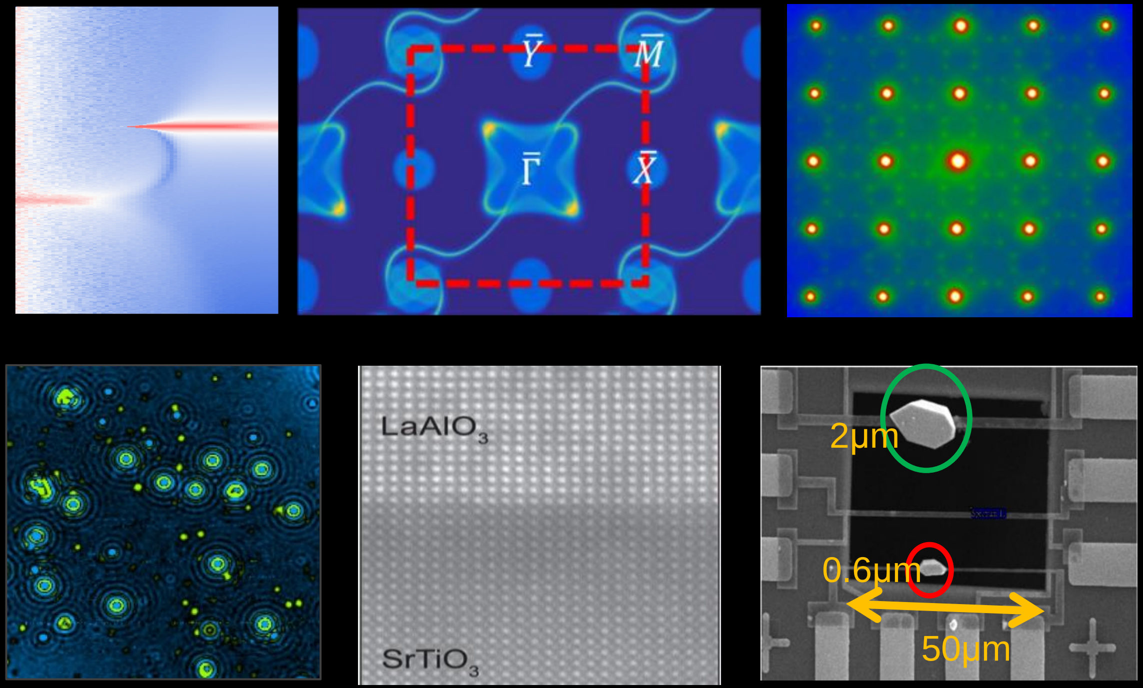
“Introduction” to Quantum Materials Group



溫昱傑、柯忠廷
中央研究院物理研究所

Jul. 7th 2022

Who We are?

張嘉升

吳茂昆

陳洋元

李尚凡

陳啟東

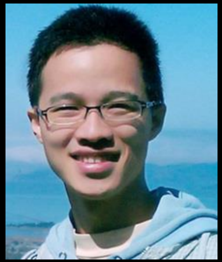
李偉立

葉崇傑

林新

胡宇光

溫昱傑



林宮玄

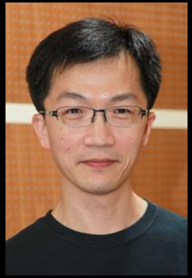
柯忠廷

Raman Sankar

黃英碩

蘇維彬

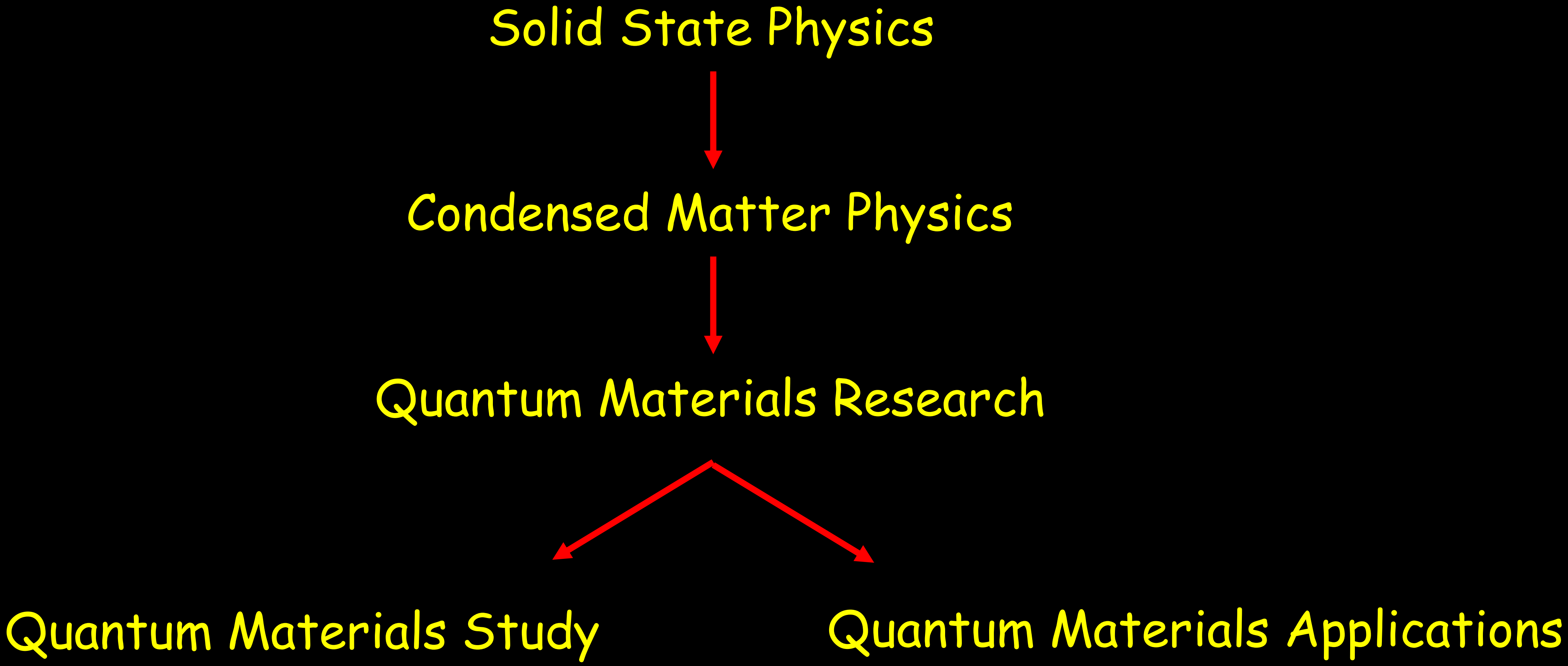
莊天明



楊志文

歐敏男

What Do We Do?



Solid State Physics

Condensed Matter Physics

Quantum Materials Research

Quantum Materials Study

Quantum Materials Applications

The Prehistoric Age

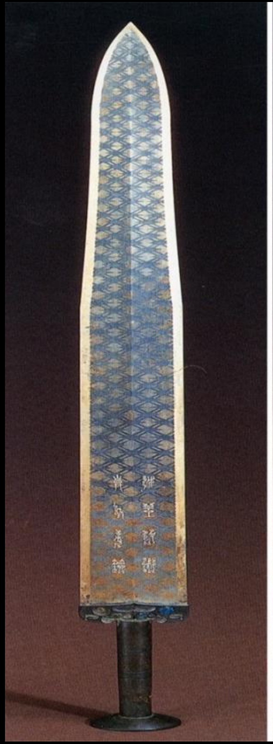
The Stone Age

How Stone Age Humans Made Hand Axes

1. The process started with a large piece of rock.
2. The humans roughly shaped the rock with a stone hammer.
3. Using a hammer made of wood, stone, or antler, they sharpened the edge.
4. They trimmed the edge by prying off tiny flakes with a pointed stick.

Viktor Vasnetsov

The Bronze Age



越王勾踐劍

呉王夫差矛

China, 770~476 BC

©CNA

The Iron Age

Iron dagger
c.650BC

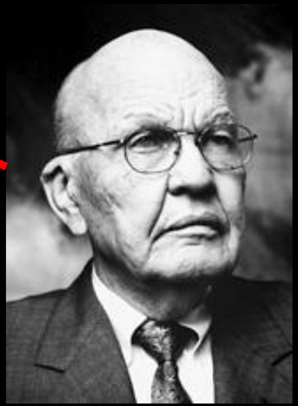
© British Museum

Impact to Our Life

CCD Sensor
W.S. Boyle & G.E. Smith

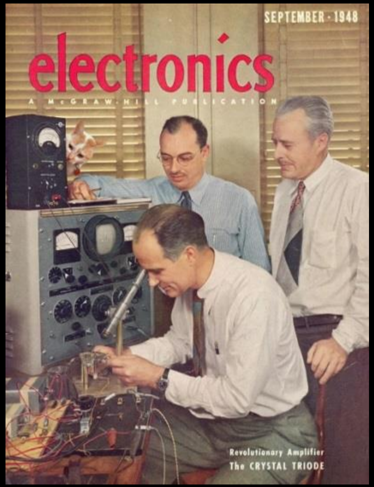
Nobel Prize in 2009

IC
Jack Kilby



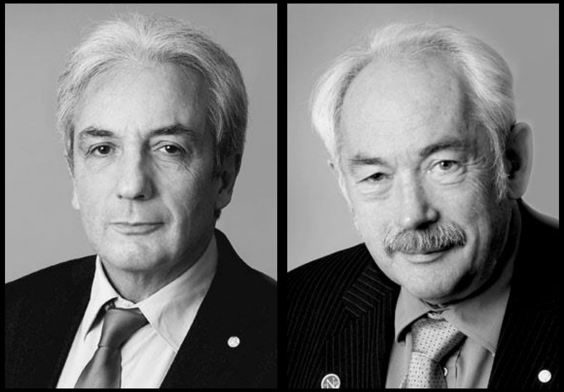
Nobel Prize in 2000

Transistor by Shockley,
Brattain & Bardeen



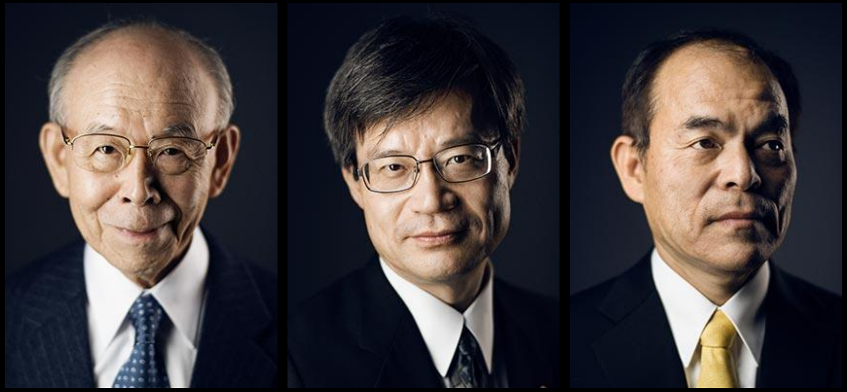
Nobel Prize in 1956

Magnetic Storage
A. Fert & P. Grünberg



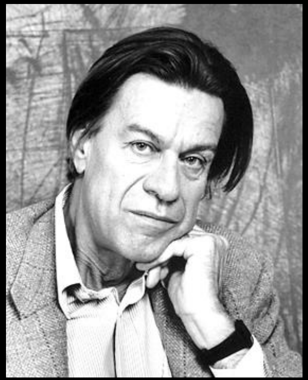
Nobel Prize in 2007

Blue LED
Akasaki, Amano & Nakamura



Nobel Prize in 2014

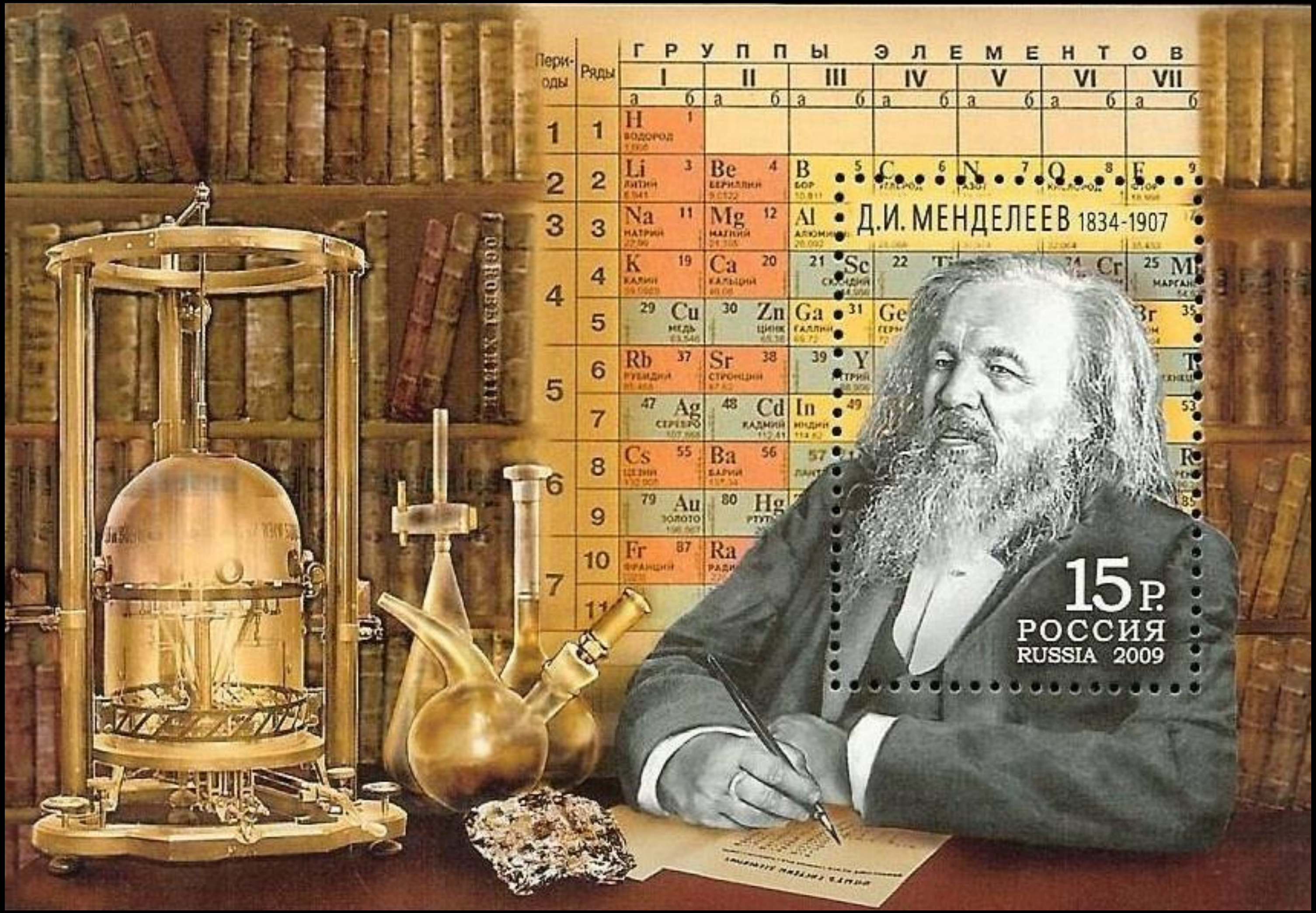
Liquid crystal
de Gennes



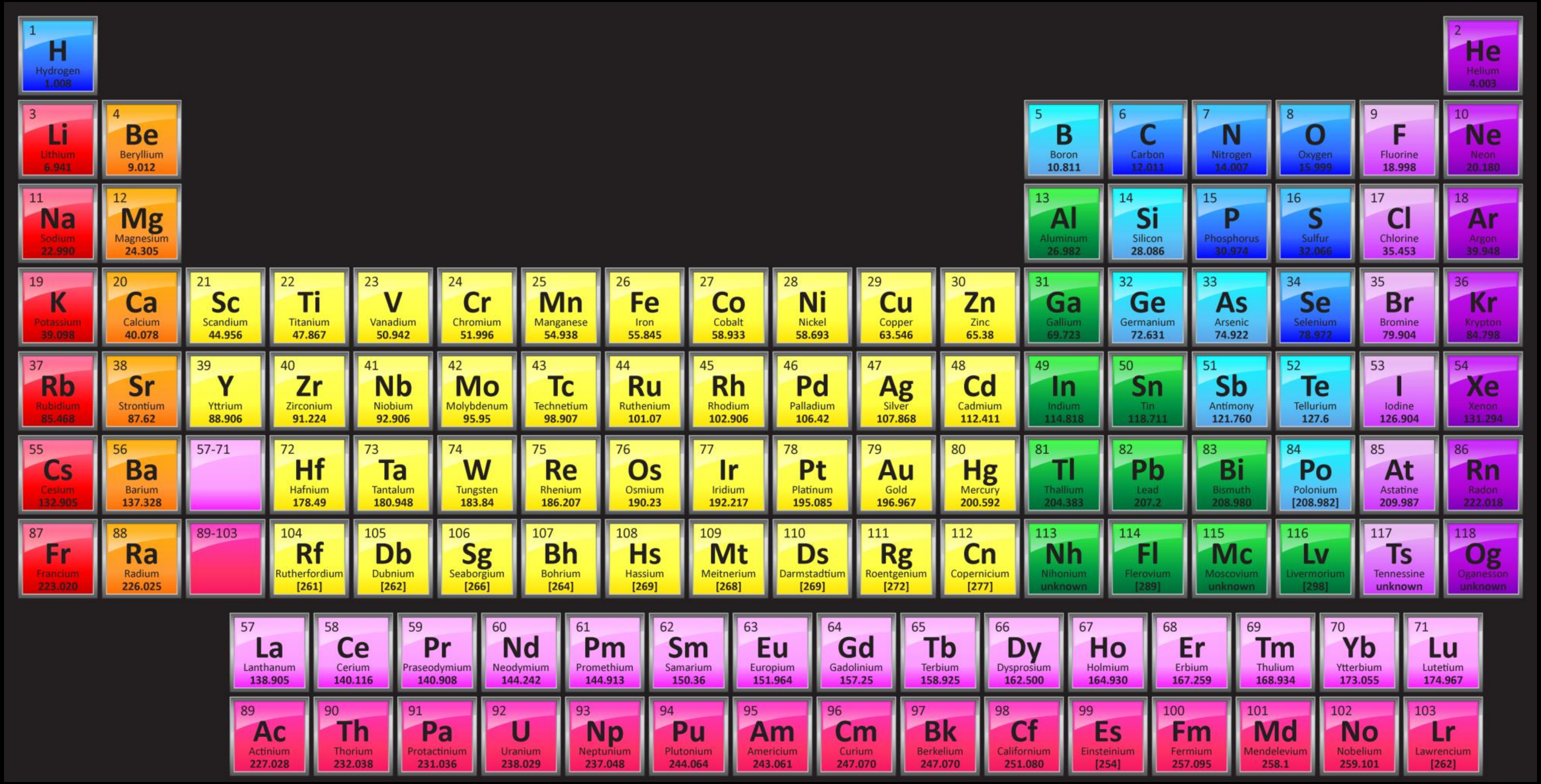
Nobel Prize in 1991

Periodic Table of Elements

Arranged by atomic weight
Dmitri Mendeleev in 1869



Periodic Table of Elements, 2016



1 **H** Hydrogen 1.008																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012											5 **B** Boron 10.811	6 **C** Carbon 12.011	7 **N** Nitrogen 14.007	8 **O** Oxygen 15.999	9 **F** Fluorine 18.998	10 **Ne** Neon 20.180
11 **Na** Sodium 22.990	12 **Mg** Magnesium 24.305											13 **Al** Aluminum 26.982	14 **Si** Silicon 28.086	15 **P** Phosphorus 30.974	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.453	18 **Ar** Argon 39.948
19 **K** Potassium 39.098	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.956	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.942	24 **Cr** Chromium 51.996	25 **Mn** Manganese 54.938	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933	28 **Ni** Nickel 58.693	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.38	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.631	33 **As** Arsenic 74.922	34 **Se** Selenium 78.972	35 **Br** Bromine 79.904	36 **Kr** Krypton 84.798
37 **Rb** Rubidium 85.468	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.906	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.906	42 **Mo** Molybdenum 95.95	43 **Tc** Technetium 98.907	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.906	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.868	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.711	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.6	53 **I** Iodine 126.904	54 **Xe** Xenon 131.294
55 **Cs** Cesium 132.905	56 **Ba** Barium 137.328	57-71	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.948	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.085	79 **Au** Gold 196.967	80 **Hg** Mercury 200.592	81 **Tl** Thallium 204.383	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.980	84 **Po** Polonium [208.982]	85 **At** Astatine 209.987	86 **Rn** Radon 222.018
87 **Fr** Francium 223.020	88 **Ra** Radium 226.025	89-103	104 **Rf** Rutherfordium [261]	105 **Db** Dubnium [262]	106 **Sg** Seaborgium [266]	107 **Bh** Bohrium [264]	108 **Hs** Hassium [269]	109 **Mt** Meitnerium [268]	110 **Ds** Darmstadtium [269]	111 **Rg** Roentgenium [272]	112 **Cn** Copernicium [277]	113 **Nh** Nihonium unknown	114 **Fl** Flerovium [289]	115 **Mc** Moscovium unknown	116 **Lv** Livermorium [298]	117 **Ts** Tennessine unknown	118 **Og** Oganesson unknown
			57 **La** Lanthanum 138.905	58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.908	60 **Nd** Neodymium 144.242	61 **Pm** Promethium 144.913	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.925	66 **Dy** Dysprosium 162.500	67 **Ho** Holmium 164.930	68 **Er** Erbium 167.259	69 **Tm** Thulium 168.934	70 **Yb** Ytterbium 173.055	71 **Lu** Lutetium 174.967
			89 **Ac** Actinium 227.028	90 **Th** Thorium 232.038	91 **Pa** Protactinium 231.036	92 **U** Uranium 238.029	93 **Np** Neptunium 237.048	94 **Pu** Plutonium 244.064	95 **Am** Americium 243.061	96 **Cm** Curium 247.070	97 **Bk** Berkelium 247.070	98 **Cf** Californium 251.080	99 **Es** Einsteinium [254]	100 **Fm** Fermium 257.095	101 **Md** Mendelevium 258.1	102 **No** Nobelium 259.101	103 **Lr** Lawrencium [262]

Topological Quantum Matters

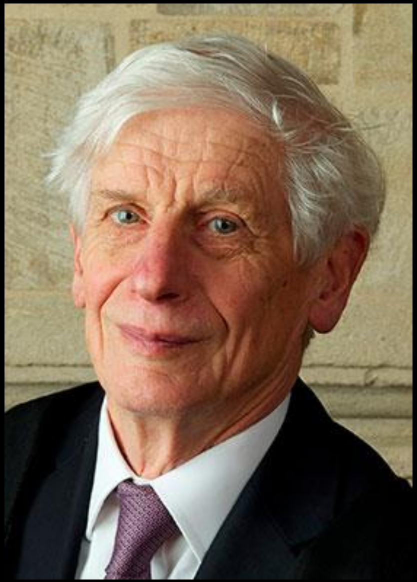
Quantum Hall effect

"Theoretical discoveries of topological phase transitions and topological phases of matter".

Klaus von Klitzing

Nobel Prize, 1985

David J. Thouless



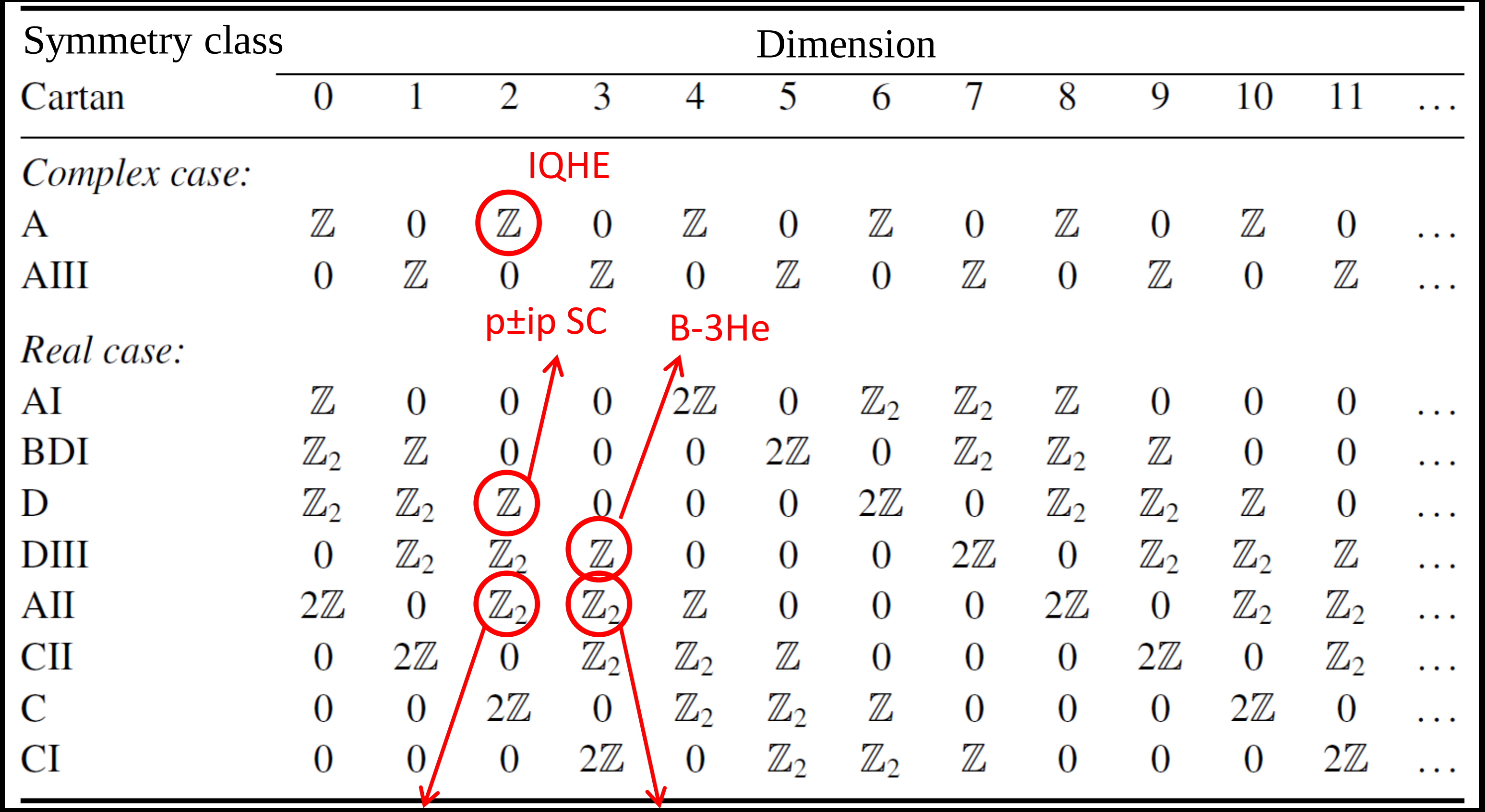
F. Duncan M. Haldane

Nobel Prize, 2016

J. Michael Kosterlitz

“Periodic Table” of Topological Materials

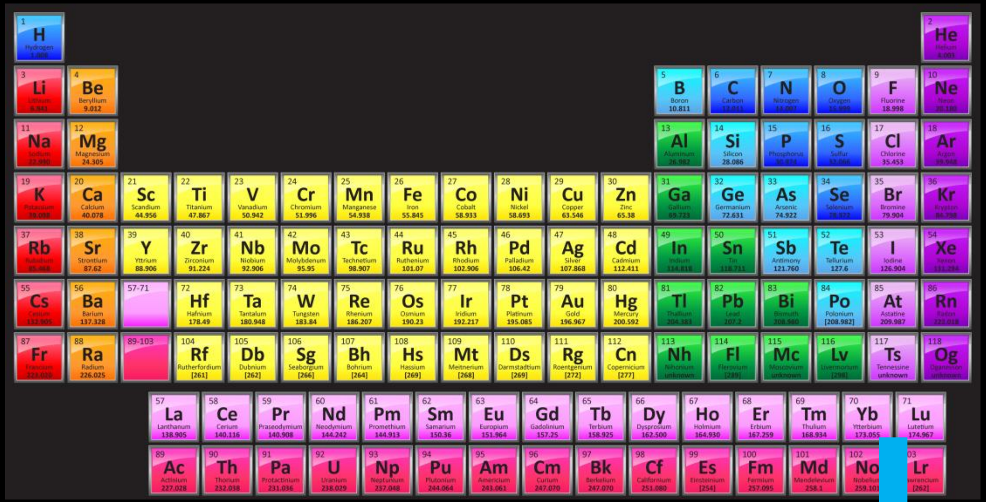
Classification of topological insulators and superconductors as a function of spatial dimension d and symmetry class:

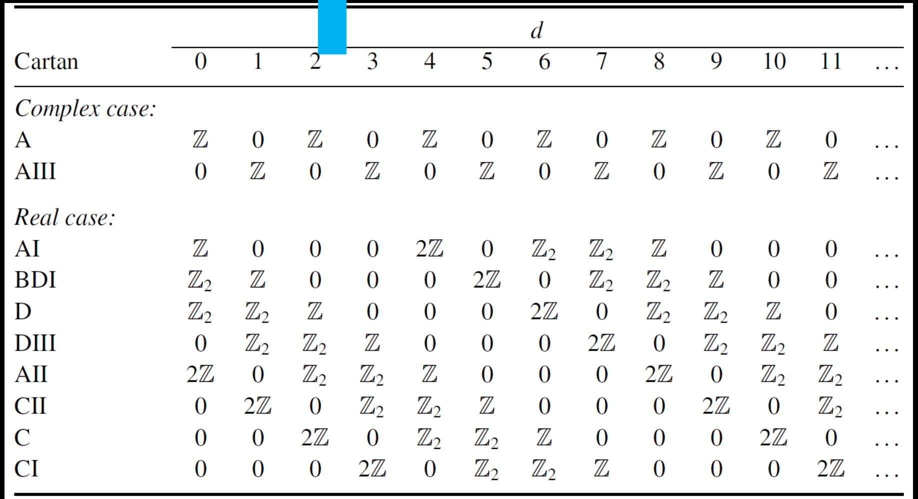


Symmetry class	Dimension												
Cartan	0	1	2	3	4	5	6	7	8	9	10	11	…
Complex case:													
A	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	…
AIII	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	…
Real case:													
AI	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	…
BDI	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	…
D	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	…
DIII	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	…
AII	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	…
CII	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	…
C	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	…
CI	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	…

New Journal of Physics 12, 065010 (2010)

Development of New Quantum Materials

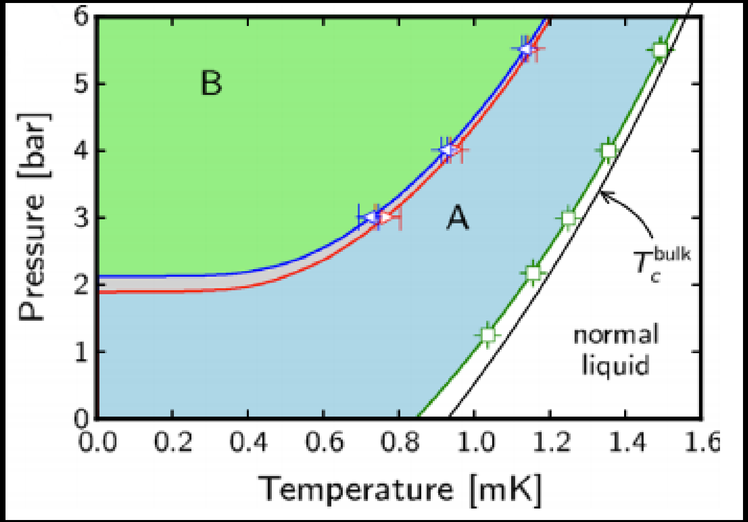




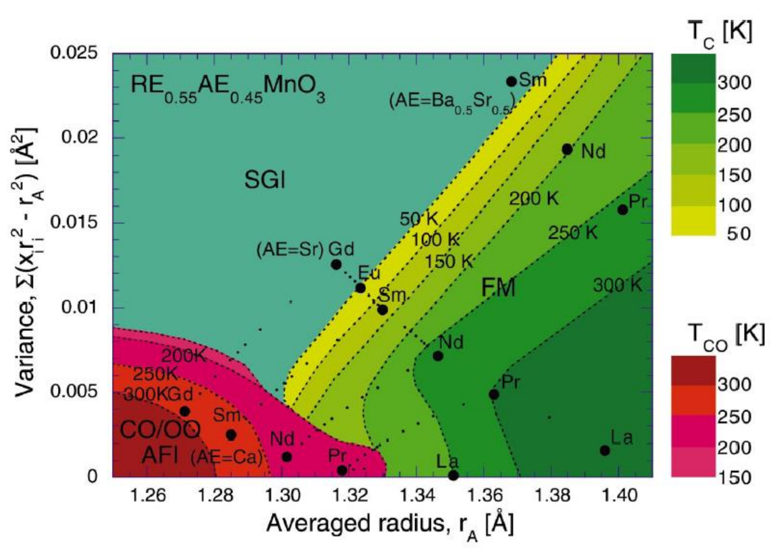
	d												
Cartan	0	1	2	3	4	5	6	7	8	9	10	11	…
Complex case:													
A	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	…
AIII	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	0	$\mathbb{Z}$	…
Real case:													
AI	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	…
BDI	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	…
D	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	…
DIII	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	…
AII	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	…
CII	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	…
C	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	0	…
CI	0	0	0	$2\mathbb{Z}$	0	$\mathbb{Z}_2$	$\mathbb{Z}_2$	$\mathbb{Z}$	0	0	0	$2\mathbb{Z}$	…

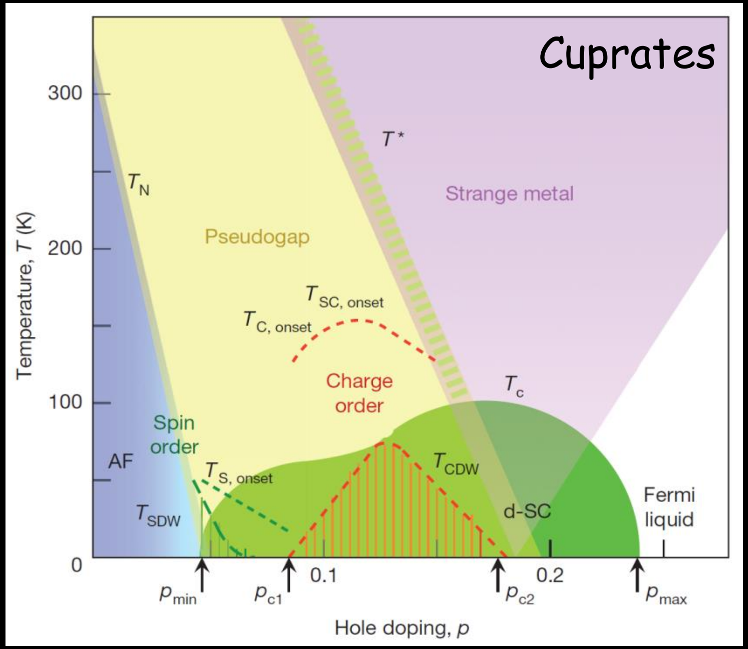
Complex Phases of Quantum Matters

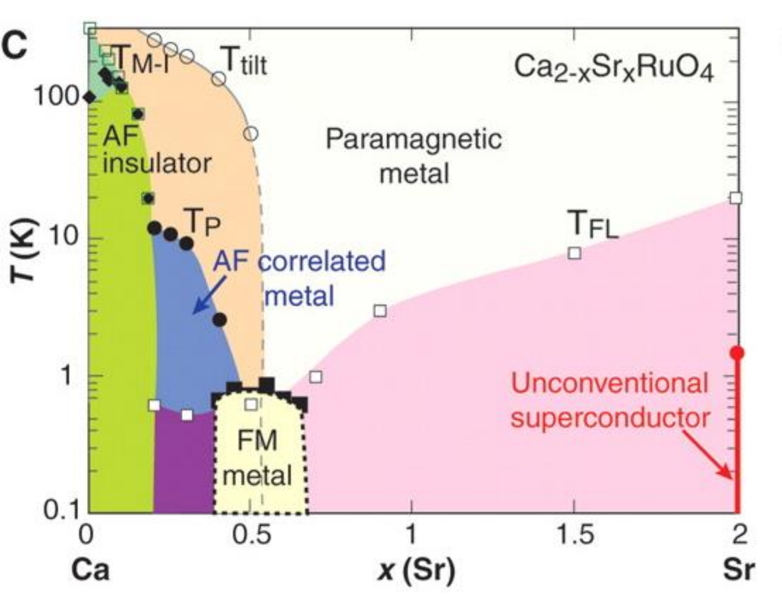
Superfluid ^{3}He



CMR manganites

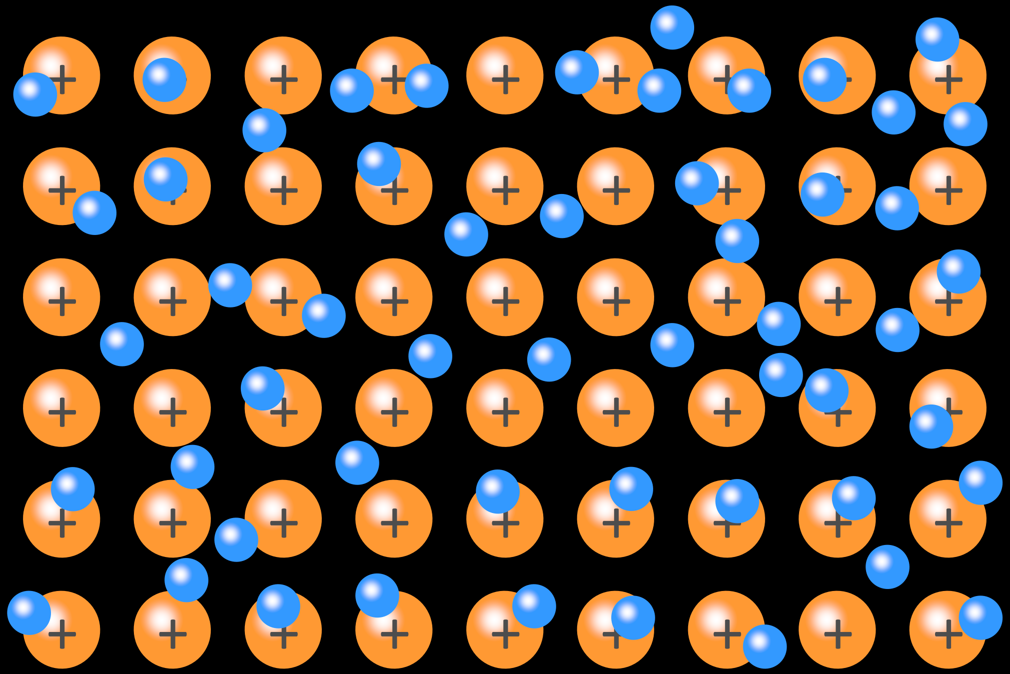






Electrons in Real Materials

$$-\frac{\hbar^2}{2m}\sum_{i}\nabla_i^2\Psi(\vec{r_1},\vec{r_2},,t)-\sum_{i,j}\frac{Ze^2}{|\vec{r_i}-\vec{R_j}|}\Psi(\vec{r_1},\vec{r_2},..,t)+\frac{1}{2}\sum_{i,j}\frac{e^2}{|\vec{r_i}-\vec{r_j}|}\Psi(\vec{r_1},\vec{r_2},..,t)=i\hbar\frac{\partial}{\partial t}\Psi(\vec{r_1},\vec{r_2},..,t)$$

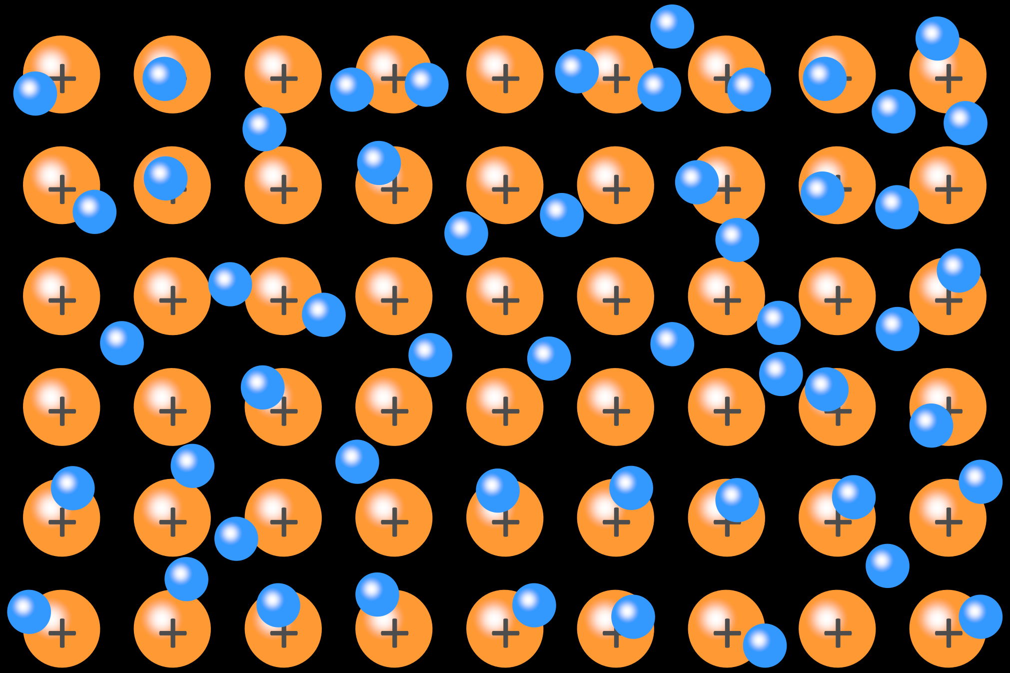


Erwin Schrödinger

Nobel Prize in 1933

Electrons in Real Materials

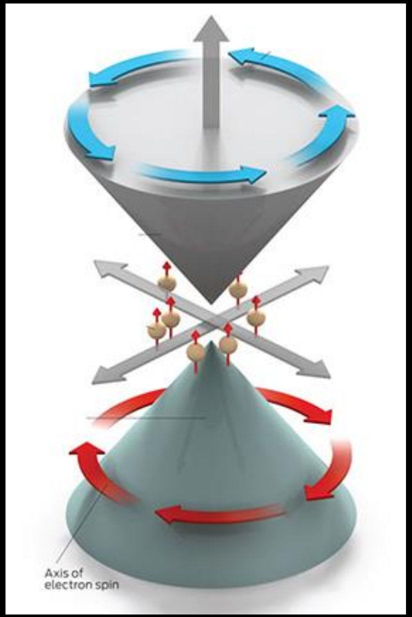
$$-\frac{\hbar^2}{2m}\sum_i \nabla_i^2\Psi(\vec{r_1},\vec{r_2},,t)-\sum_{i,j}\frac{Ze^2}{|\vec{r_i}-\vec{R_j}|}\Psi(\vec{r_1},\vec{r_2},..,t)+\frac{1}{2}\sum_{i,j}\frac{e^2}{|\vec{r_i}-\vec{r_j}|}\Psi(\vec{r_1},\vec{r_2},..,t)=i\hbar\frac{\partial}{\partial t}\Psi(\vec{r_1},\vec{r_2},..,t)$$



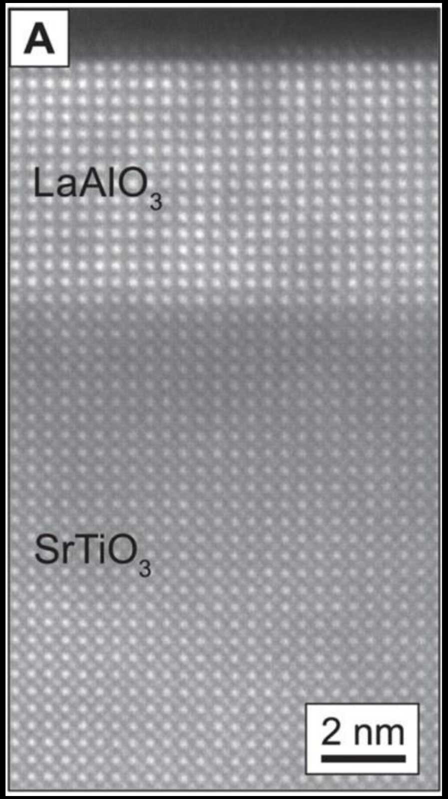
Quantum Material Studies in IoP/AS

High Tc Superconductivity

Topological Materials



Oxides Interface



Theory

葉崇傑、林新

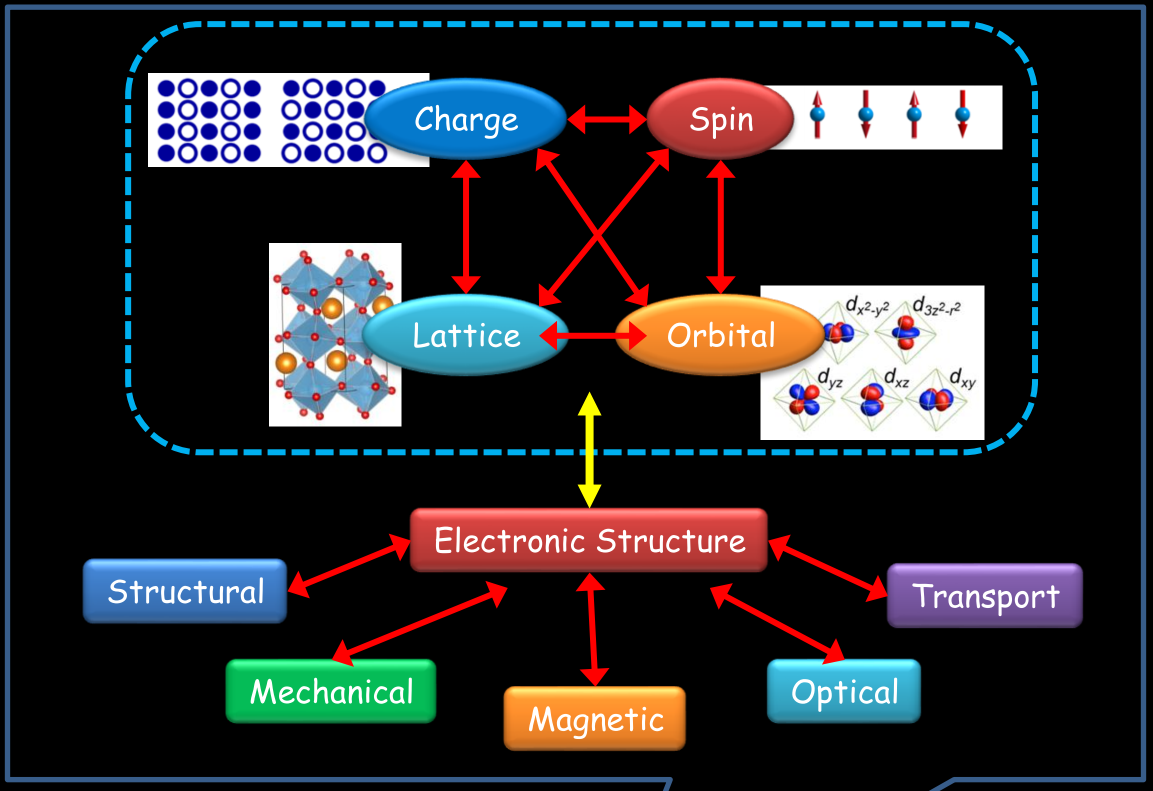
Material growth

吳茂昆、 Raman Sankar、歐敏男

Material Characterization

李尚凡、黃英碩、林宮玄、張嘉升、莊天明、李偉立、蘇維彬、楊志文、
胡宇光、溫昱傑、陳洋元、柯忠廷

Quantum Material Studies in IoP/AS


Charge
Spin
Lattice
Orbital

Electronic Structure
Structural
Transport
Mechanical
Magnetic
Optical

Theory

葉崇傑、林新

Material growth

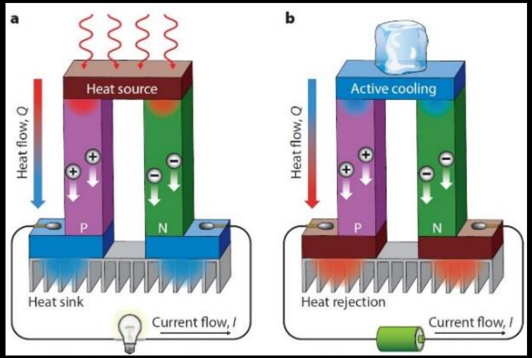
吳茂昆、 Raman Sankar、歐敏男

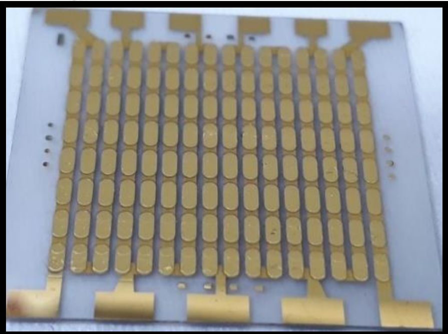
Material Characterization

李尚凡、黃英碩、林宮玄、張嘉升、莊天明、李偉立、蘇維彬、楊志文、
胡宇光、溫昱傑、陳洋元、柯忠廷

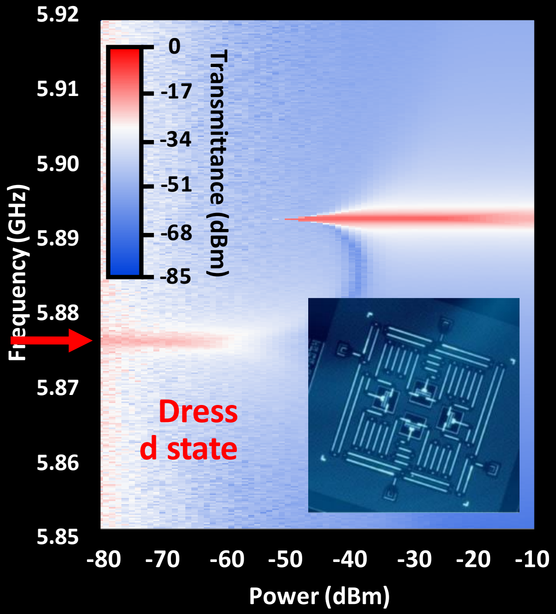
Quantum Material *Applications* in IoP/AS

Thermoelectric Materials



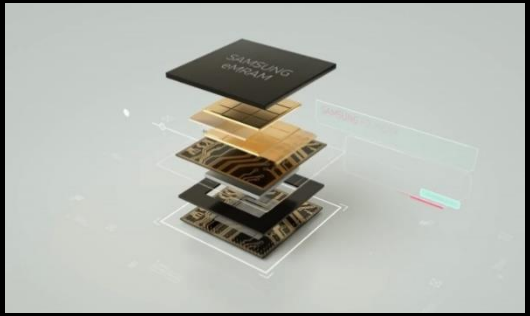


Nanotechnology
Quantum computer



Lithium-ion battery

Spin/magnetoresistivity Ram

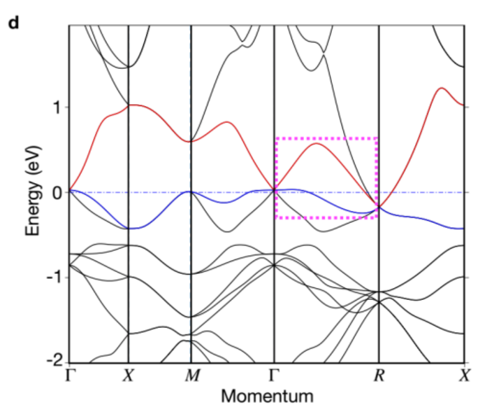


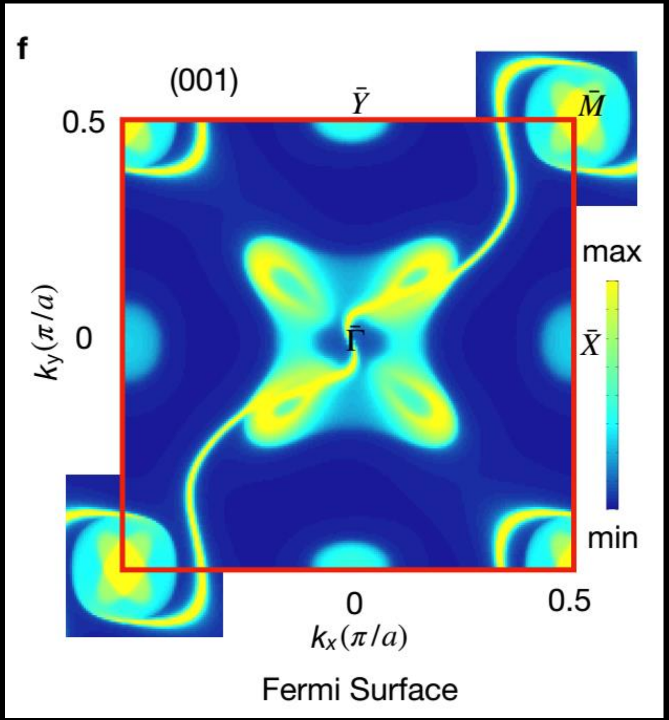
led by 陳啟東、陳洋元、柯忠廷、吳茂昆、李尚凡

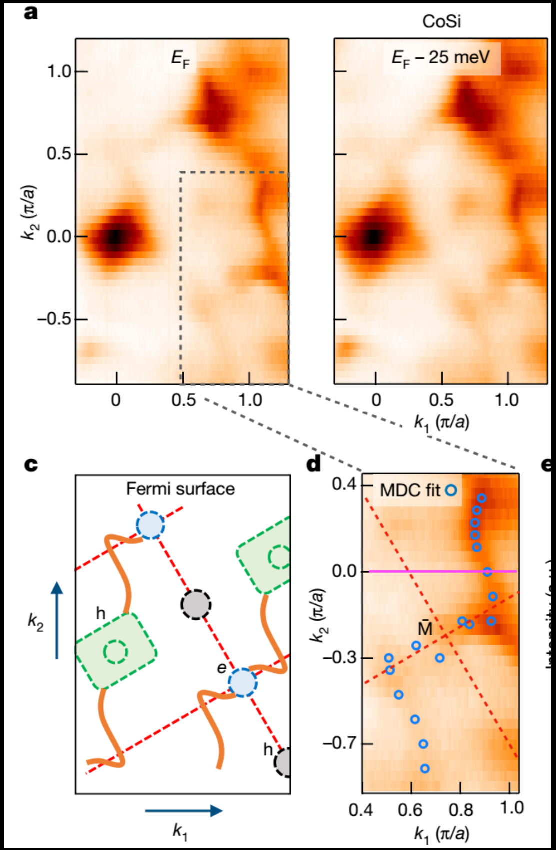
Topological chiral crystals with the longest surface Fermi arcs

林新
Hsin Lin

In a recent collaboration with Prof. Hasan’s experimental group at Princeton University, our predictions of the longest possible surface Fermi arcs on the surface of chiral crystals RhSi and CoSi are confirmed by the angle-resolved photoemission experiments.





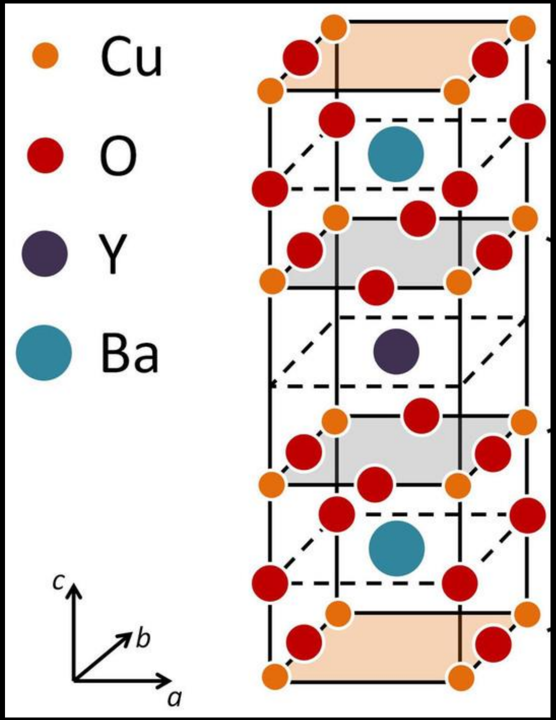


Sanchez, Belopolski, Cochran, Xu, Yin, Chang, Xie, Manna, Süß, Huang, Alidoust, Multer, Zhang, Shumiya, Wang, Wang, Chang, Felser, Xu, Jia, Lin & Hasan, *Nature* **567**, 500 (2019).

High Tc Superconductors

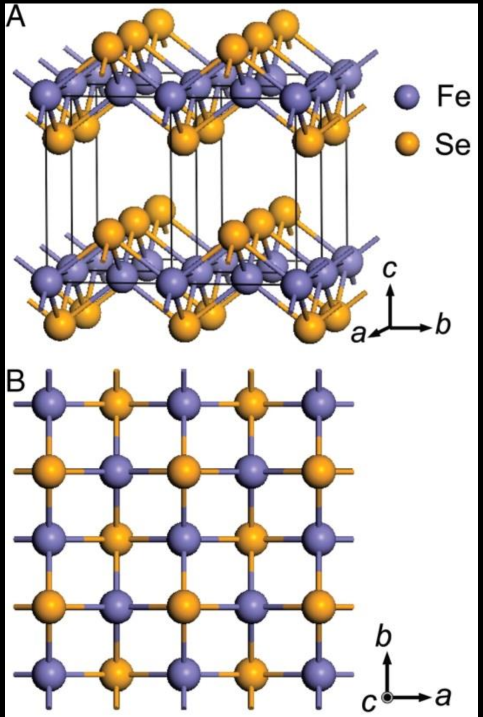
吳茂昆

$YBa_2Cu_3O_{7-\delta}$, Tc~93K
#2 of PRL Top 10



M. K. Wu *et al.*, PRL **58**, 908 (1987)

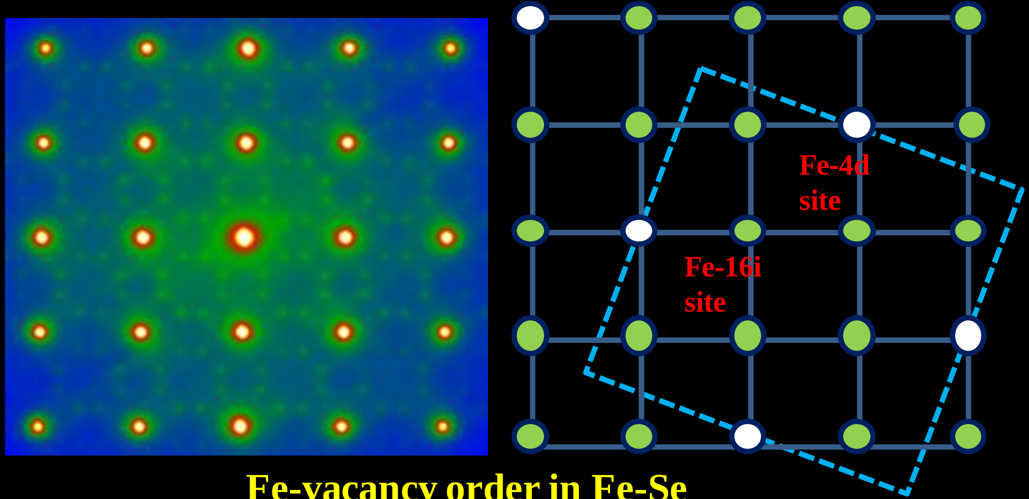
FeSe, Tc~8K
Single layer FeSe on STO, Tc>80K !!!



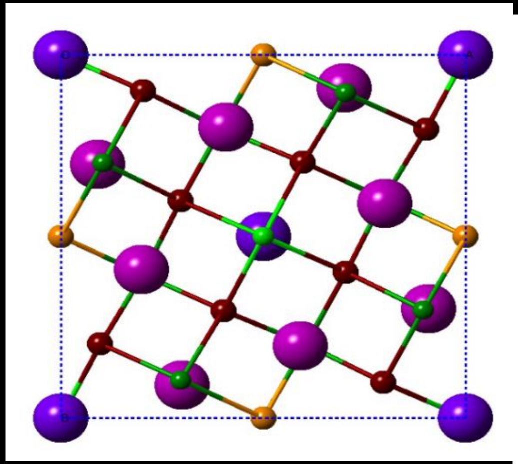
F.C. Hsu *et al.*, PNAS105, 14262 (2008)
Cited by 2509 times up to April, 2019.

Understanding the Material Origin for Superconductivity in K-FeSe

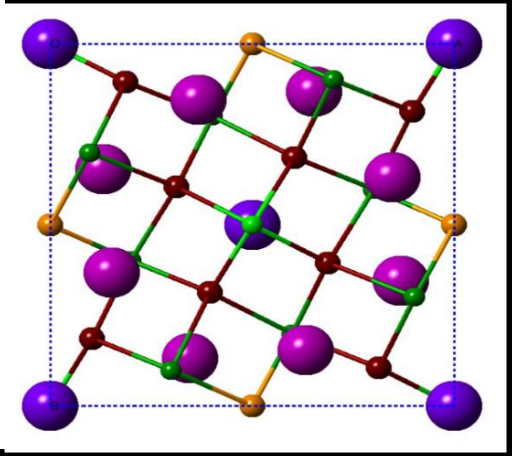
吳茂昆



Fe-vacancy order in Fe-Se

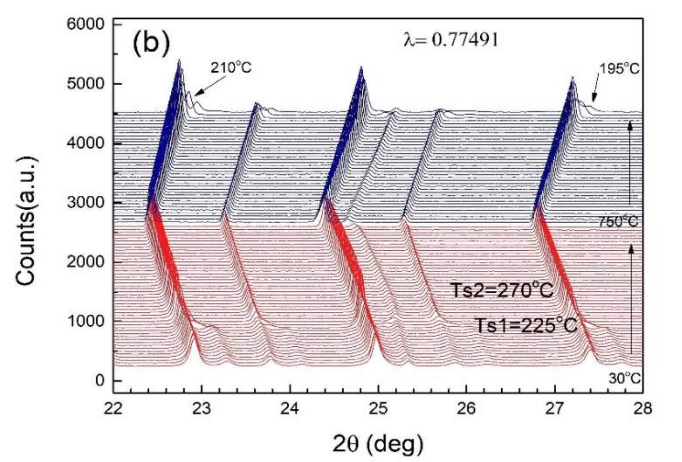


Material quenched from 650C shows negligible lattice distortion — no superconductivity



Material quenched from 790C shows high lattice distortion –with high volume superconductivity

X-ray diffraction patterns of KFeSe superconductor



Based on high temperature structural studies:

1. There are two Fe sites in FeSe; the Fe-16i (occupied) and Fe-4d (empty) sites
2. Its parent phase is a Mott insulator due to the presence of Fe-vacancy order
3. Extra Fe-atom or high temperature annealing of FeSe lead to occupation of Fe-atom in Fe-4d empty sites and cause distortion of lattice
4. More disordered occupation of Fe-atoms in Fe-4d sites introduces more carriers to close the insulating gap, and the presence of both metallic and semiconducting phases lead to superconductivity

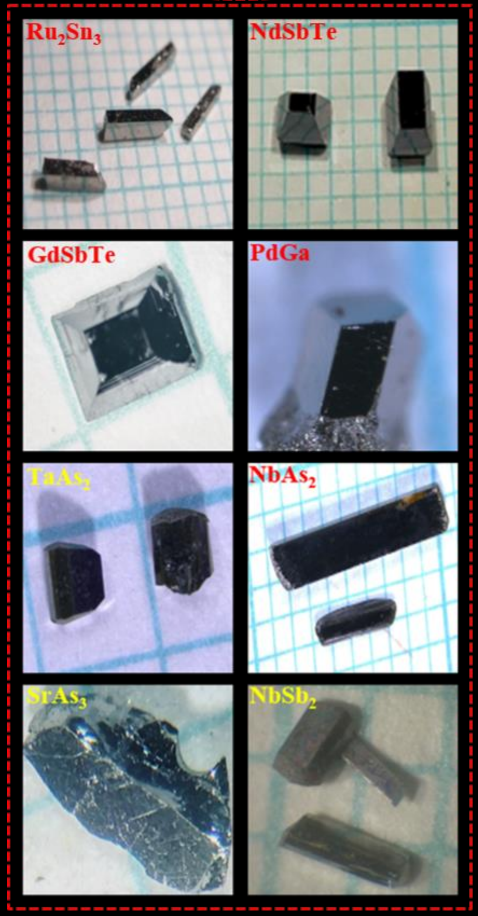
C.H. Wang et al., PNAS, 2019

Novel Quantum Materials and Single Crystal Growth

Raman Sankar

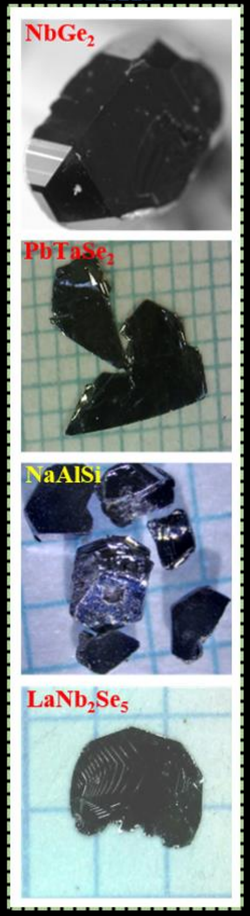
In Dr. Raman Sankar's Laboratory, We study the fundamental properties of single crystals such as "Dirac Semi-metals, Surface Topological studies, Topological Insulators, Topological Crystalline Insulators, High Tc superconductors, Weyl Semi-metals, 2D materials, Thermoelectric materials, etc.,".

Topological Semimetal

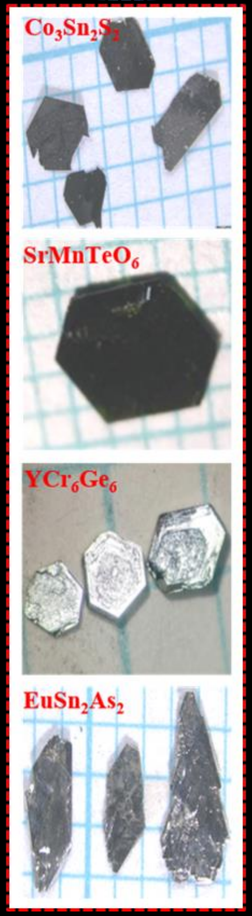


Weyl Semimetal

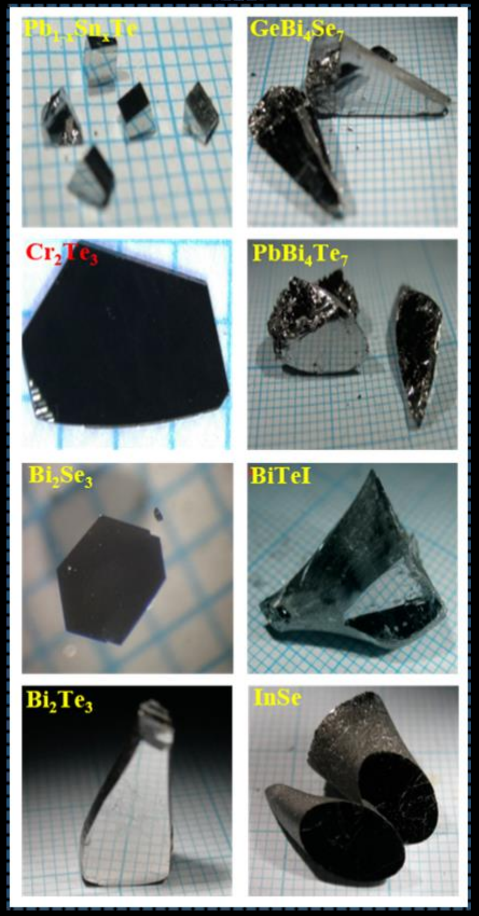
Superconductors



Kagome Crystals



Topological Insulator



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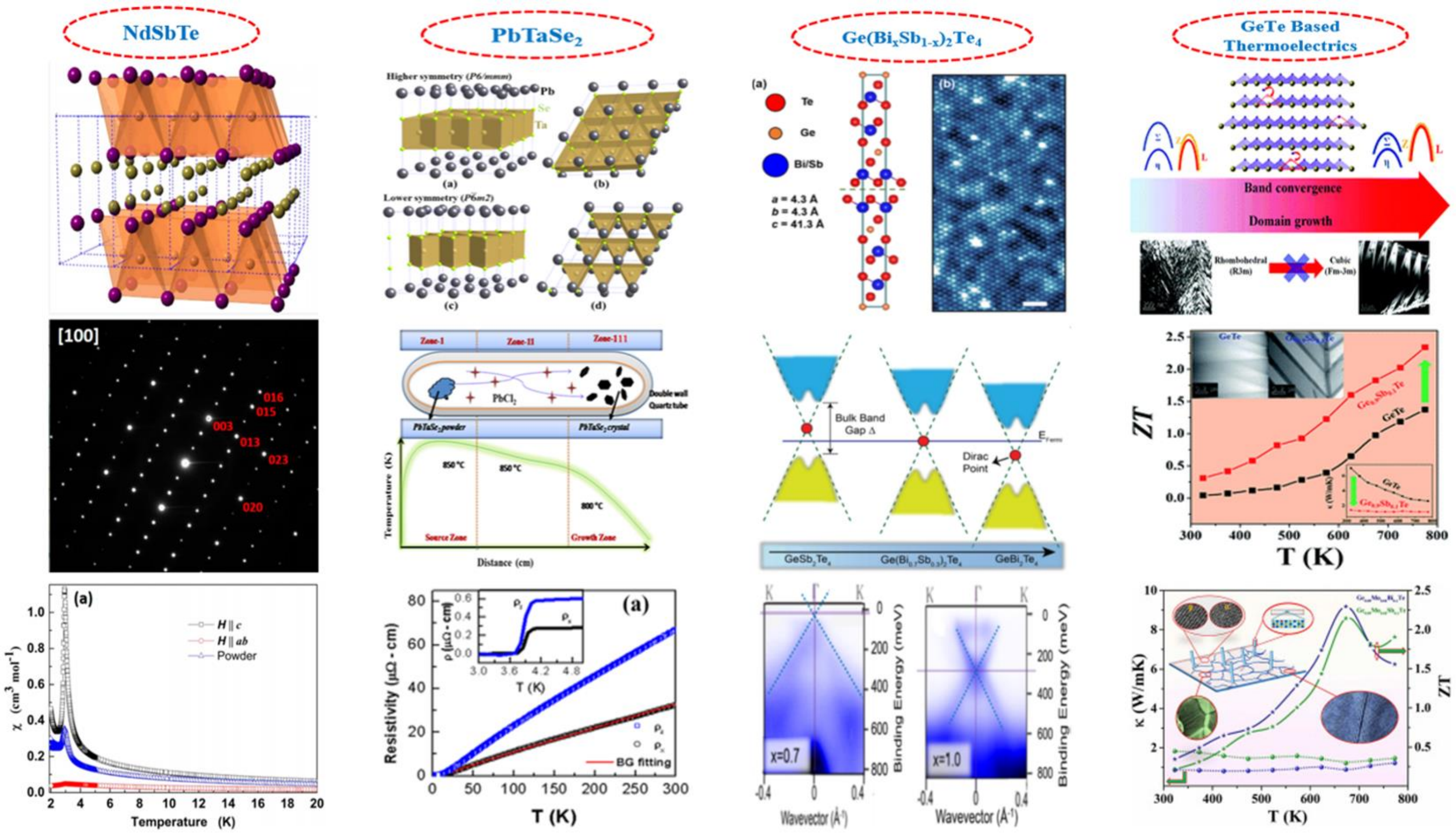
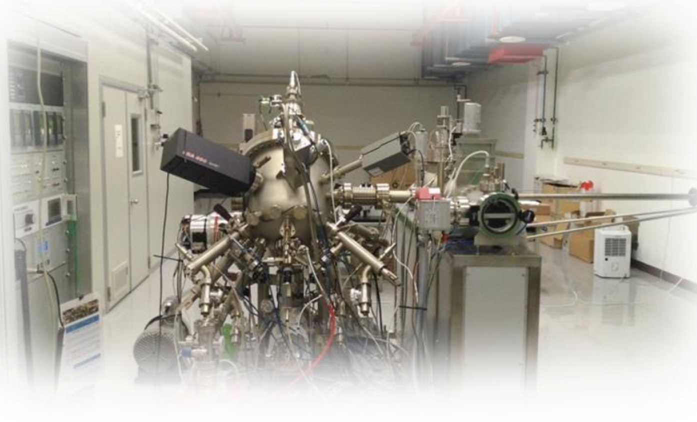
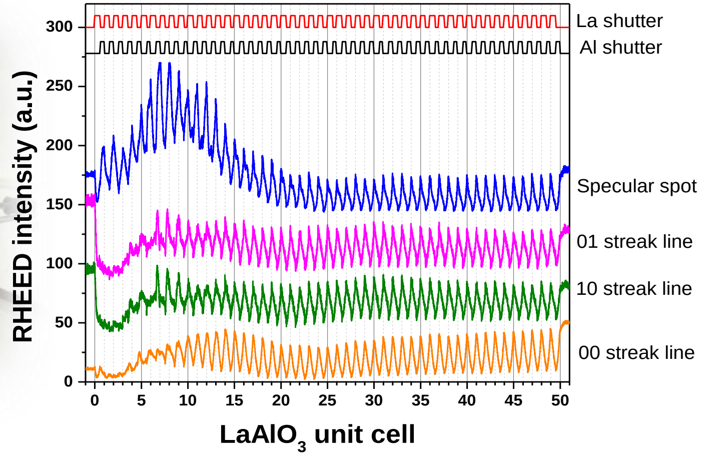


Oxide MBE system with ozone distiller

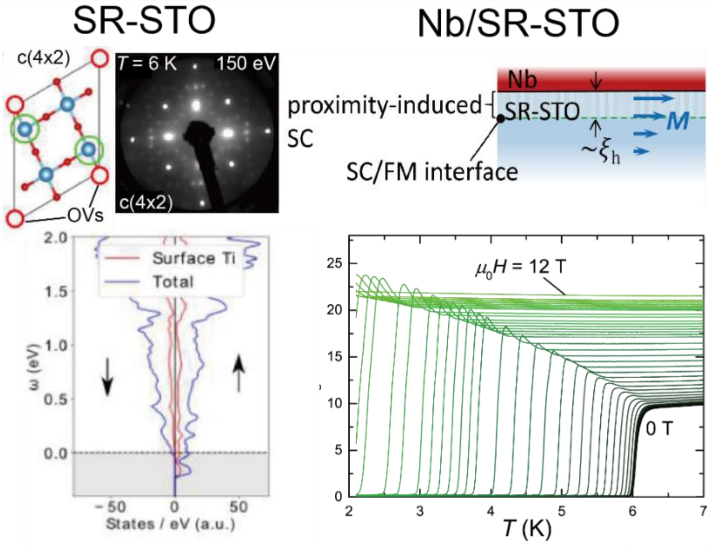
李偉立 Wei-Li Lee



In-situ RHEED monitor

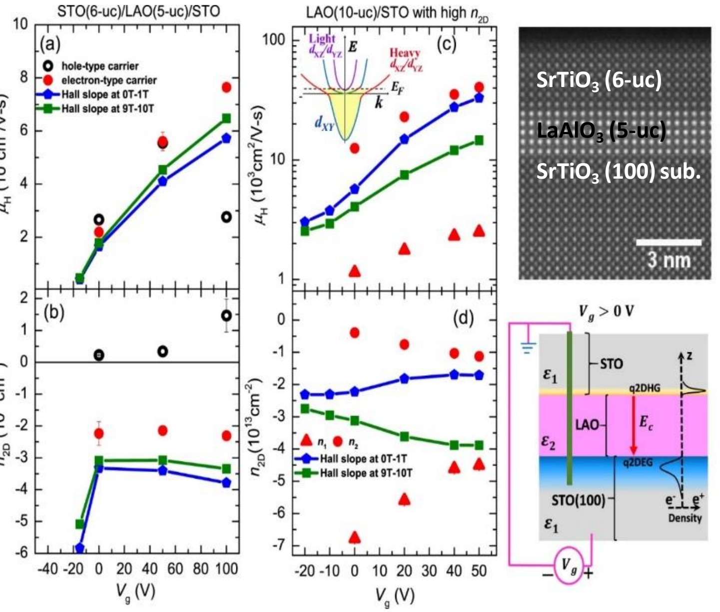


Spin-polarized in-gap states in surface-Reconstructed SrTiO3



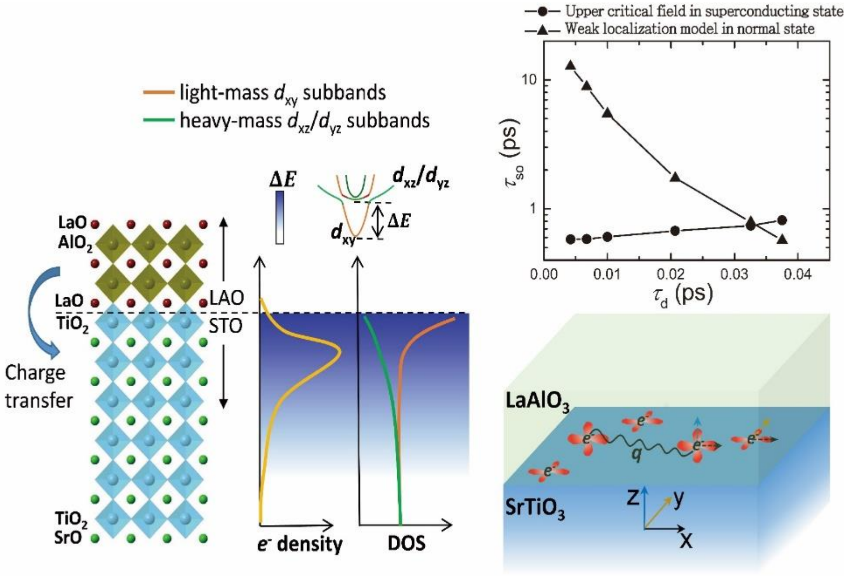
npj Quantum Mater. 5, 45 (2020)

Quasi-two-dimensional hole gas at complex oxide interface



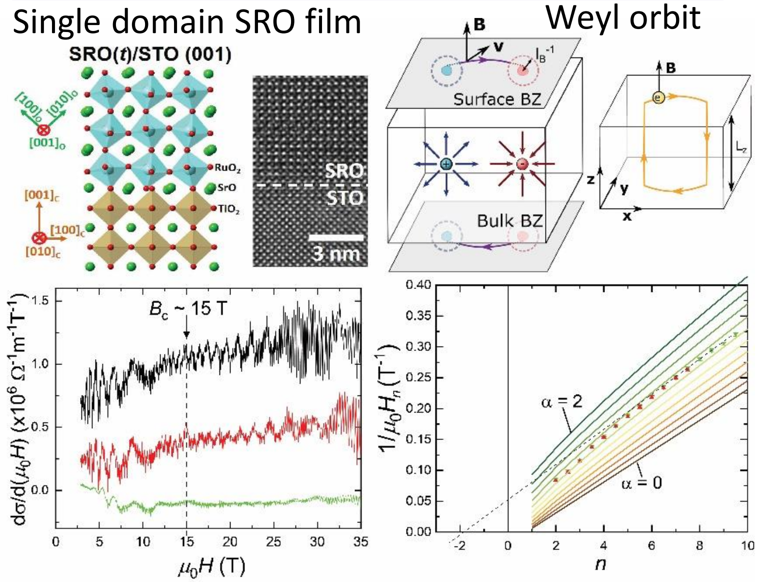
Phys. Rev. Materials 2, 114009 (2018)

Orbital selectivity for Cooper pairing at superconducting interface



Phys. Rev. Research 2, 013311 (2020)

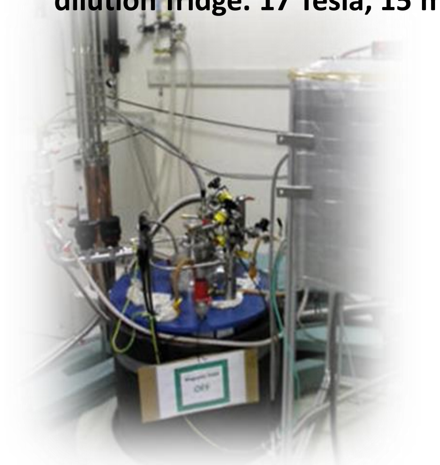
Weyl-orbit quantum oscillation in topological Weyl semimetal SrRuO3



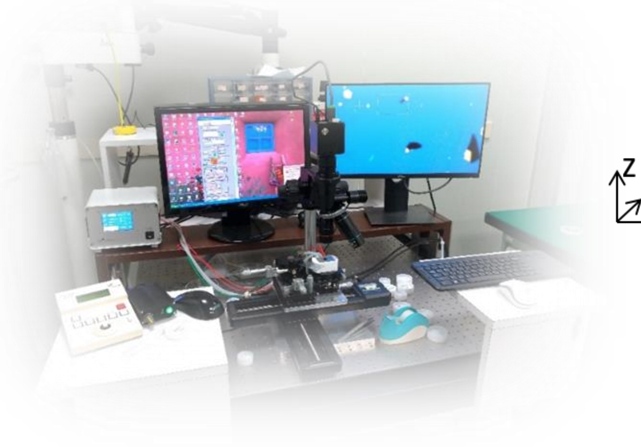
Magnetotransport study in quantum materials

李偉立 Wei-Li Lee

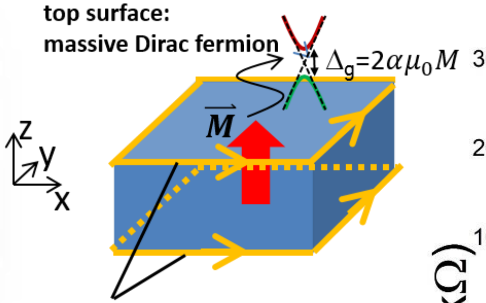
Supercond. magnet with dilution fridge. 17 Tesla, 15 mK



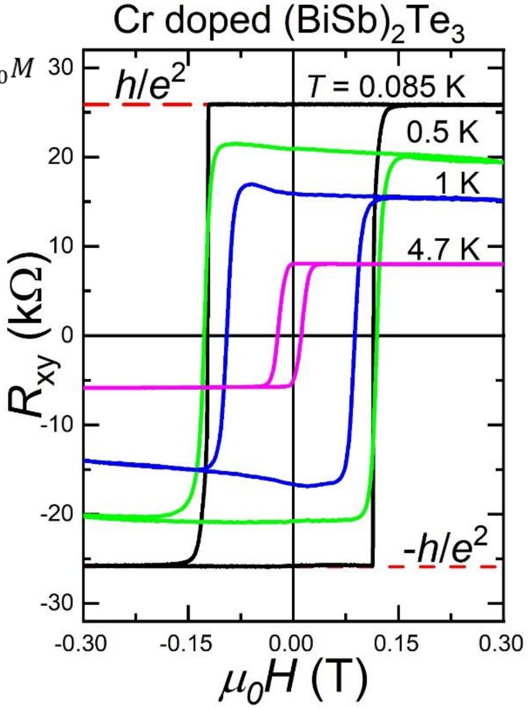
2D microcrystal dry transfer system

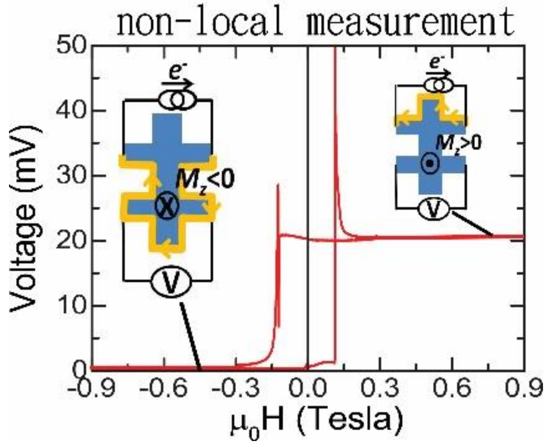


Quantum anomalous Hall effect (QAHE) in ferromagnetic topological insulator



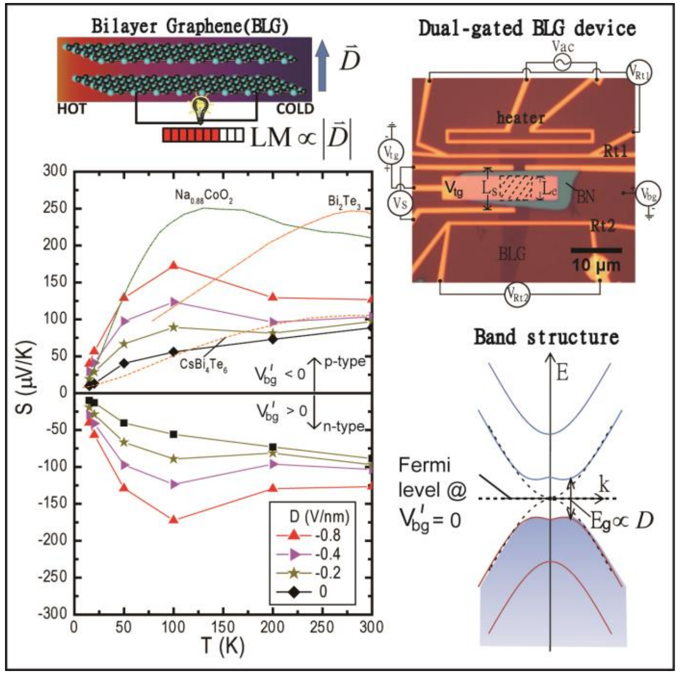
dissipationless chiral edge channel at Dirac fermion mass domain-wall





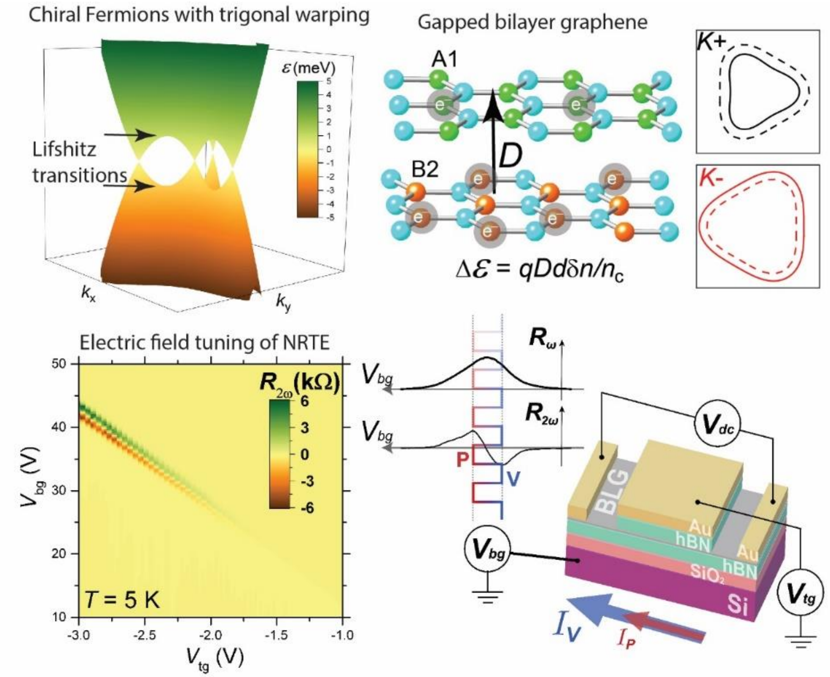
Physical Review Letters 113, 137201 (2014)

Full electric field tuning of thermoelectric power in Dual-Gated Bilayer Graphene



Physical Review Letters 107, 186602 (2011)

Nonreciprocal and nonlinear charge transport in massive chiral Fermions with trigonal warping



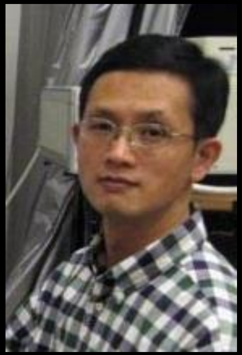
Physical Review Research 3, 033160 (2021)

Characterization of Quantum Materials in IoP/AS

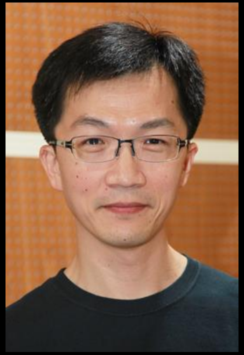
Surface and Nanoscience Group

Direct visualization/manipulation of physical properties
of materials or nanostructruces with atomic resolution.

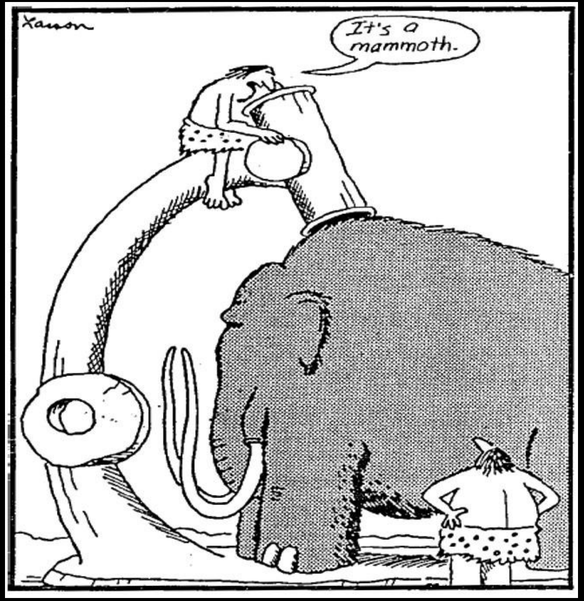

張嘉升


黃英碩


蘇維彬

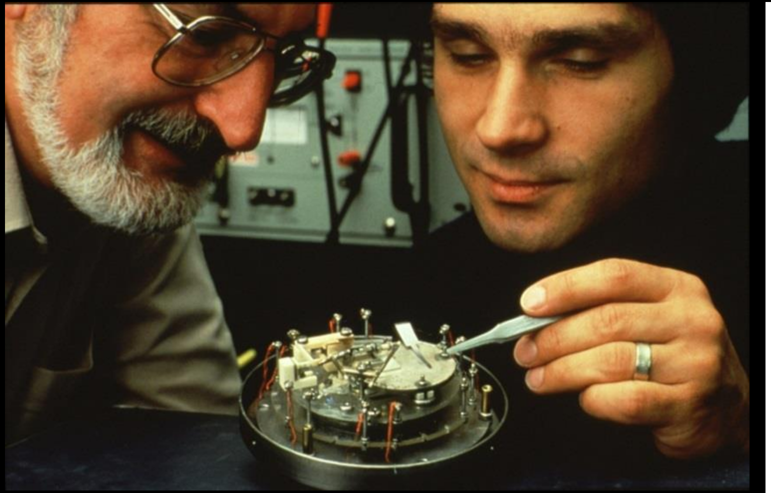

莊天明

http://www.phys.sinica.edu.tw/~nano/



© Gary Larson

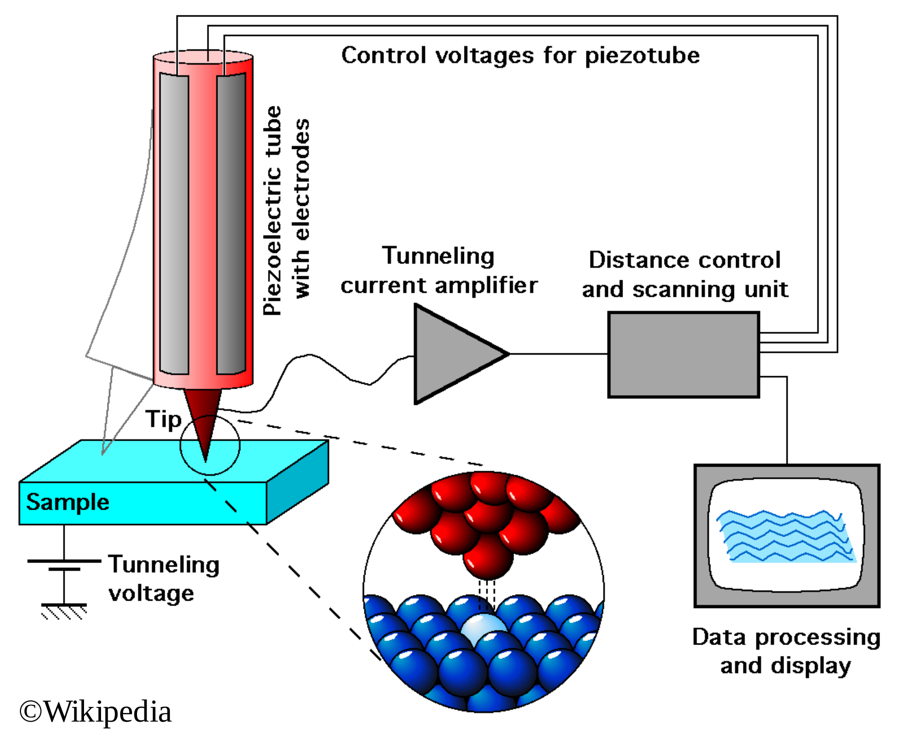
Scanning Tunneling Microscope (STM)



STM

Heinrich Rohrer & Gerd Binnig

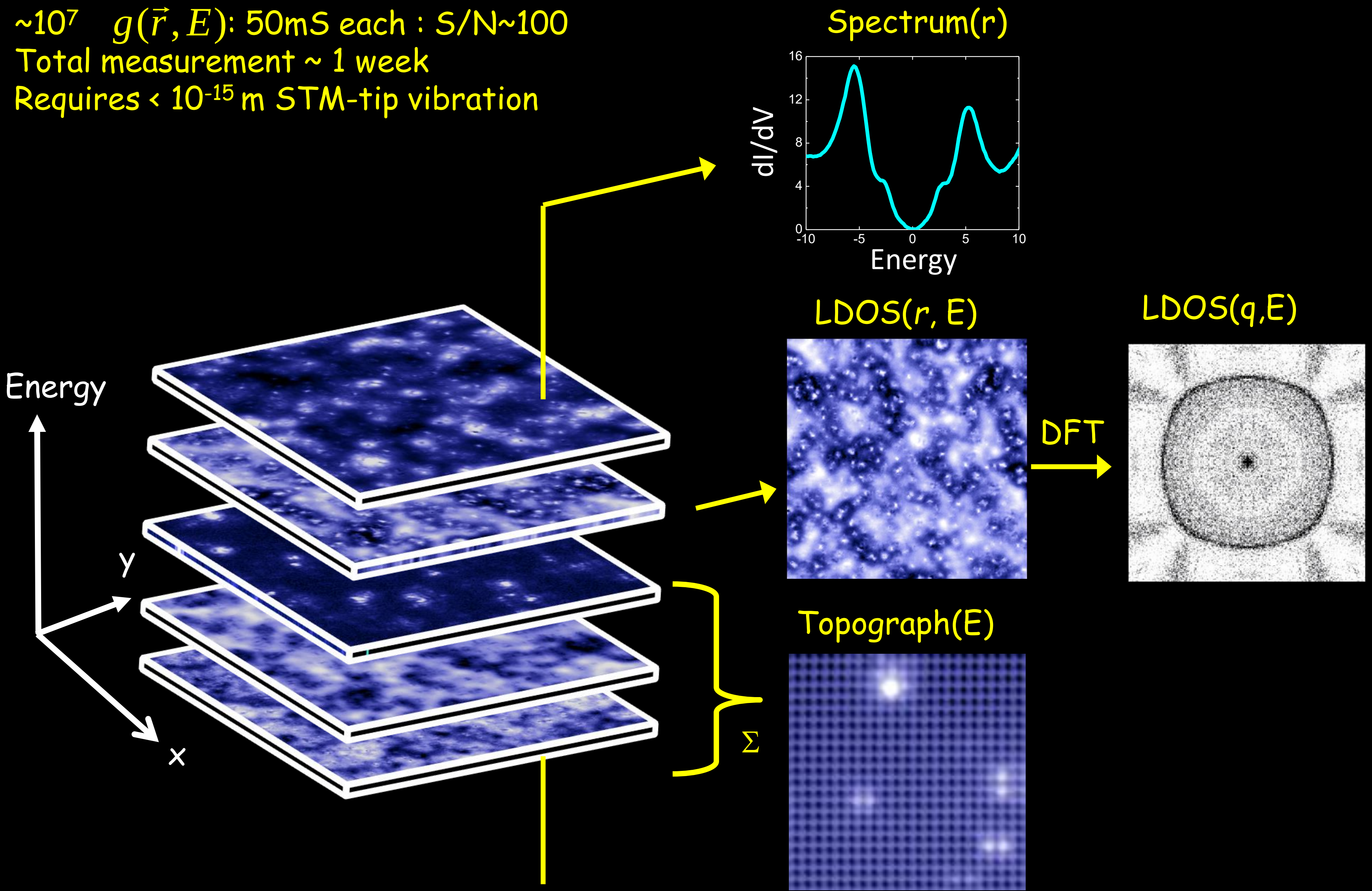
Nobel Prize in 1986 ©IBM



©Wikipedia

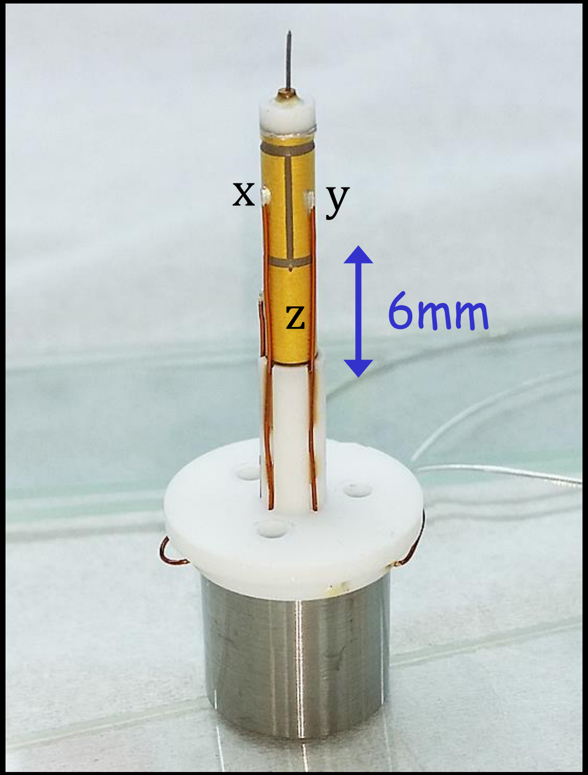
Atomic Resolution Energy Resolved Images, LDOS(r,E)

~10^7 $g(\vec{r},E)$: 50mS each : S/N~100
Total measurement ~ 1 week
Requires < 10^{-15} m STM-tip vibration

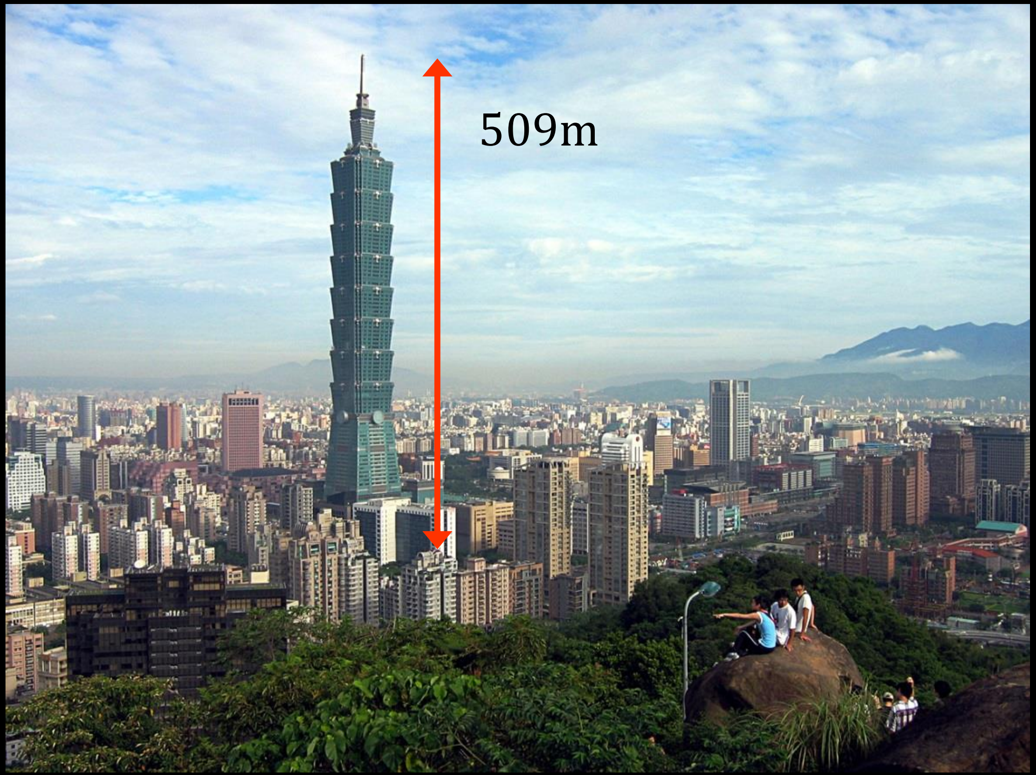


Our Resolution and Stability

STM Tip on Piezo Scanner



Taipei 101

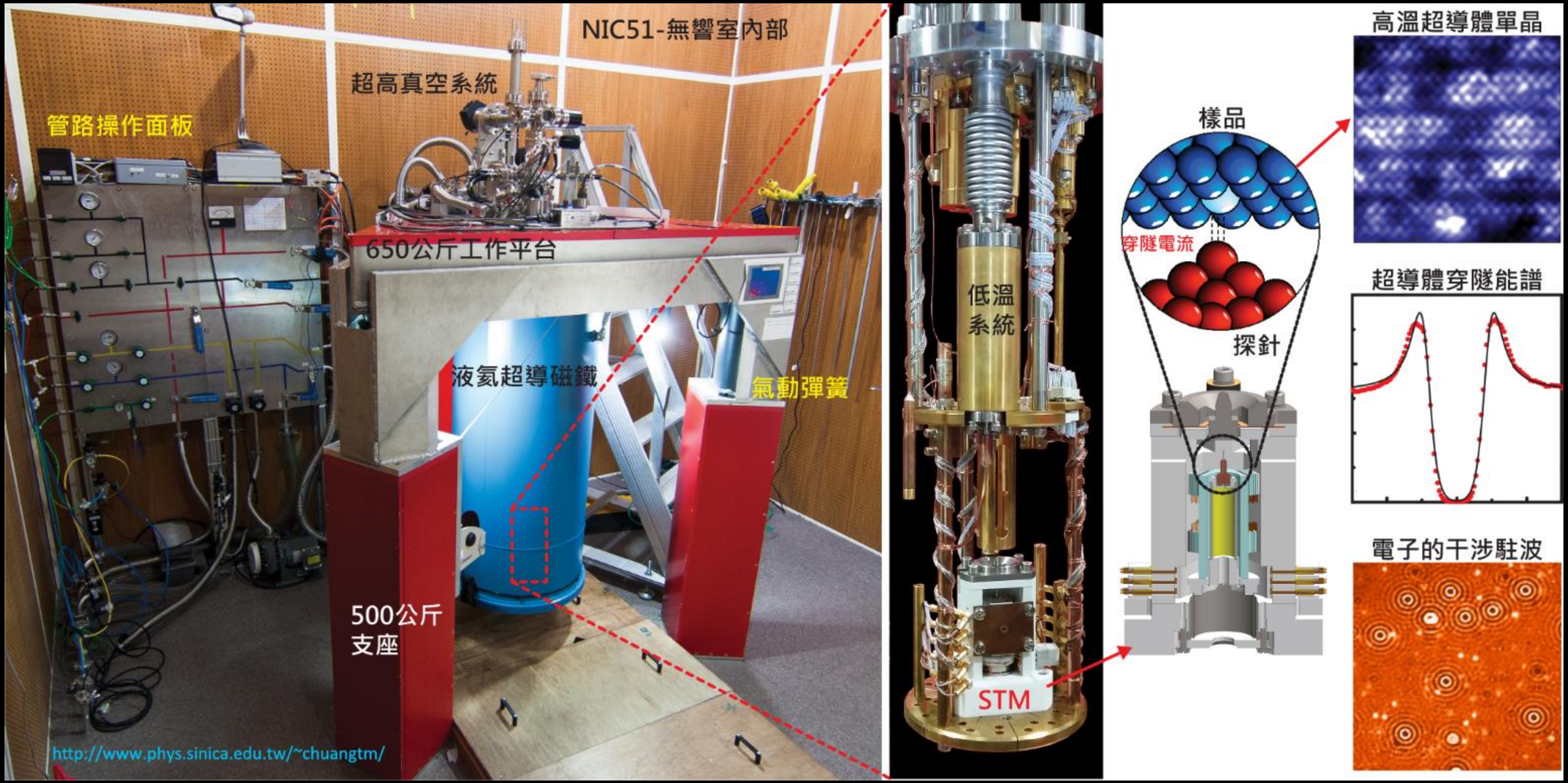


@Wikipedia

0.1pm/6mm → ~8nm/509m!

Spectroscopic Imaging Lab

利用掃描穿隧顯微鏡(Scanning Tunneling Microscope, STM) 在原子尺度下觀察新穎材料的表面結構並研究其電子能帶結構，結合理論計算來瞭解其物性的背後物理機制。我們目前主要研究課題為拓樸超導、高溫超導體、拓樸半金屬等材料。

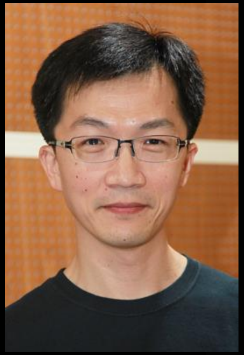


http://www.phys.sinica.edu.tw/~chuangtm/

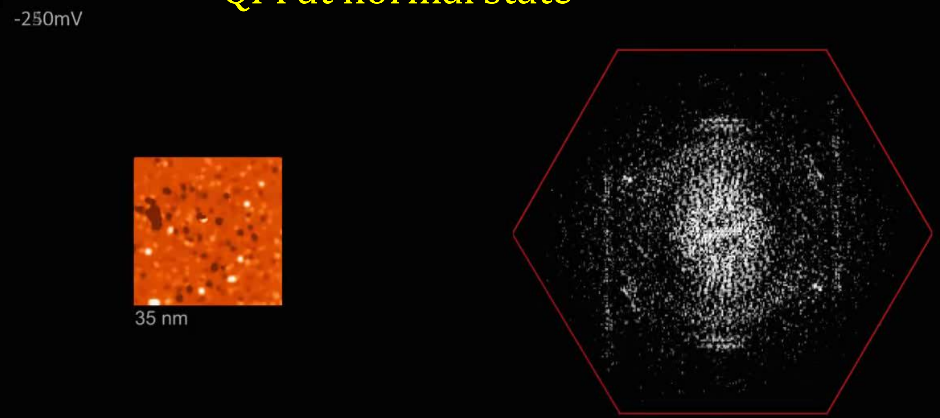
Superconducting Topological Surface States in $PbTaSe_2$

張嘉升

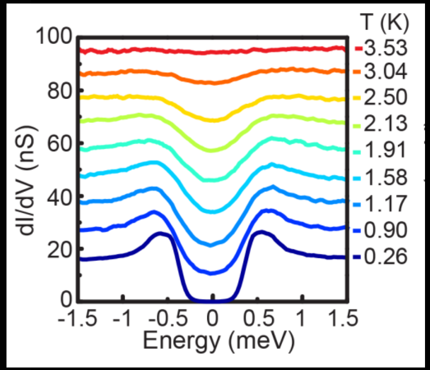
莊天明



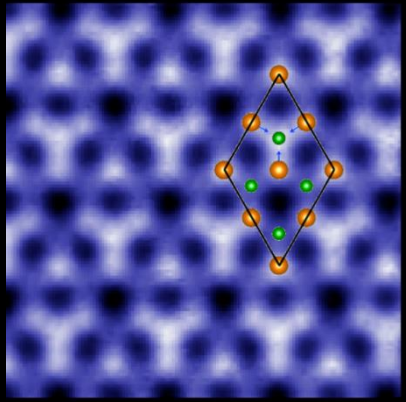
QPI at normal state

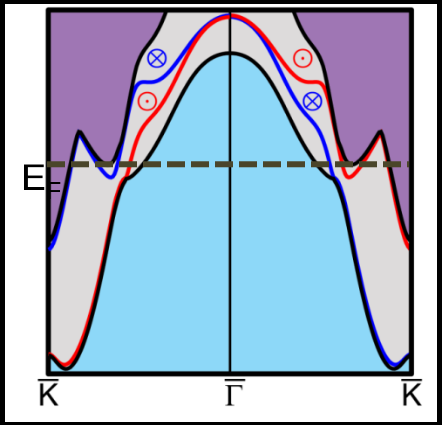


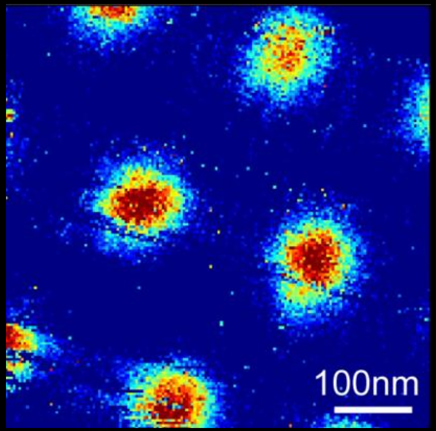
Fully gapped SC



Majorana zero mode @ vortex cores?

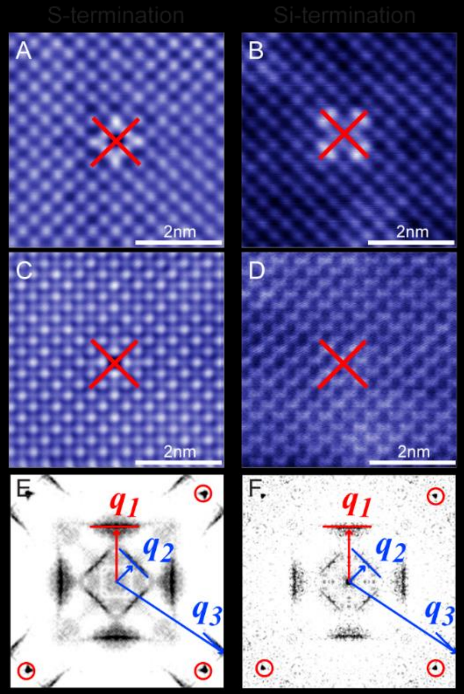




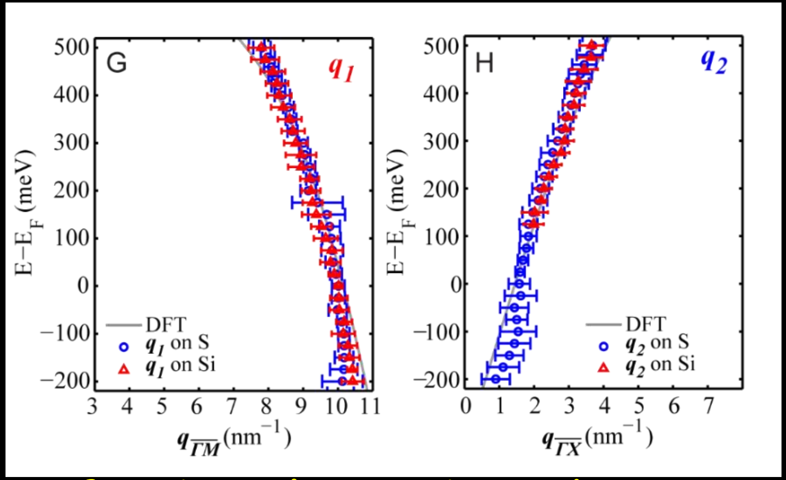


S.-Y. Guan & P.-J. Chen *et al.*, Sci. Adv. 2, e1600894 (2016)

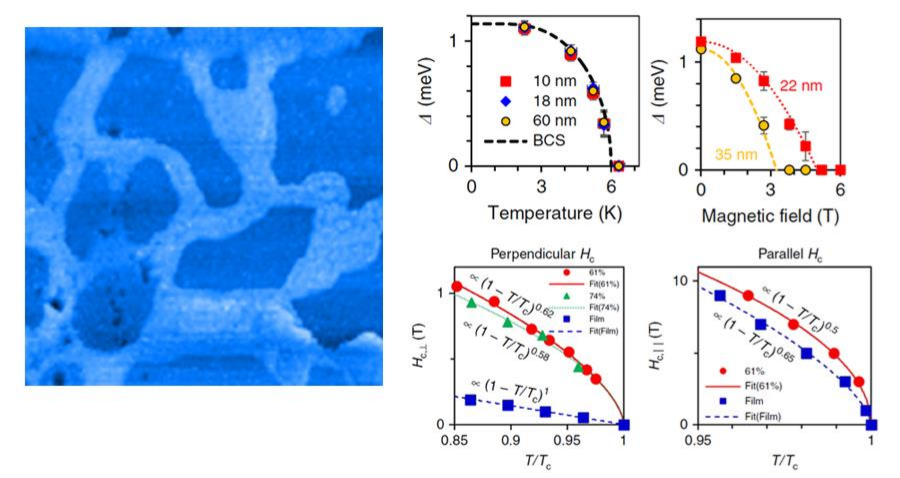
Surface-dependent STM Study on Dirac nodal line semimetal ZrSiS



Our surface-dependent STM results support the importance of Zr-d orbitals on the calculated band structures. It also shows that the sp3 orbital hybridization for Si is the key controlling factor for the non-symmorphic symmetry of ZrSiS. - Su *et al.*, New J. Phys. 20, 103025



Geometric quenching of orbital pair breaking in a single crystalline superconducting nanomesh network in collaboration with C.-K. Shih



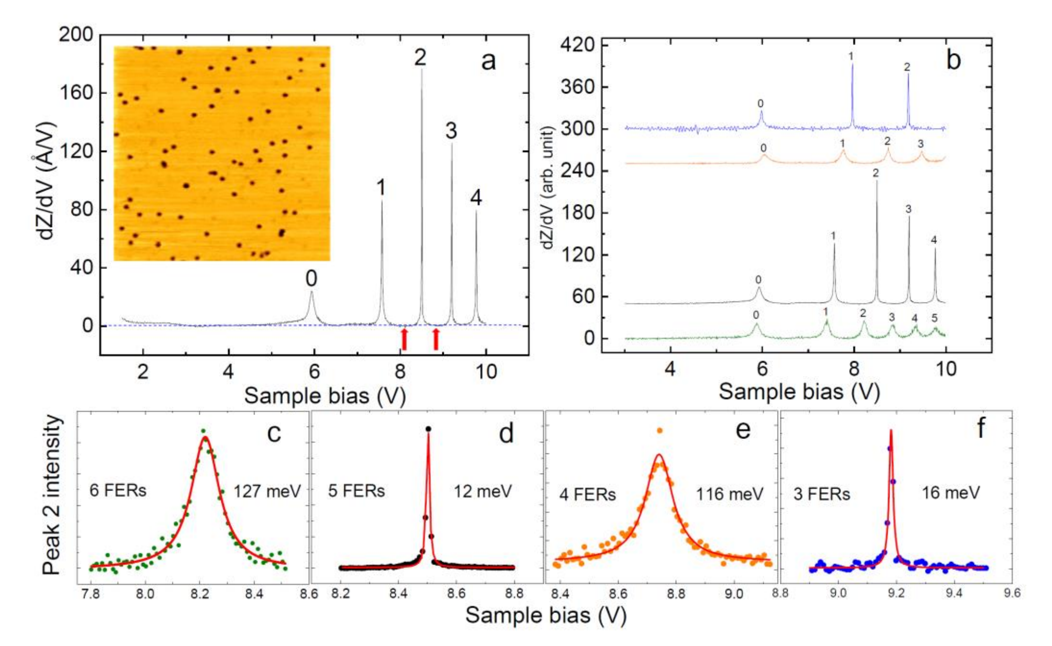
We show the superconductivity pair breaking can be significantly suppressed by nanoscale engineering and opens new strategies to optimize superconducting quantum devices.

Nam *et al.*, Nature Communications 9, 5431

Observing quantum trapping through lifetimes of field emission resonant electrons

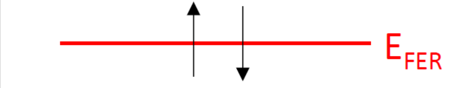
蘇維彬

Lifetime modulation with electric field on MoS_2



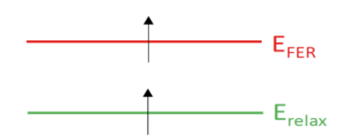
Due to following mechanisms:

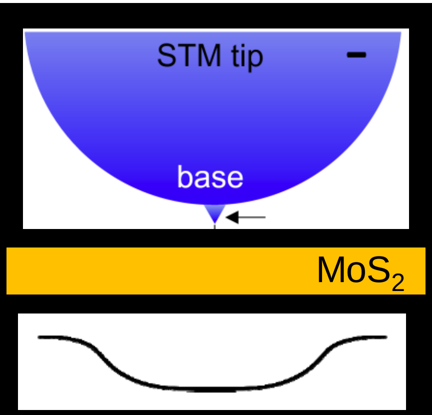
1. two-electron tunneling through exchange interaction occurs in FER.



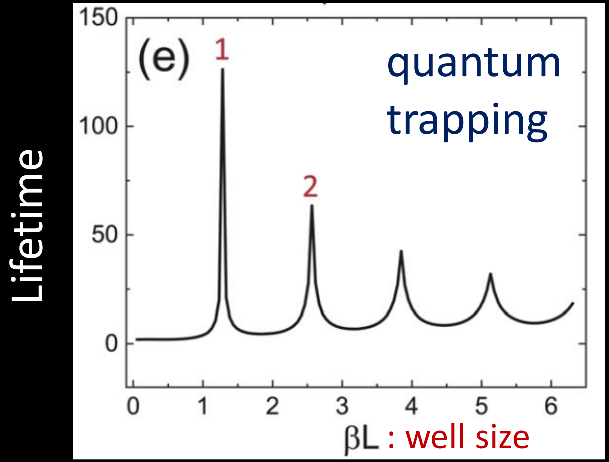
2. One of electrons relaxes first through light emission and its spin flips due to Hund's rule.

3. Because of Pauli exclusion principle, another electron cannot emit light while the relaxed electron remains trapped in the well.





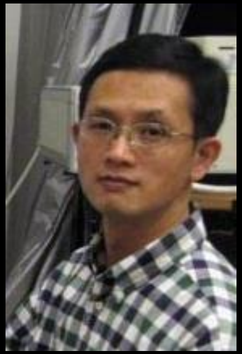
Potential well



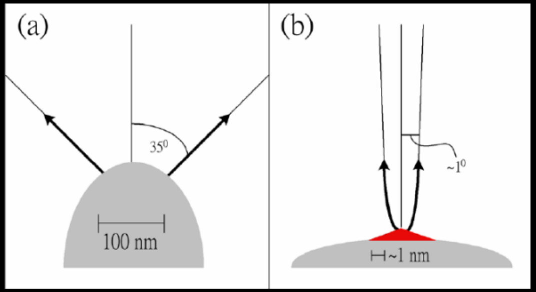
Nanoscale Advances **2**, 5848 (2020).
Physical Review B **105**, 195411 (2022)

Visualizing Graphene Ripples at the Nanometer Scale with Electron Diffraction

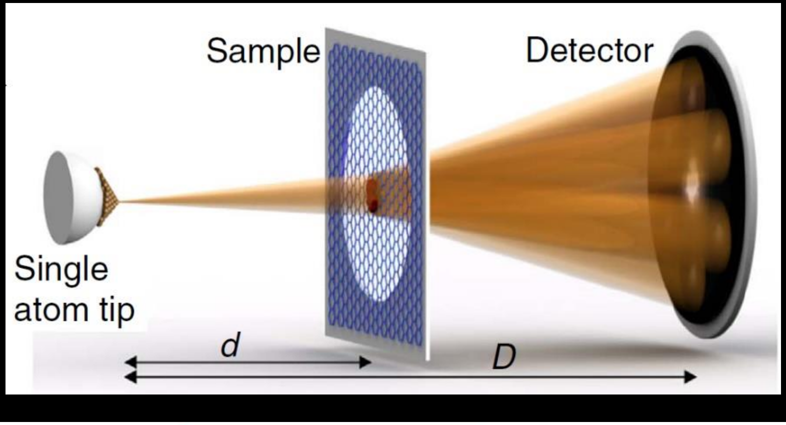
黃英碩



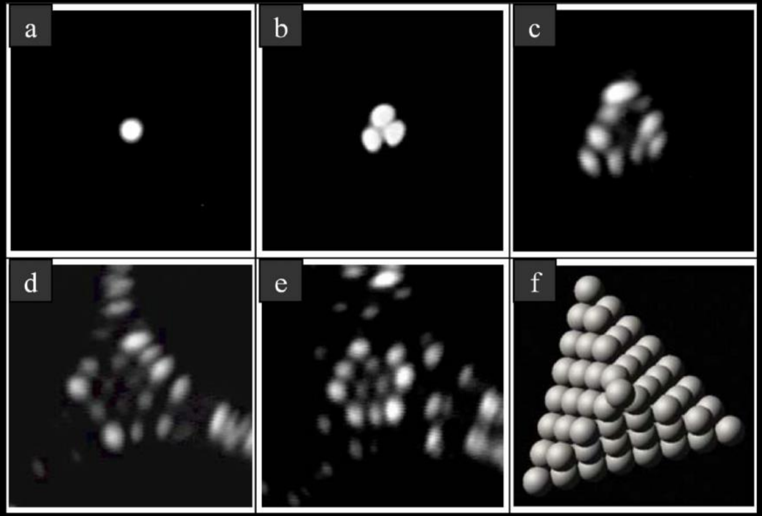
Regular Tip Single Atom Tip

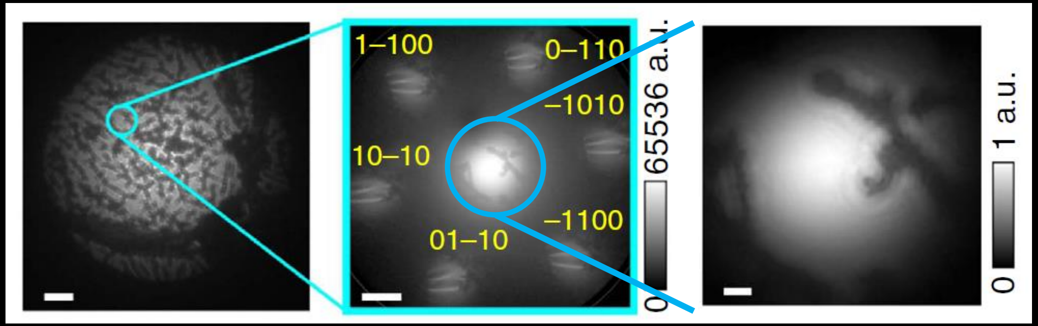


Divergent Beam Electron Diffraction



FIM image of a single atom tip

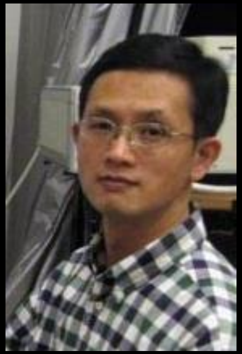




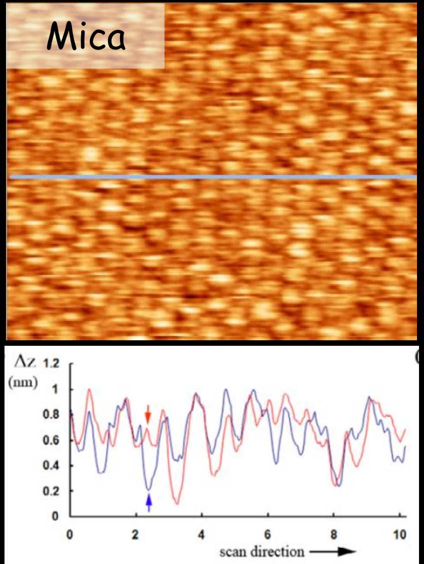
Nature Communications 8, 14440 (2017)

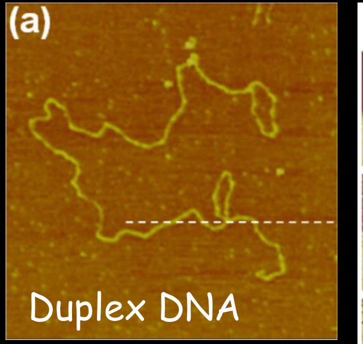
Instrumentation Development

黃英碩

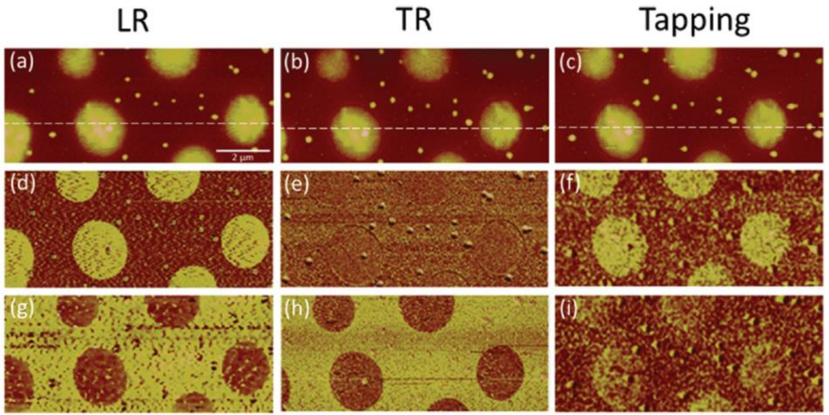


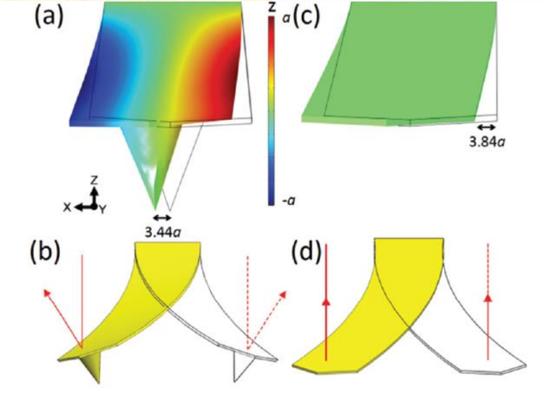
High Speed AFM in Liquid





High-sensitivity imaging with lateral resonance mode AFM



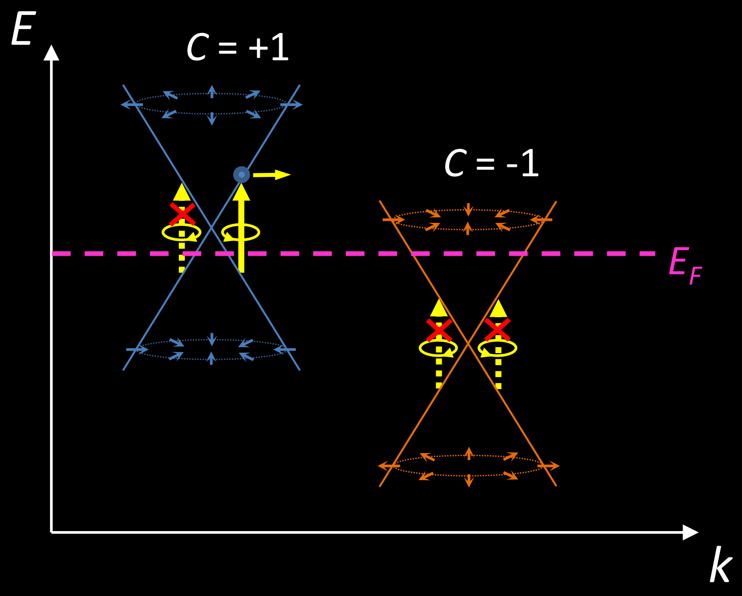


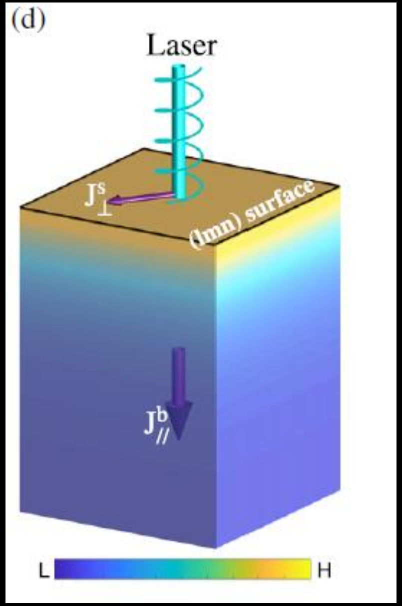
Nanoscale 8, 18421 (2016)
Nanotechnology 21, 065710 (2010)

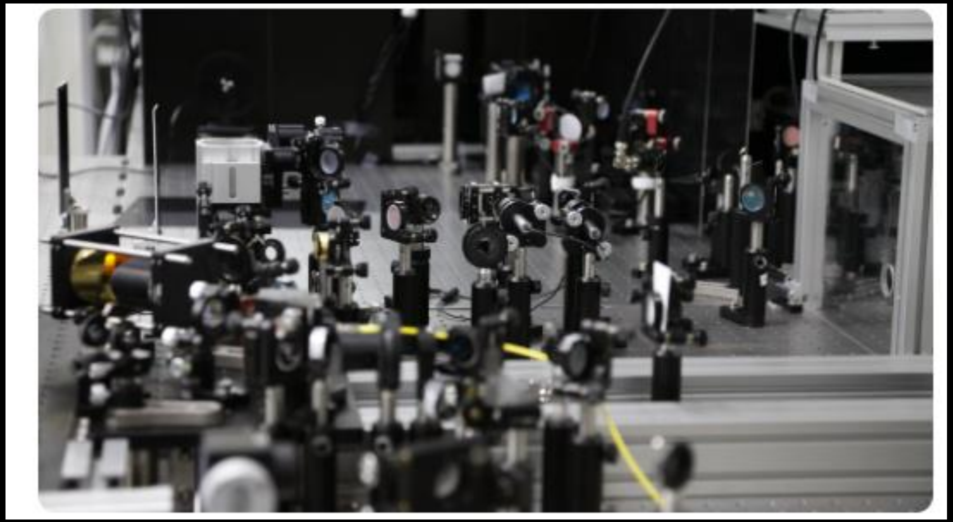
Optical Physics Lab

溫昱傑

Light-matter interactions in Weyl semimetals (WSMs)







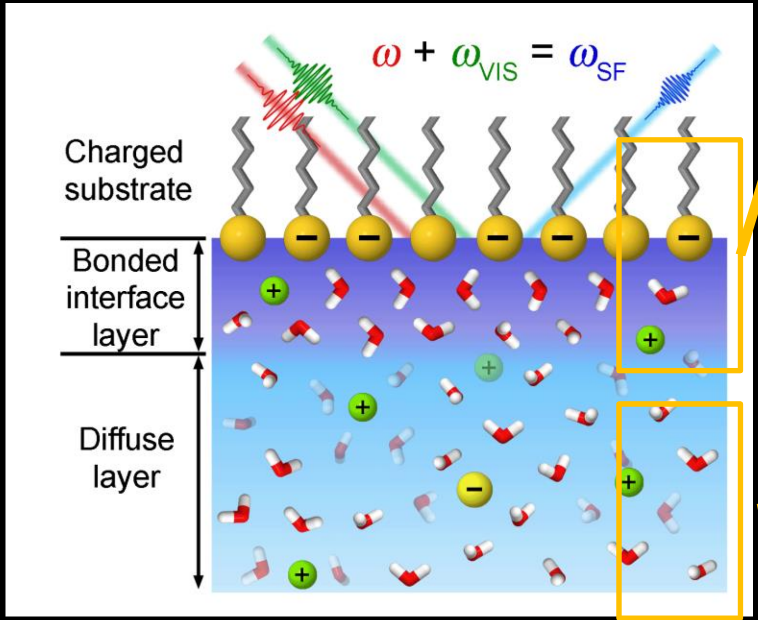
Wen group focuses on nonlinear optical spectroscopic research on Weyl semimetals in the THz and mid-infrared ranges, where the optical transition of an electron within a single Weyl cone occurs.

New Physics

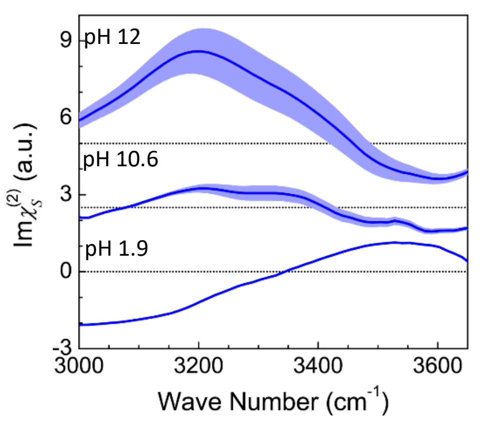
- Quantization of circular photogalvanic effect
- Berry-phase-induced giant photovoltaic effect
- Nonlinear Hall effect at THz

Unveiling Microscopic Structures and Charging of Water Interfaces by Optical Sum-Frequency Vibrational Spectroscopy

溫昱傑

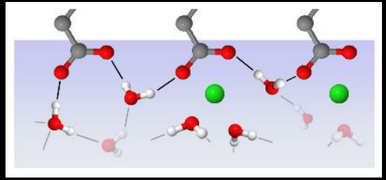


Spectra of **bonded interface layer** at lipid/water interface

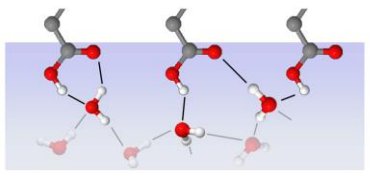


Deduced microscopic interface structure for varying charge state of lipid headgroup

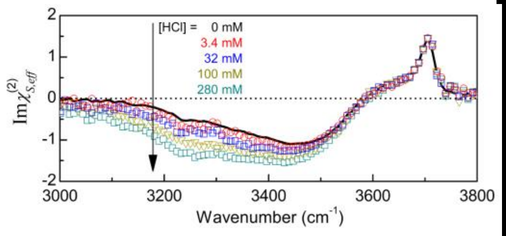
Deprotonated state



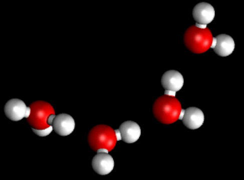
Protonated state

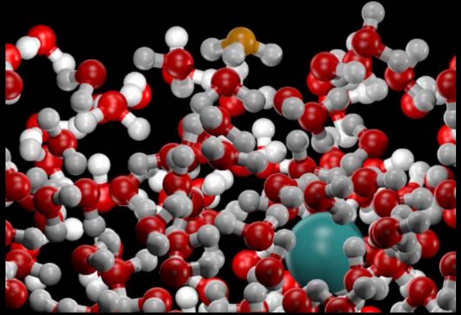


Spectra of **electric diffuse layer**



Quantification of surface ion density and surface pH (pOH)



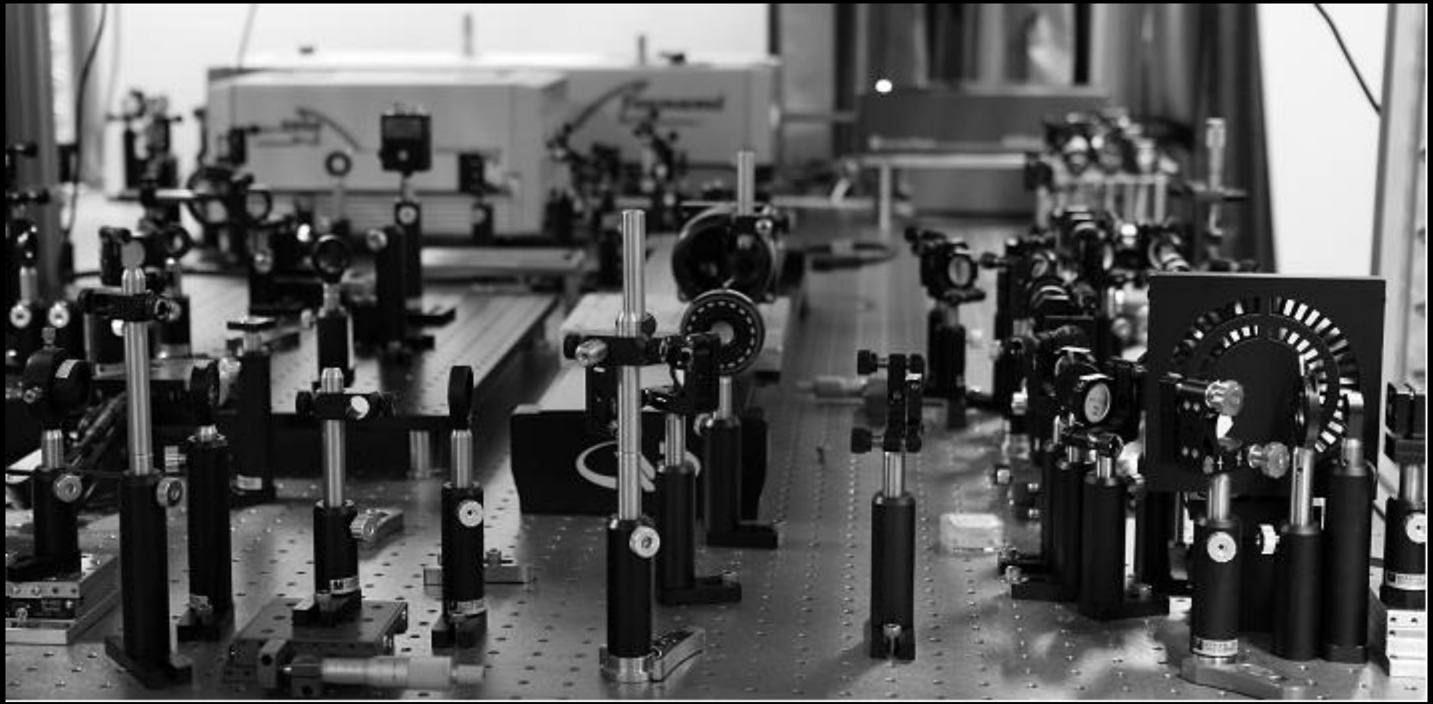


Wen *et. al.*, *Phys. Rev. Lett.* (2016)
Dalstein and Wen *et. al.*, *J. Phys. Chem. Lett* (2019)
Chiang and Wen *et. al.*, *J. Phys. Chem. Lett* (2020)

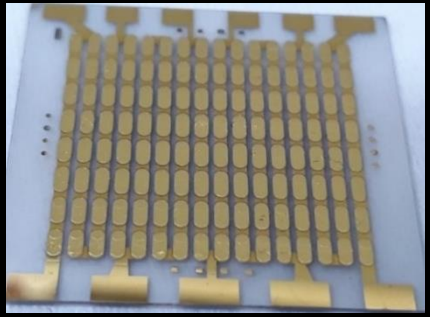
中研院物理所雷射光譜實驗室

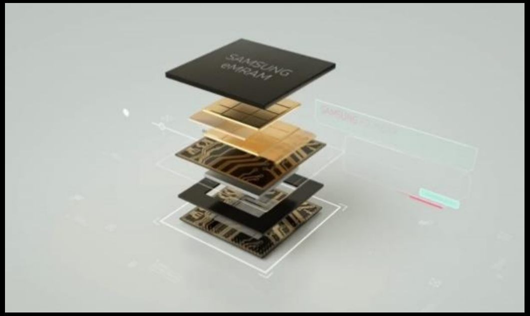
林宮玄

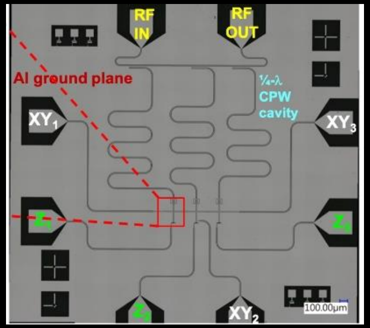
實驗室主持人：林宮玄



超快雷射時間解析光譜
飛秒雷射顯微鏡系統
材料高頻(GHz - THz)音波特性
奈米材料熱傳性質與行為







Quantum Materials Applications

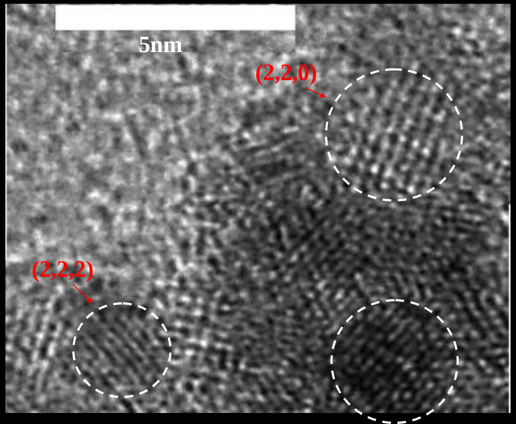
熱電、磁性、奈米科技與量子技術

奈米材料和低溫物理實驗室

陳洋元

歐敏男

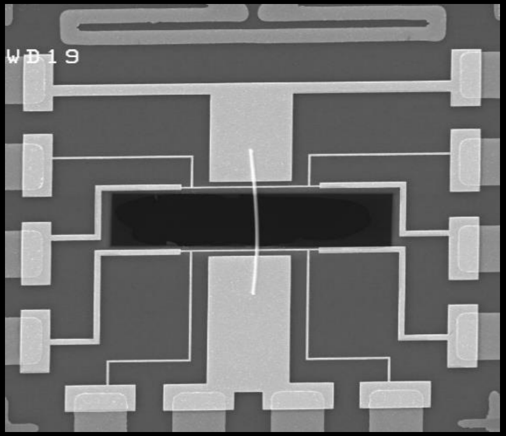
Pd 奈米顆粒



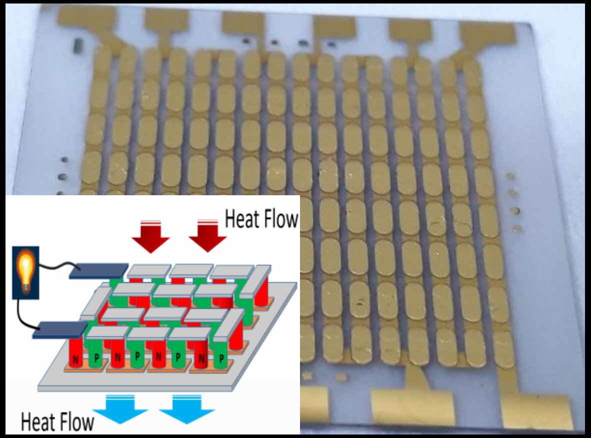
(Sb,Bi)2Te3 奈米線

SnSe 單晶

半導體致酬單根奈米
線熱電性質研究



Thermoelectric device
熱電發電晶片



磁性奈米與傳輸實驗室

李尚凡

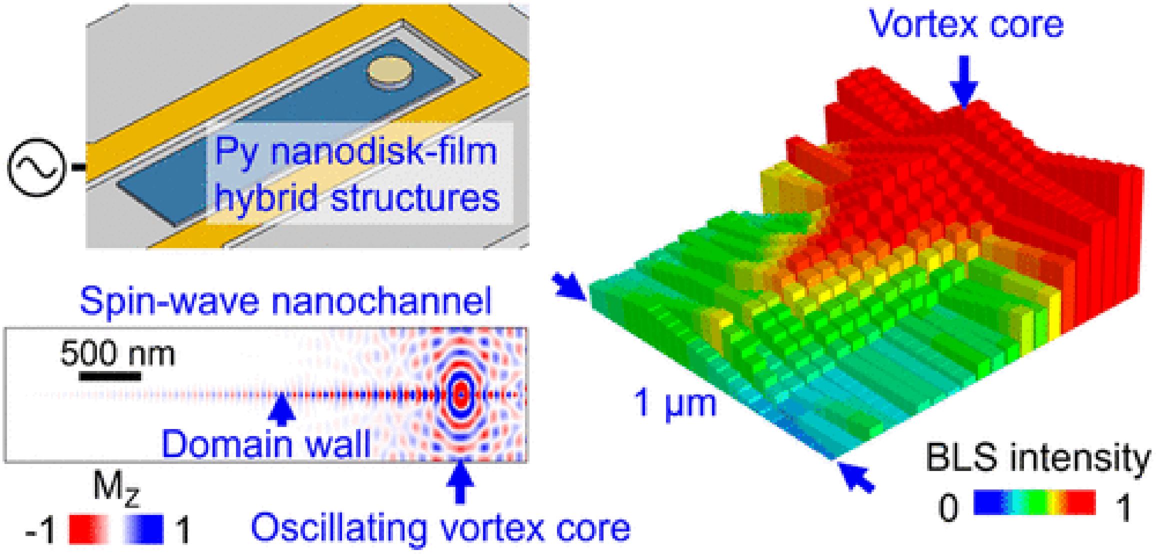
磁振子-自旋波研究 零外加磁場下的寬頻自旋波源

– 以奈米等級渦旋核產生自旋波，注入並在磁通道中傳遞

自旋波可用於資訊傳遞，且能量耗散可以相當微弱。自旋波的量子稱為磁振子。磁振子迴路中自旋波的激發與傳遞是目前自旋電子學應用的重要課題。關於磁性材料中自旋波的研究成果，刊登在 Nano Letters。該實驗證明高達15GHz，波長僅80奈米的自旋波，可以在零外加磁場下，由奈米尺度的鎳鐵磁盤渦旋核心受微波激發而產生，進而耦合至奈米寬的磁區壁中進行傳遞。更有趣的自旋波與磁區壁、skyrmion 的交互作用目前仍依賴模擬，實驗困難有待克服。

Nano Lett. 2020, **20**, 3140–3146

https://doi.org/10.1021/acs.nanolett.9b05133

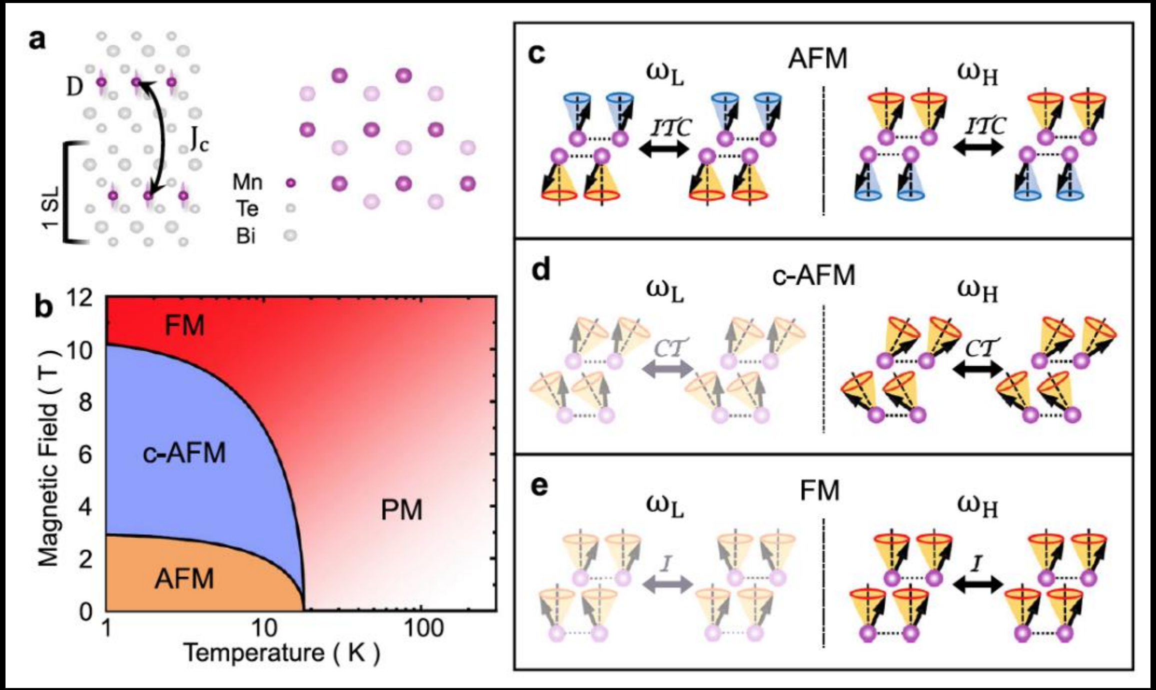


二維磁性材料 性質研究

探討磁性拓樸材料 $MnBi_2Te_4$ 在二維極限下的自旋漲落、磁振子行為。在兩個單元厚度樣品中，成功觀察到基態在外加磁場之下，從反鐵磁轉變為鐵磁狀態的磁振子特性。模型分析得到此結構中的自旋波能隙、層間交換耦合能等各項物理參數。在一單元厚度樣品中則無法觀察到訊號，可歸因於極強的量子漲落。該研究成果發表於 Nature Communications。

Nature Communications **13**, 2527 (2022).

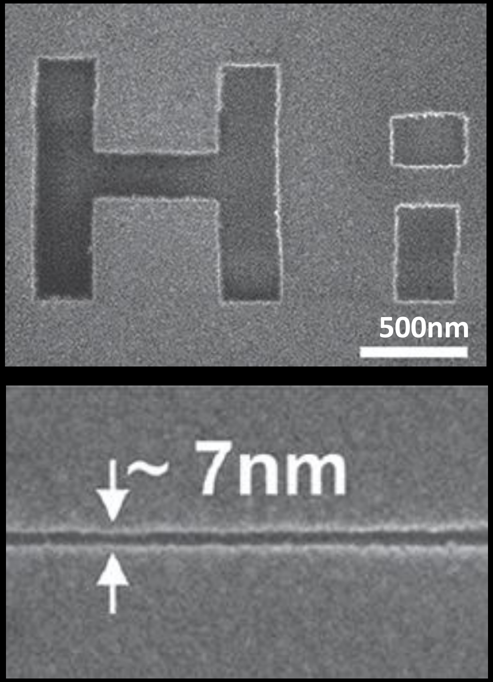
期刊連結: https://doi.org/10.1038/s41467-022-29996-w



量子電子實驗室

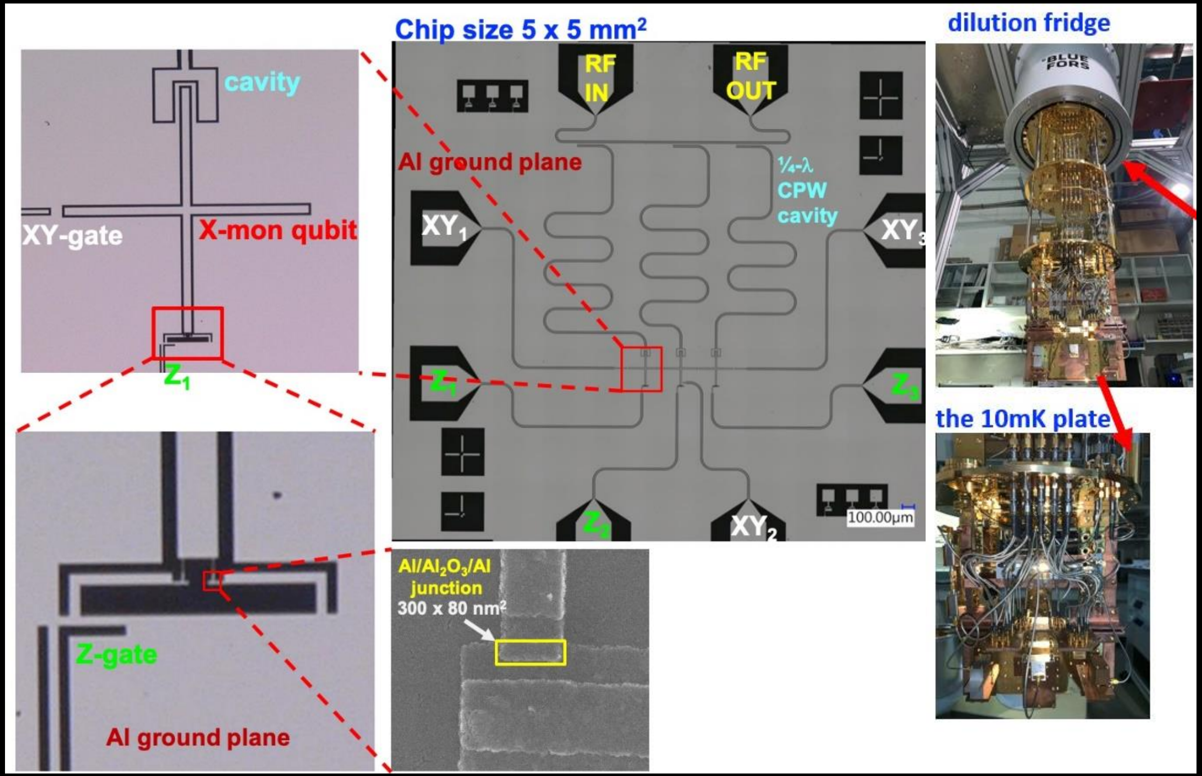
陳啟東

Polymer-free patterning of graphene at sub-10nm scale

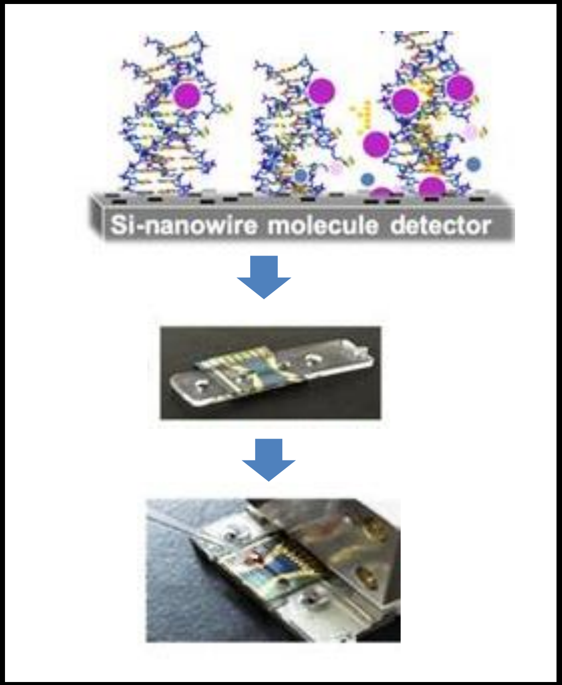


Small 10, 4778 (2014)

Superconducting qubit device

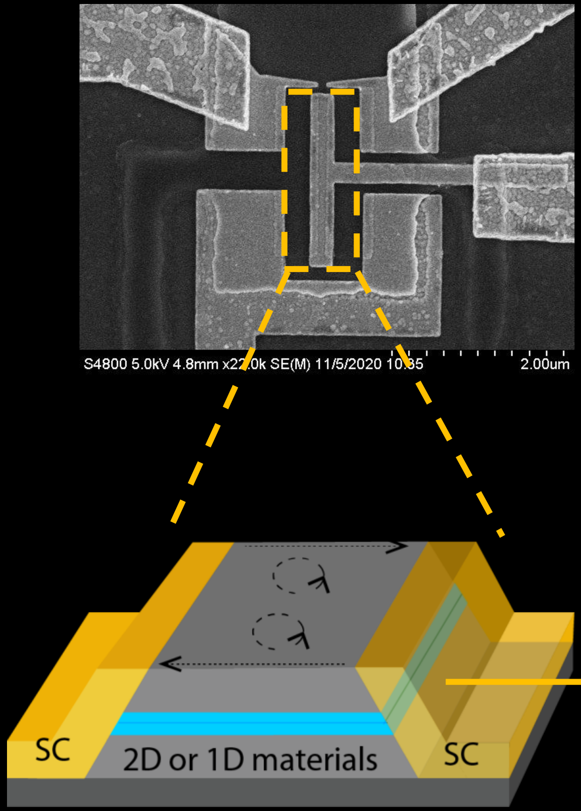


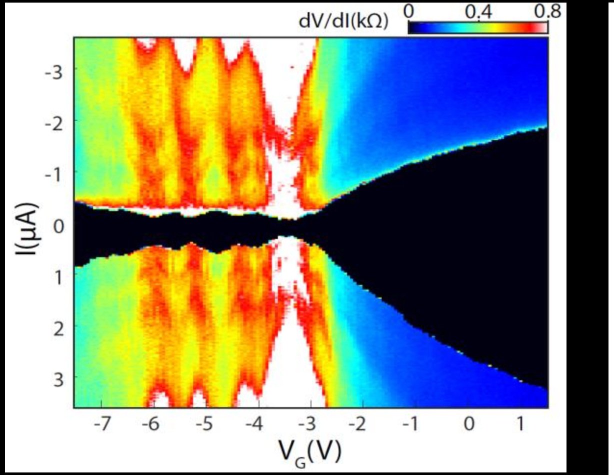
Microchip for Covid detection

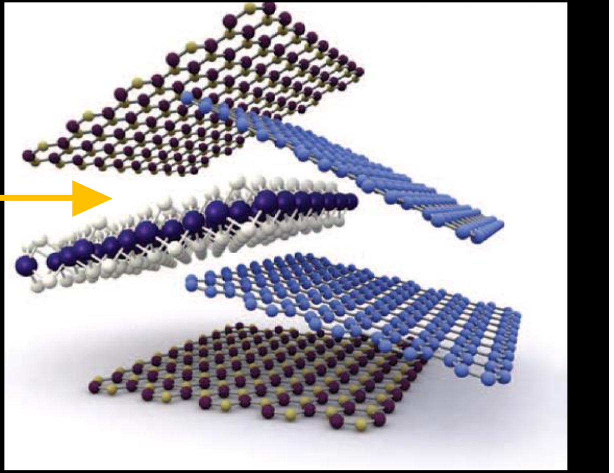


量子元件與傳輸實驗室

Using hybrid material in 2D to develop topological superconductivity

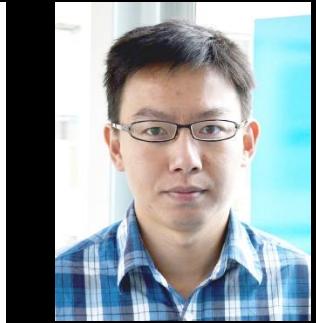


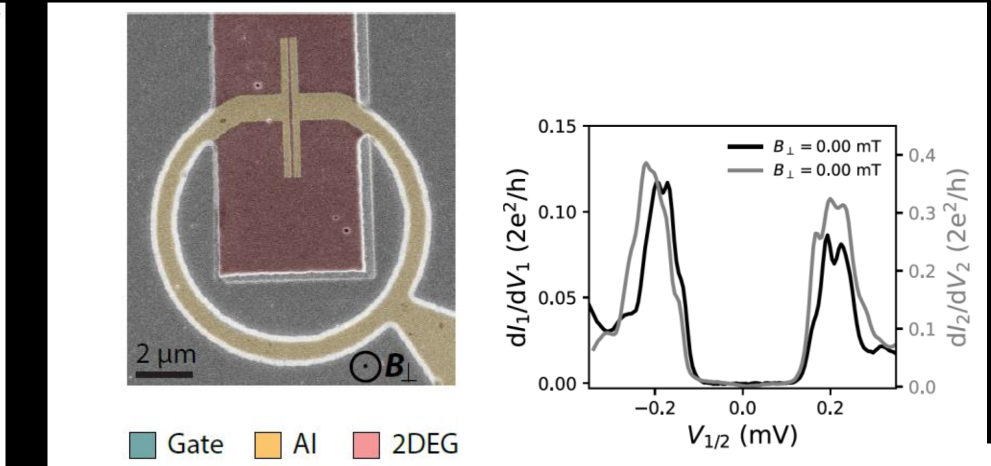


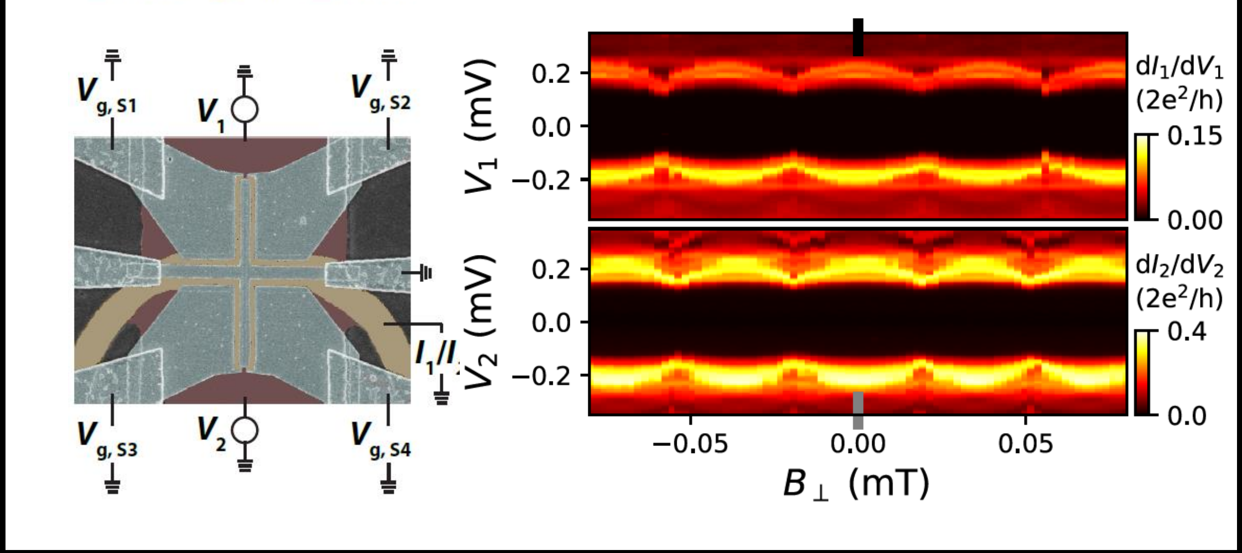


Control of supercurrent

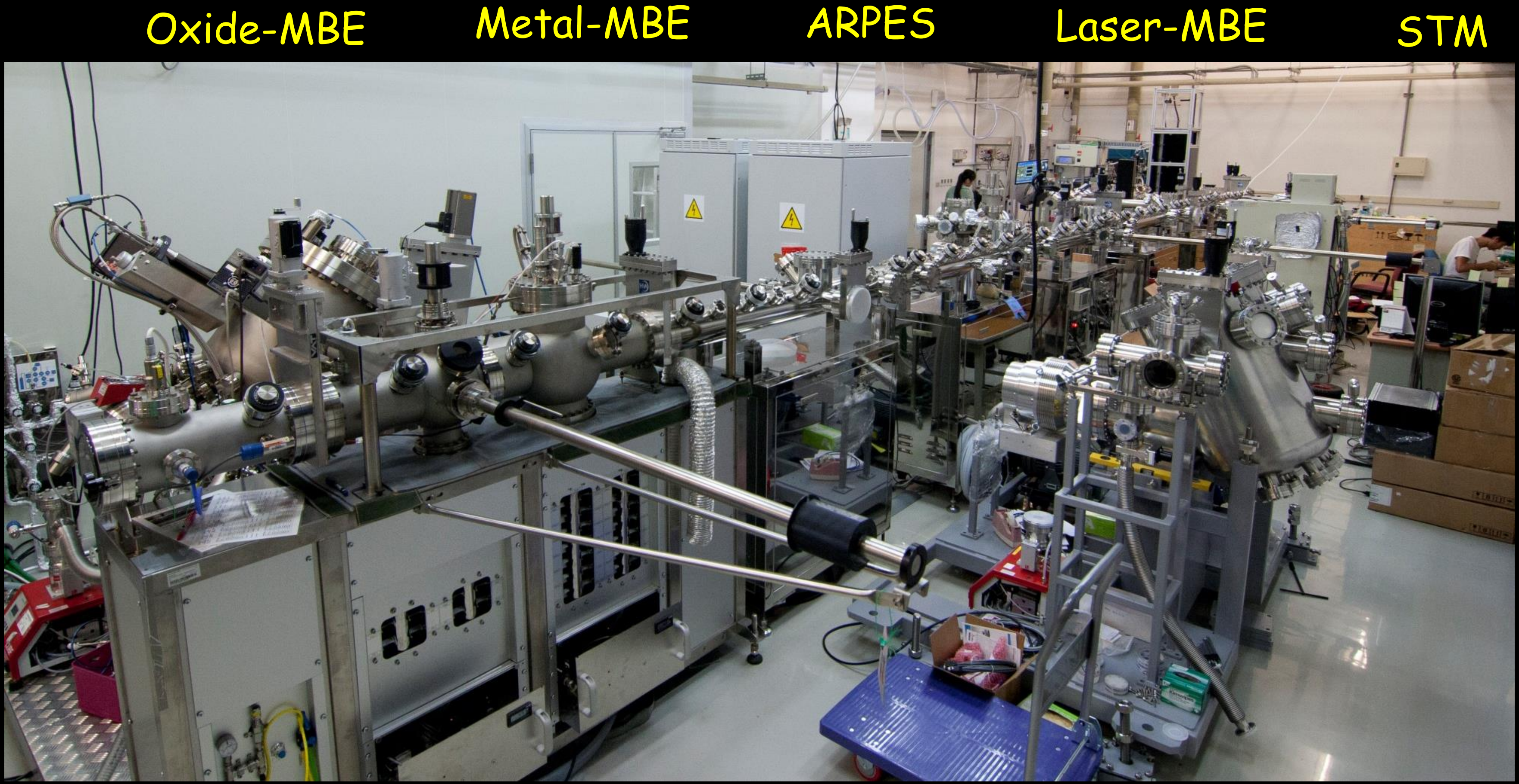
柯忠廷







Internal Joint Effort



Supporting facility

Nanofabrication in cleanroom

Precision machine shop

He liquefaction facility

Magnet & physical properties measurement

Structural characterization facility

Optical spectroscopy facility in progress.