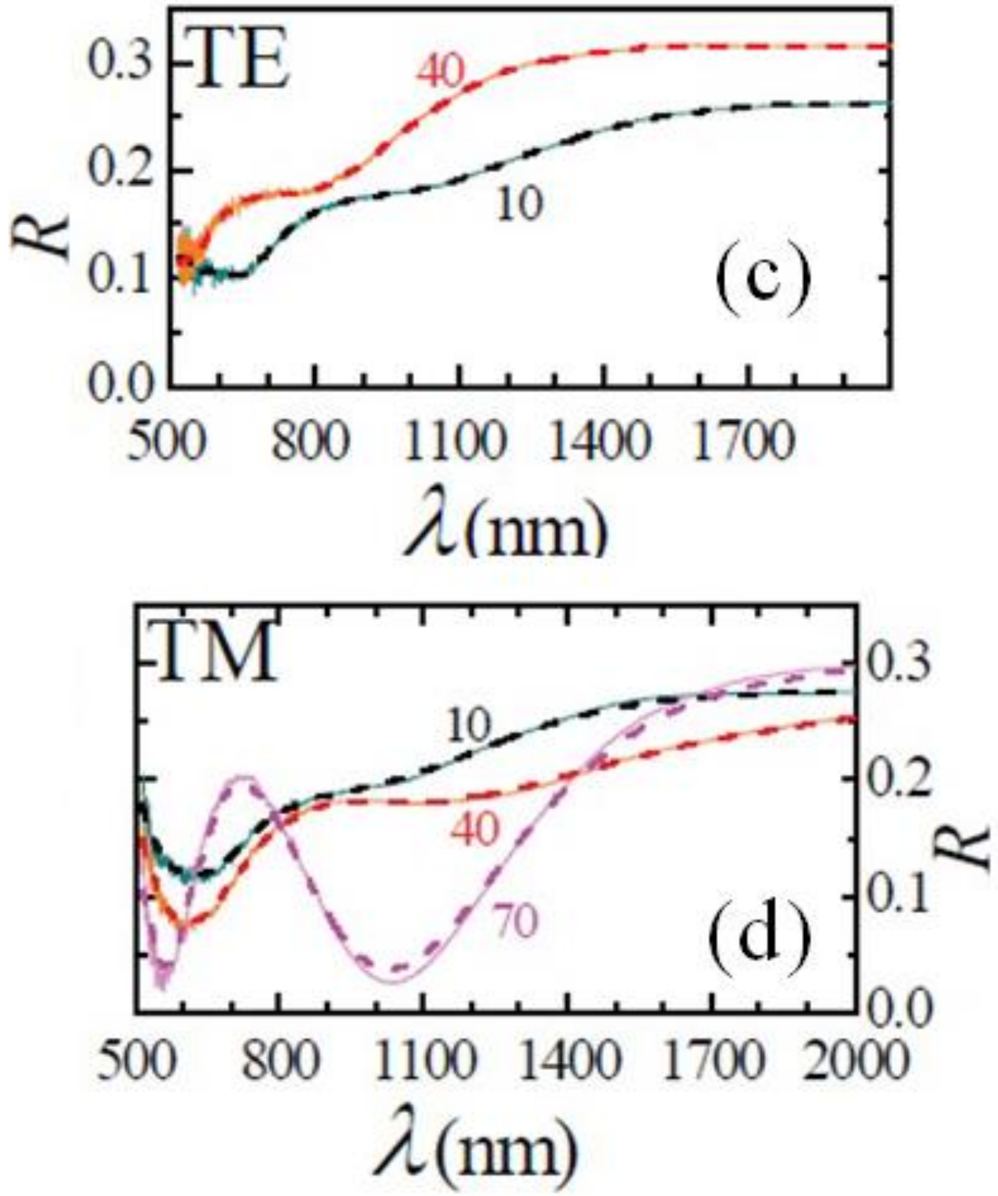
F. Floris et al., Materials 12, 3572 (2019).



Schematics of a set of samples (ii) InAs substrate with Au catalyst nanoparticles; (iii) NW assembly (c) optical measurement configuration.



Logarithmic color plot of the angle and energy-resolved calculated reflectence.



(**c**,**d**) Calculated (dashed line) and measured (solid line) reflectance for the two polarizations.

nanomaterials

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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,*]

Conclusions

- Semiconductor nanowires detectors using topological insulator (TI) may allow the measurement of axions.

- Numerical simulations allowed for identifying the geometrical features of the core–shell nanowires leading to the design of optimal structures for the detectors.

- The self-assembled NW technology enables fast and cost-effective realization of detectors. NWs are relevant in view of sensitive detection, thanks to the exceptional surface-to-volume ratio due to the high aspect ratio of the NWs.

- Owing to their large surface-to-volume ratio, NWs and NW-based systems bear great potential for sensing applications. They powerful detection platform for a broad range of radiation detection for astro-particle physics.