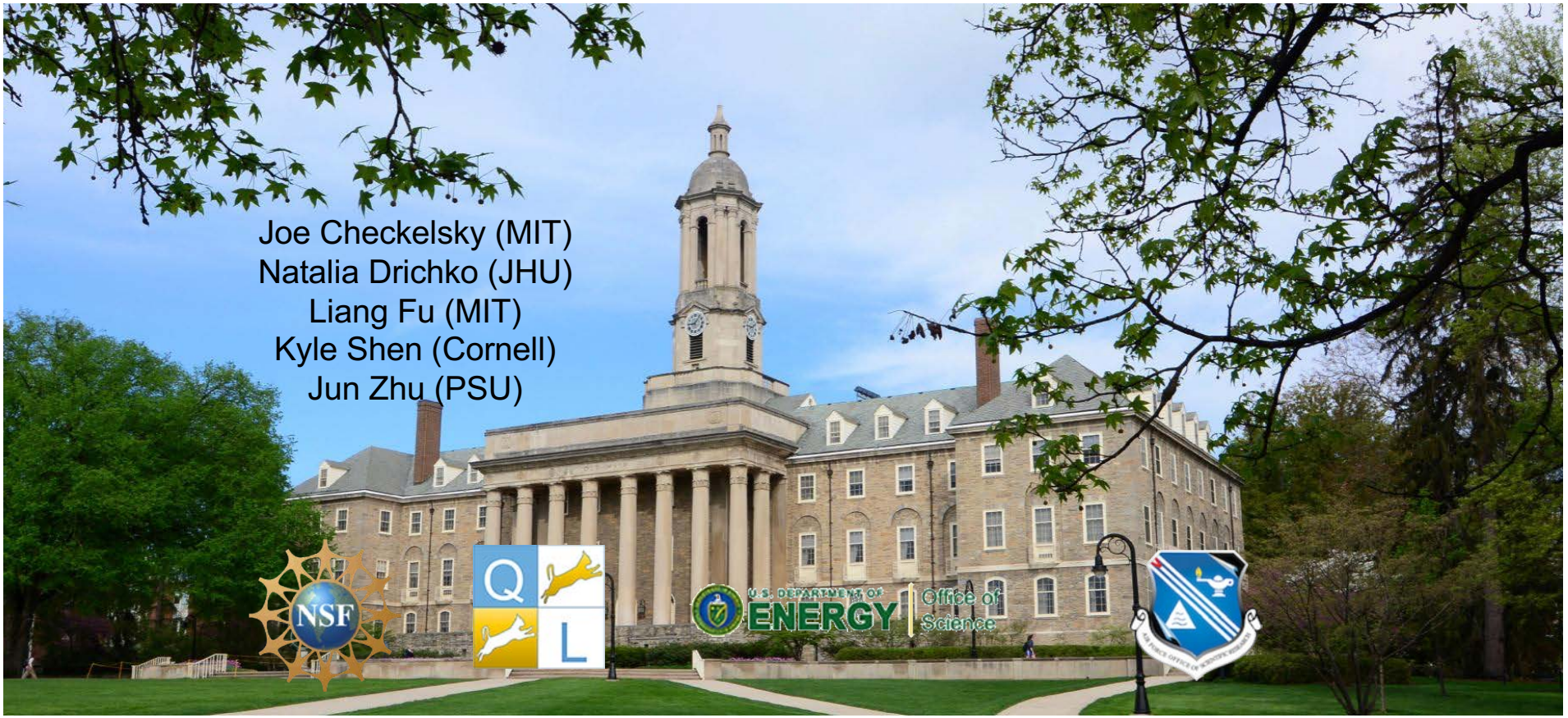
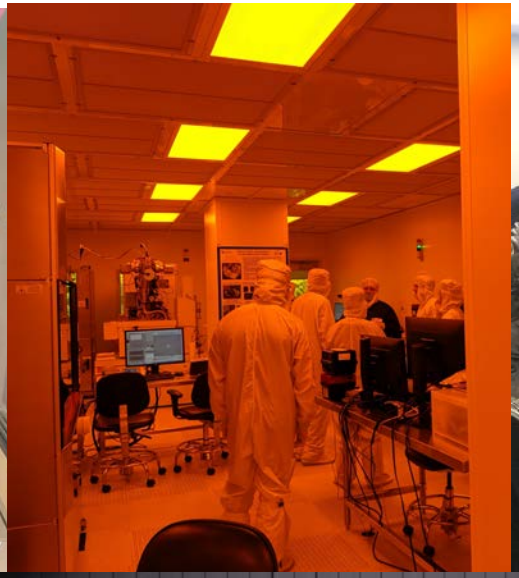
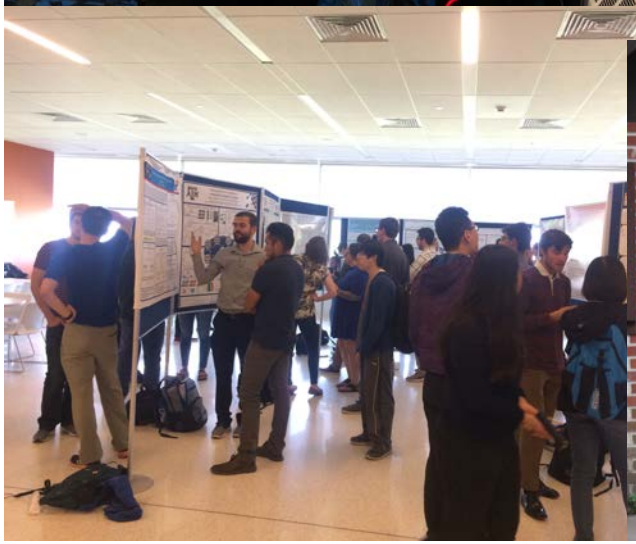
2019 NSF/DOE/AFOSR
Quantum Science Summer School

PennState

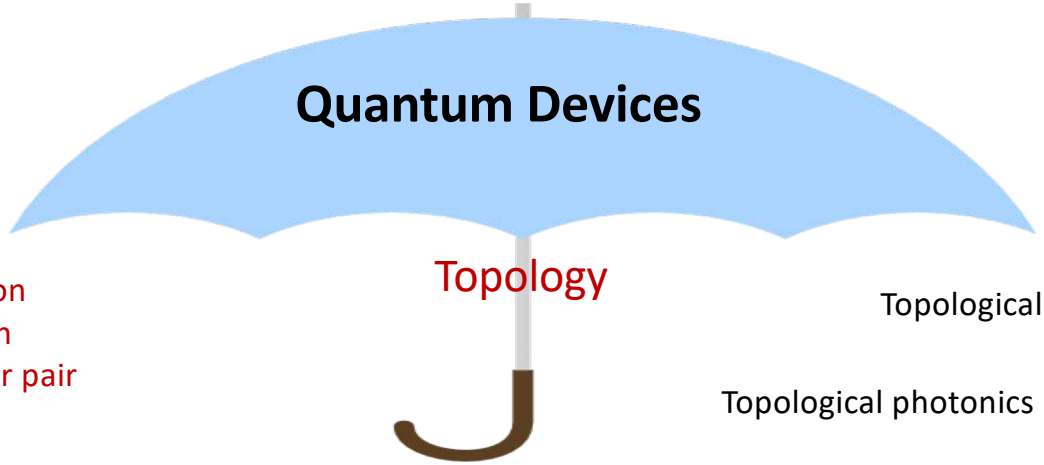





PUTTING TOGETHER THE QD-CAVITY SYSTEM
What do you think is important here?
Cavity
PUTTING TOGETHER THE QD-CAVITY SYSTEM
What do you think is important here?
Cavity



Fundamentals and Applications of Quantum Devices



Electron
Photon
Cooper pair
Spin
Valley
Exciton
NV centers
Majorana Zero modes

Topological edge states

Topological photonics

Topological spintronics

Majorana zero modes

Josephson junction

Topological superconductivity

Hybrid 1D, 2D and 3D structures

Topological quantum computing

Quantum sensing and imaging

Photonic cavity engineering

Spin torque transfer

Ania Bleszynski Jayich

Scott Crooker

Sergey Frolov

James Hone

Evelyn Hu

Katja Nowack

Mikael Rechtsman

Nitin Samarth

Jay Sau

Jonathan Sun (IBM)

Dale Van Harlingen

Steven A. Vitale (Lincoln Lab)

Zhenghan Wang (Microsoft)

Joseph Broz (SRI)

Susan Trolier-McKinstry

Sau: Symmetry, Topology and Majoranas

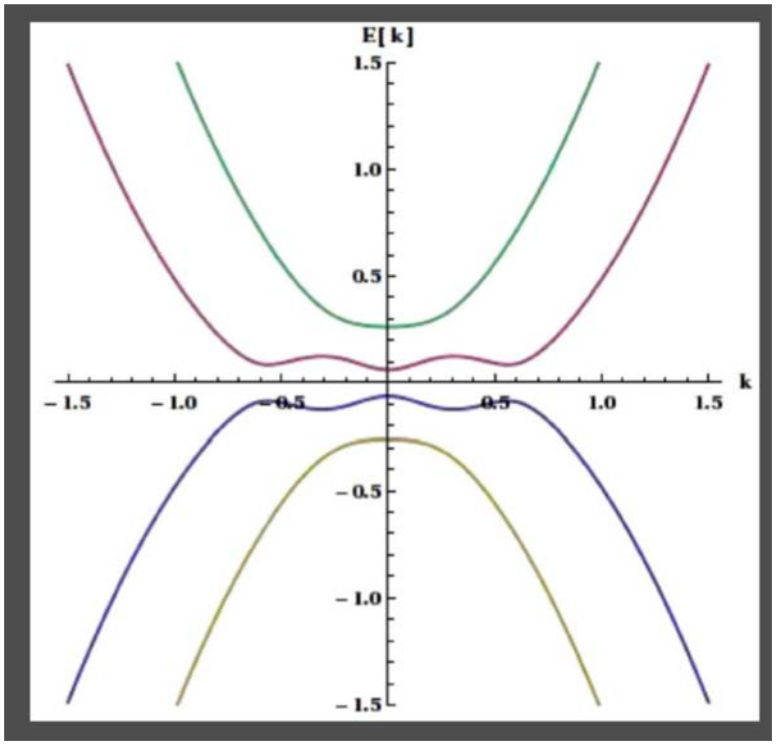
Ingredients for Majoranas

•The induced superconducting gap Δ, which is required to make particle-hole symmetry

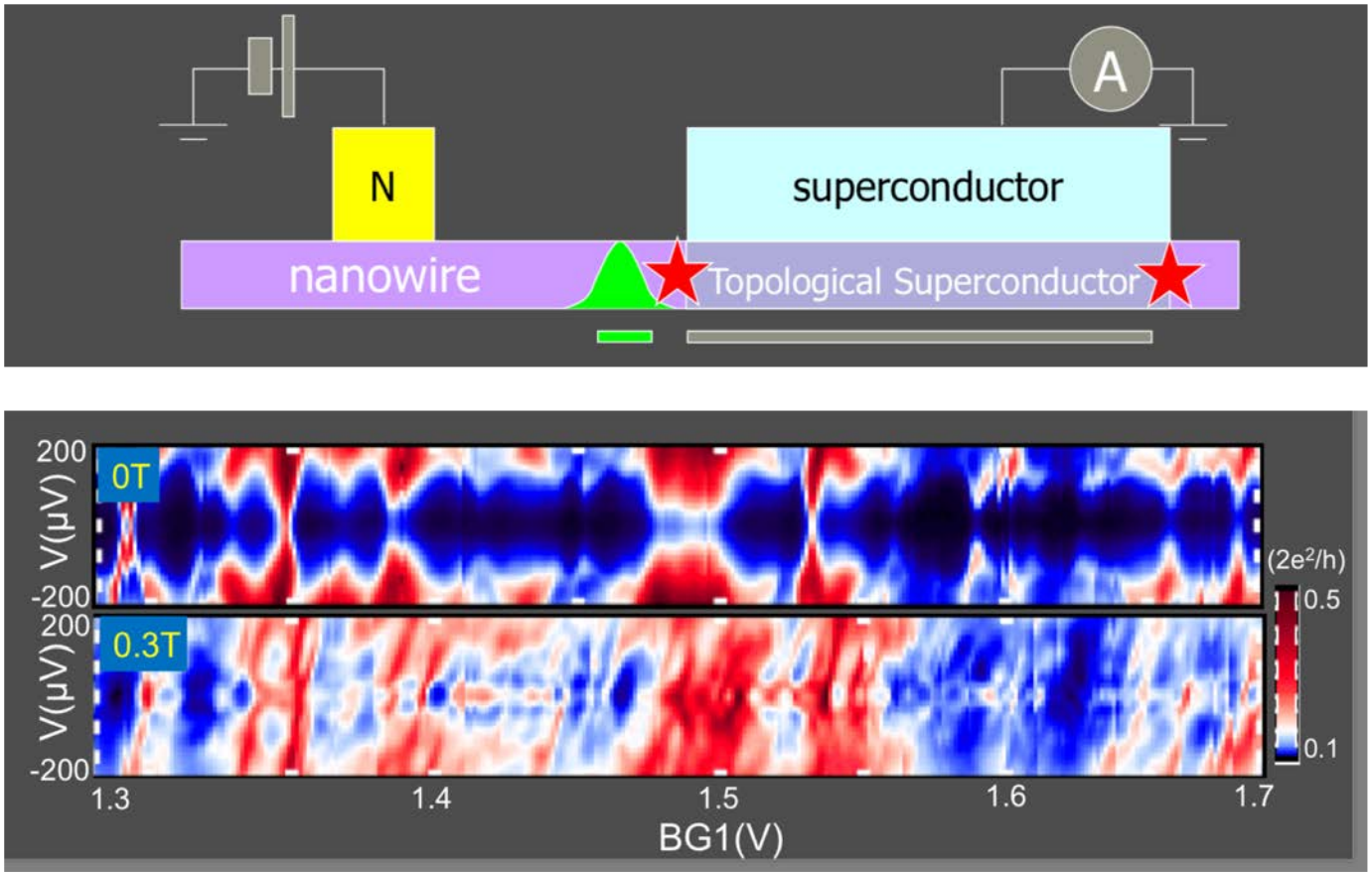
•The spin-orbit coupling α, which breaks spin conservation.

•The Zeeman field B, which breaks Kramers degeneracy.

• The chemical potential μ, which sets the overall density of the wire

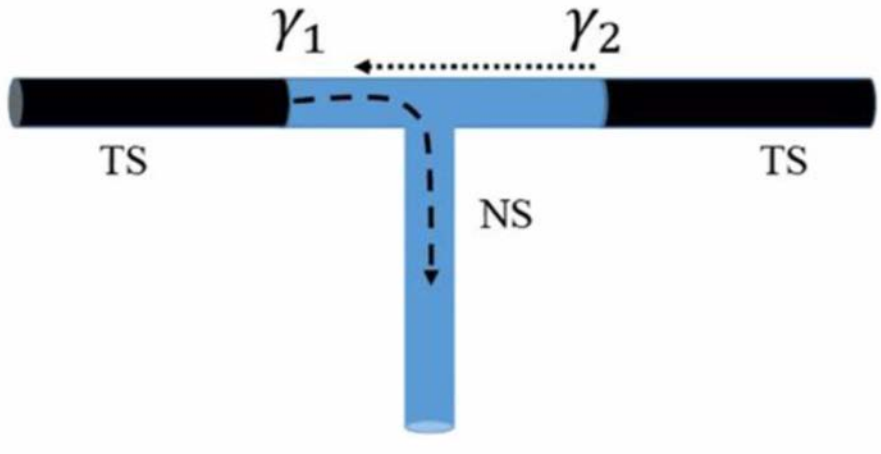


Frolov: Searching for Majorana zero modes in nanowires

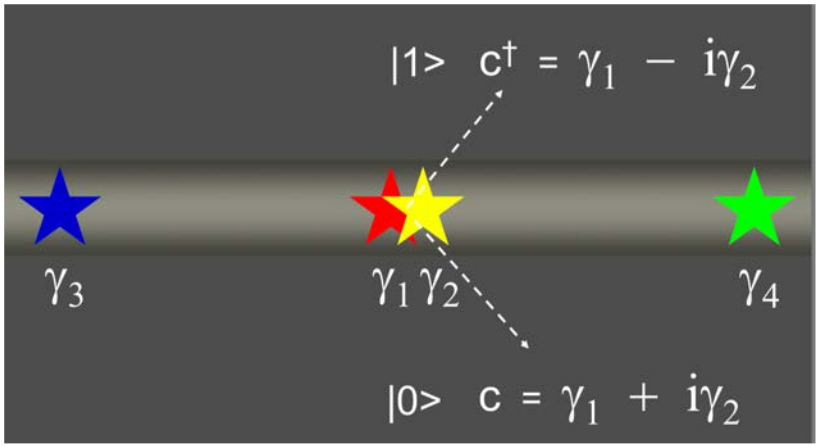


Wang: Topological Quantum Computing

Braiding



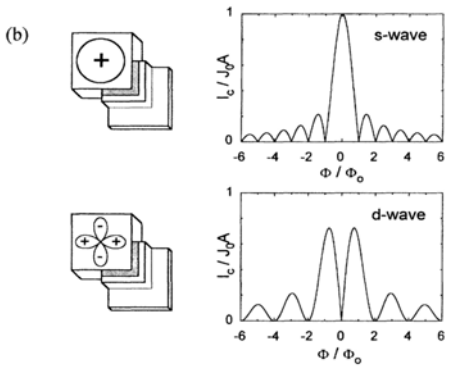
Fusing (measurement)



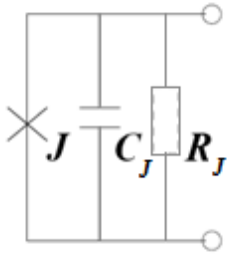
Topologically protected quantum computing operations, but a long, long way to go…

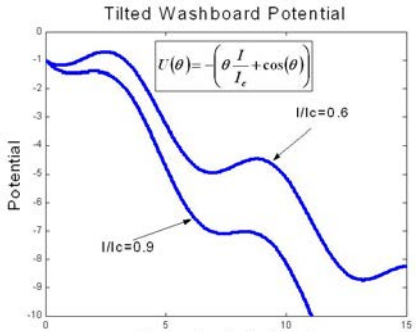
Van Harlingen : SQUIDs for Unconventional Superconductors

Phase-sensitive measurements

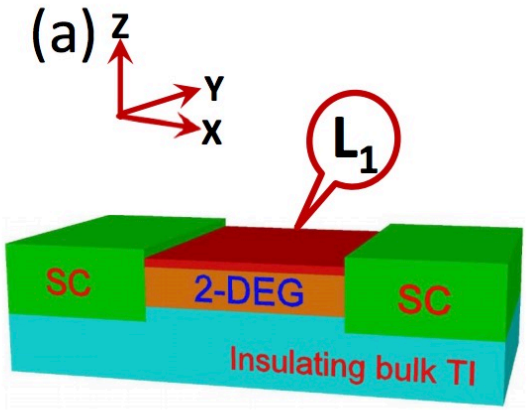


SQUID Fundamentals



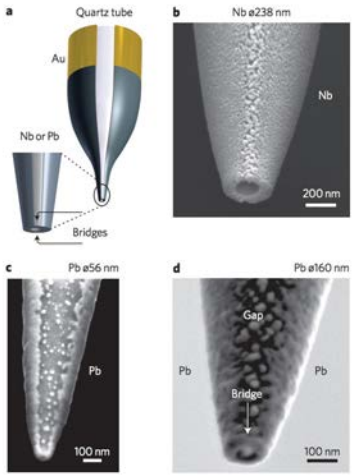


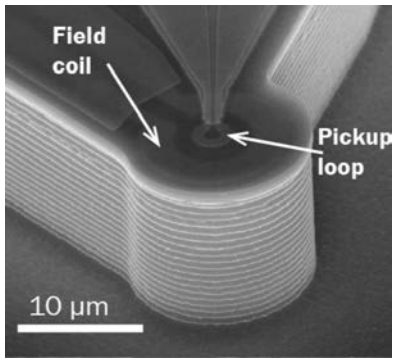
SQUIDs based on TIs



Nowack : Scanning SQUIDs for Quantum Devices

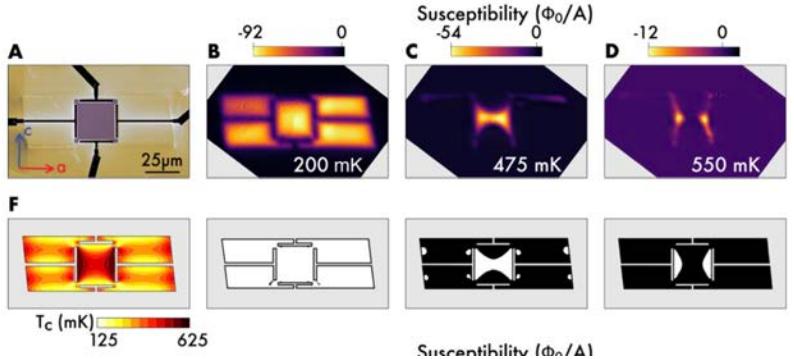
SQUID imaging



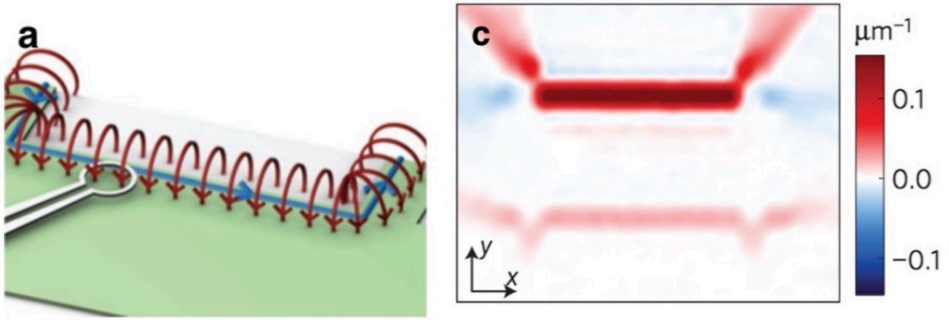


Sensitive to:
flux, current, local temperature…

Strain-modulated superconductivity

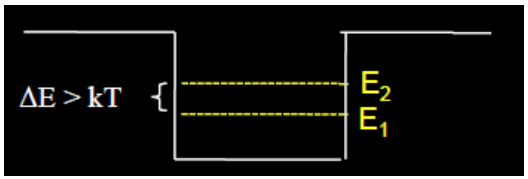


Quantum Spin-Hall Edge Currents

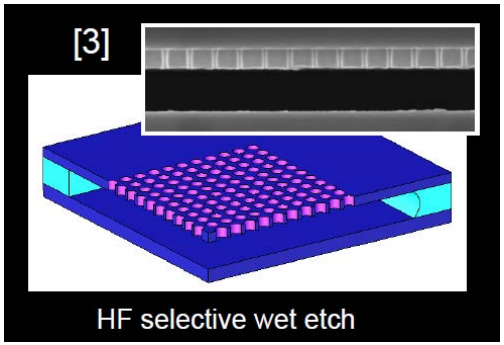


Hu: Semiconductor Optical Cavities

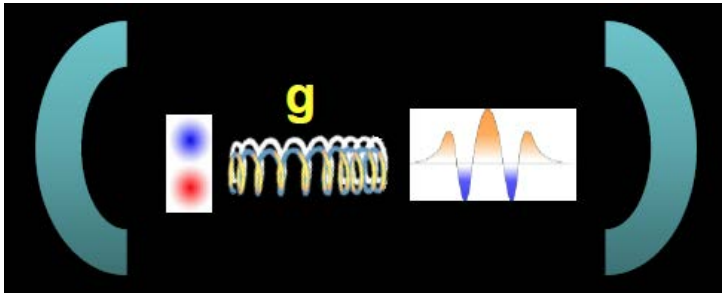
Quantum Dots as Artificial Atoms

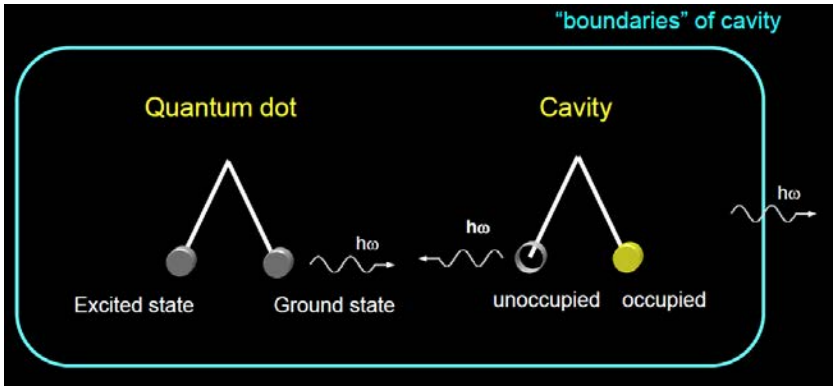


Cavity: A membrane patterned with structures at the 100 nm scale

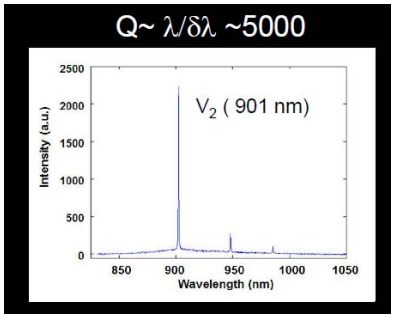


QD-Cavity System





Cavity Matching Gives High *Q*

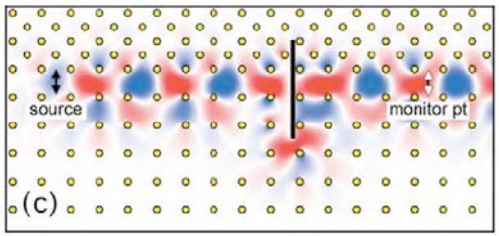


Transfer of energy between quantum dot (matter) and cavity (photons)!

Rechtsman : Topological Photonics

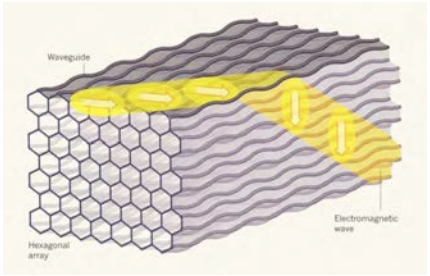
Bringing Topological Robustness to Photonics

Wang et. al., PRL (2008)

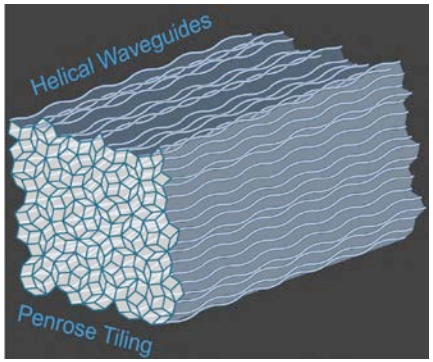


Edge modes, Weyl points, in photonics

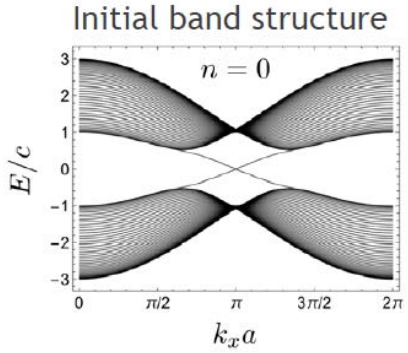
Electromagnetic Edge Modes

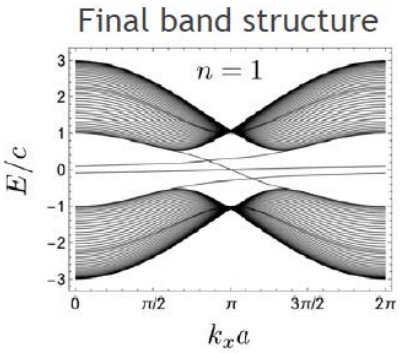


Even in Quasicrystalline systems!



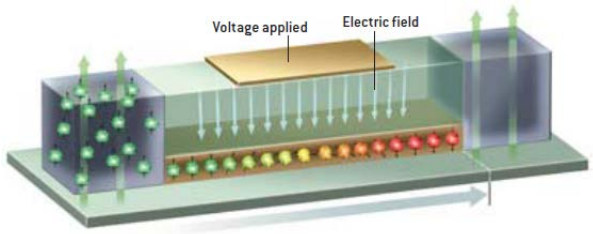
Creation of “slow light” modes



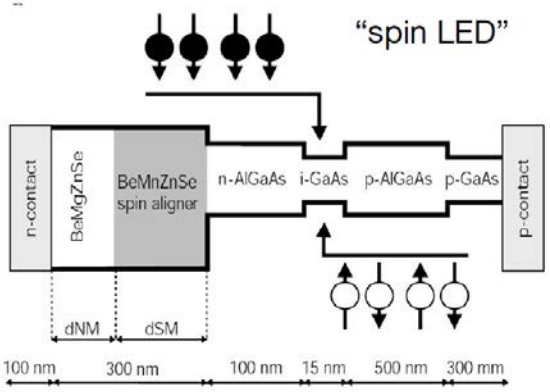


Samarth: Spintronics and Topological Insulators

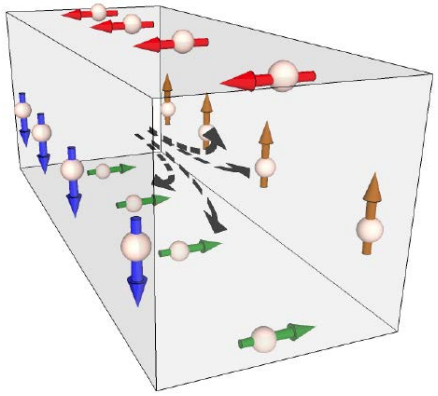
Spin-based Devices



Datta & Das, APL **56**, 665 (1990)

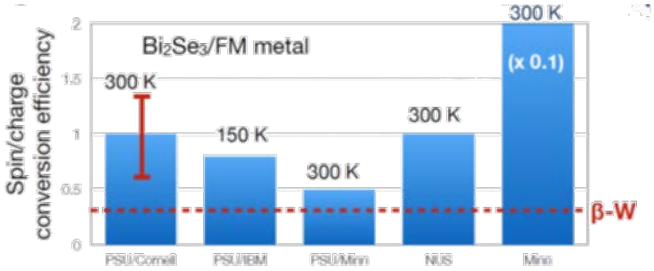


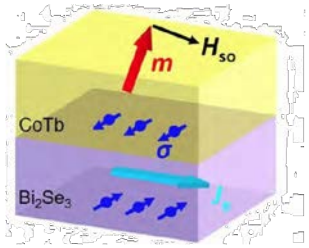
Spin Hall Effect

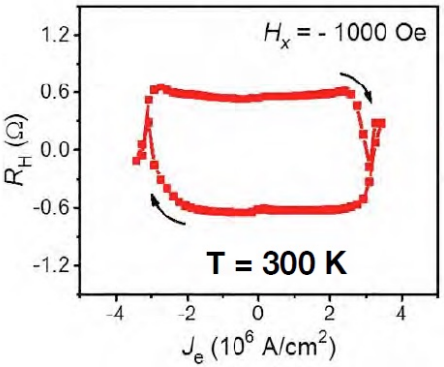


Graphic: D. C. Ralph

High Performance in Topological Materials

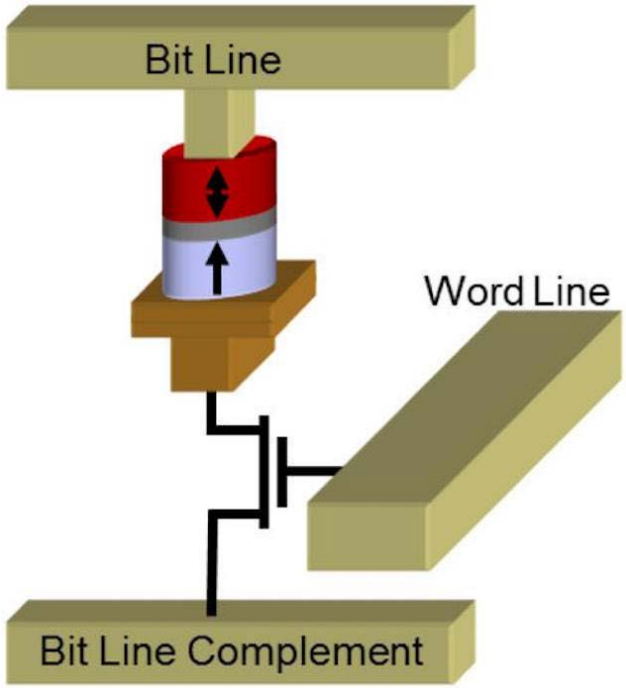


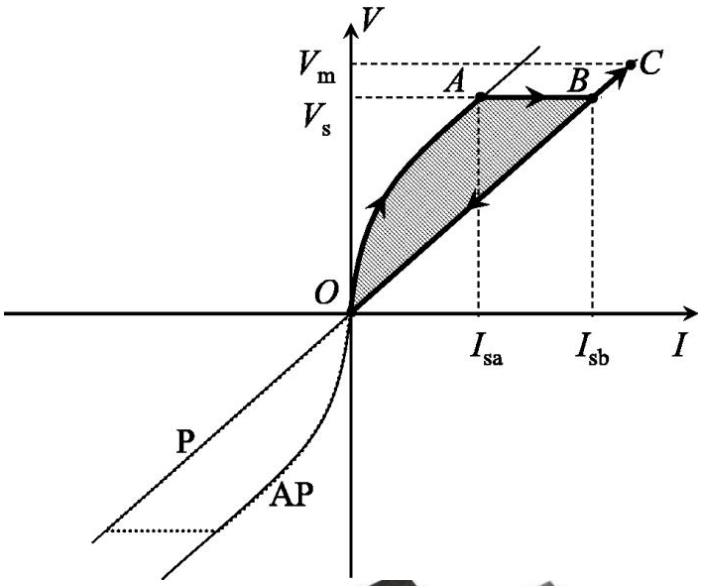




Han *et al.*, *PRL* **119** 077702 (2017)

Sun: Spin-transfer-torque based MRAM

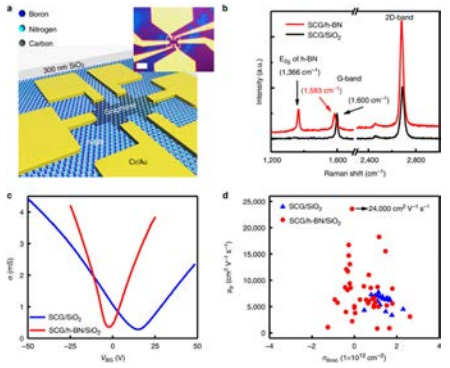


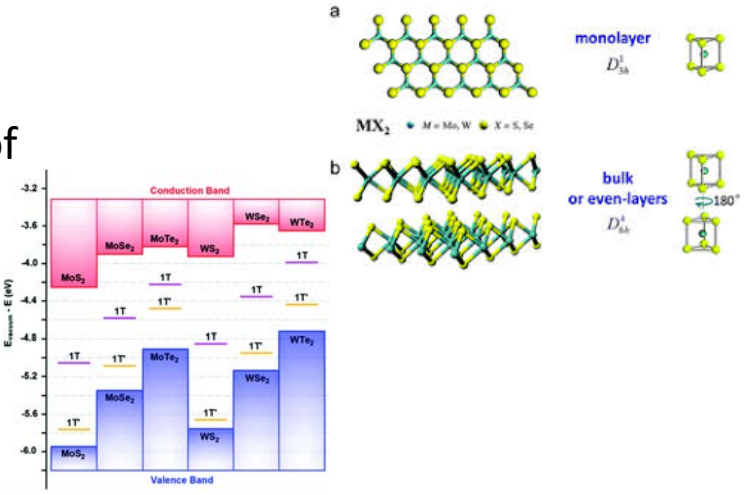


Everspin

Hone: van der Waals materials and heterostructures

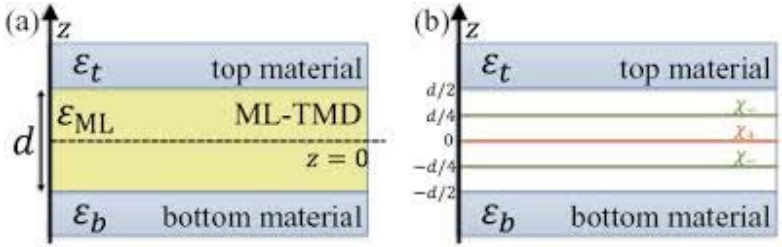
- **Graphene:** discovery and first experiments with graphene on Si/Si0_2 substrate
- Graphene on boron nitride: tremendous improvement exfoliation is still the best technique!
- Manipulations/transfer with plastic manipulator/baking
- **Transition metal dichalcogenides**: different symmetry of the layer C_3, large band gap
- Assembling heterostructures using manipulators

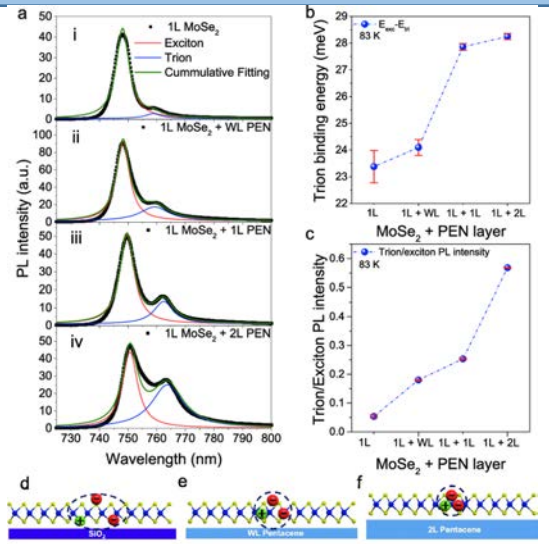


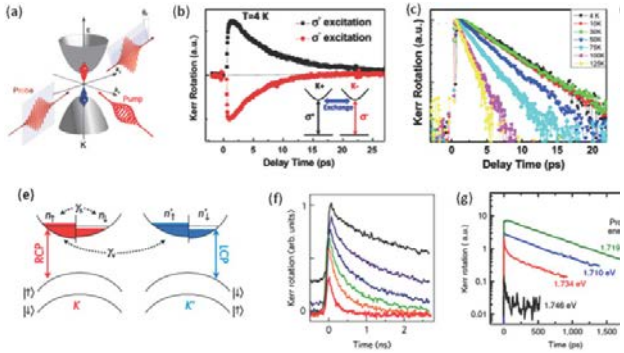


Crooker: Excitons and Valley dynamics in Monolayer TMD

- Extension of the discussion on PL and excitons as characterization of the samples
- Measuring basic properties, such as effective mass
- Dielectric screening
- Ultrafast spectroscopy: studies of dynamic response.
- Measuring relaxation times

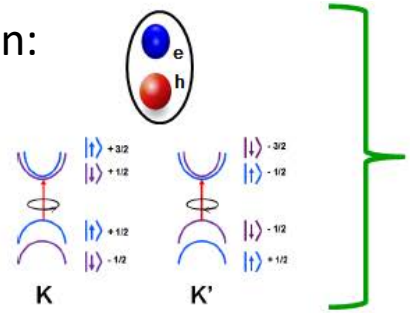






Vitale: Valleytronic Information Processing and Applications

Valleys in band structures with different spin polarization:
Can we use valleys as 0 and 1 states?

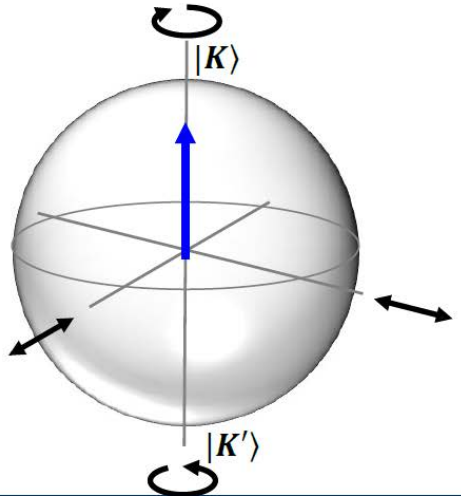


Can we exploit these properties to develop a logic device that outperforms silicon?

$$|R\rangle = \frac{1}{\sqrt{2}}(|x\rangle + i|y\rangle)$$

Hard problem #1: figure out a way to deterministically flip an exciton between $|K\rangle$ and $|-K\rangle$ states

$$|L\rangle = \frac{1}{\sqrt{2}}(|x\rangle - i|y\rangle)$$



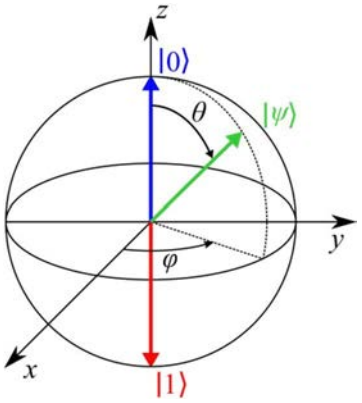
IT IS HARD!

Few problems still unsolved, including how to flip excitons between the valleys: how to switch between 0 and 1.

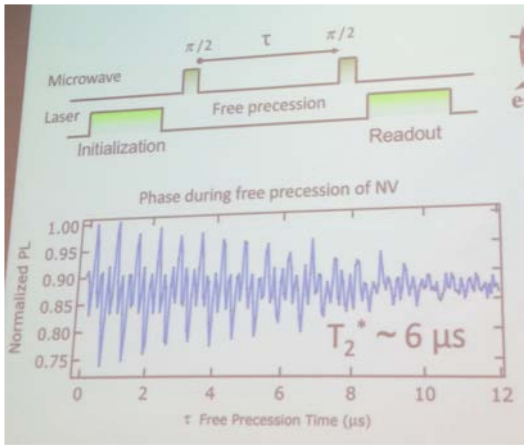
Jayich: Quantum Sensing using NV centers

Fundamentals of two level systems

Bloch sphere



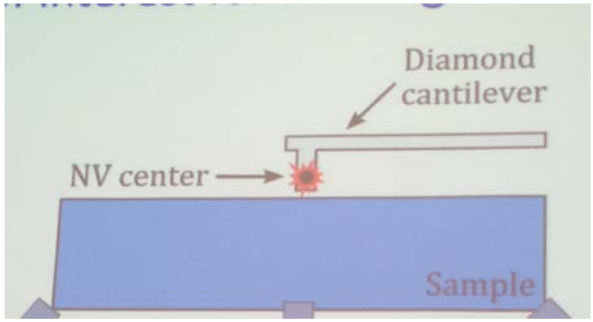
Control and measurement of spin using microwave pulses



Dephasing and relaxation sources in NV spin sensing

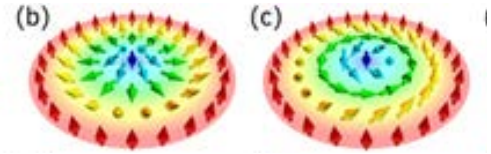
Powerful probe of electric and magnetic field noise

Decoherence at interfaces is critical to quantum sensing



Imaging material and biological systems with NV magnetometry

Viscous flow of electrons, skyrmions,



Thank You!

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Operations & User Facilities Director

Max Wetherington
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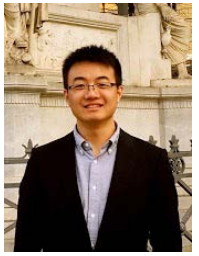
Zhu lab

Dr. Hailong Fu



Cequn Li

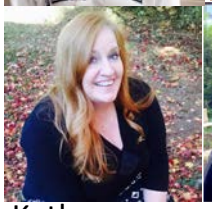
Kevin Honz

Nanofabrication facility

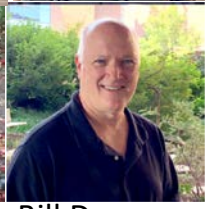
Beth

Bill M.

Bangzhi



Kathy



Bill D.

Mike

Thank you for participating!

Please fill out the survey to help us make it even better next time…