CENTER for INTEGRATED QUANTUM MATERIALS

STC Class of 2013

Center for Integrated Quantum Materials

Harvard University – PI Robert Westervelt

Howard University – co-PI Gary Harris

Massachusetts Institute of Technology – co-PI Ray Ashoori

Museum of Science, Boston – co-PI Carol Lynn Alpert

Semiconductor Technology

1950 1960 1970 1980 1990 2000 2010 **future**

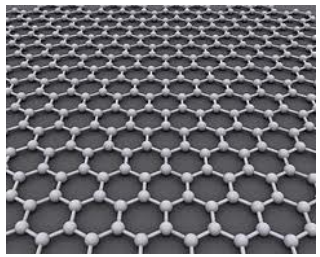
1971 Intel P4004
1st CPU by Intel.

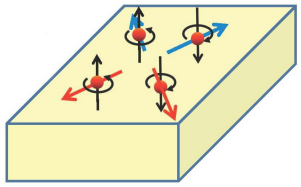
QUANTUM MATERIALS

Topological Insulators

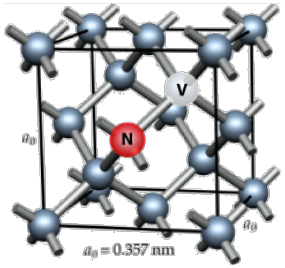
Graphene

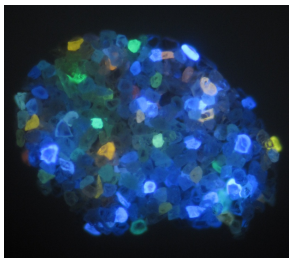
NV Center Diamond





Mission





Transform electronics and photonics to 2D atomic layers, electron surface states and single-atom devices:

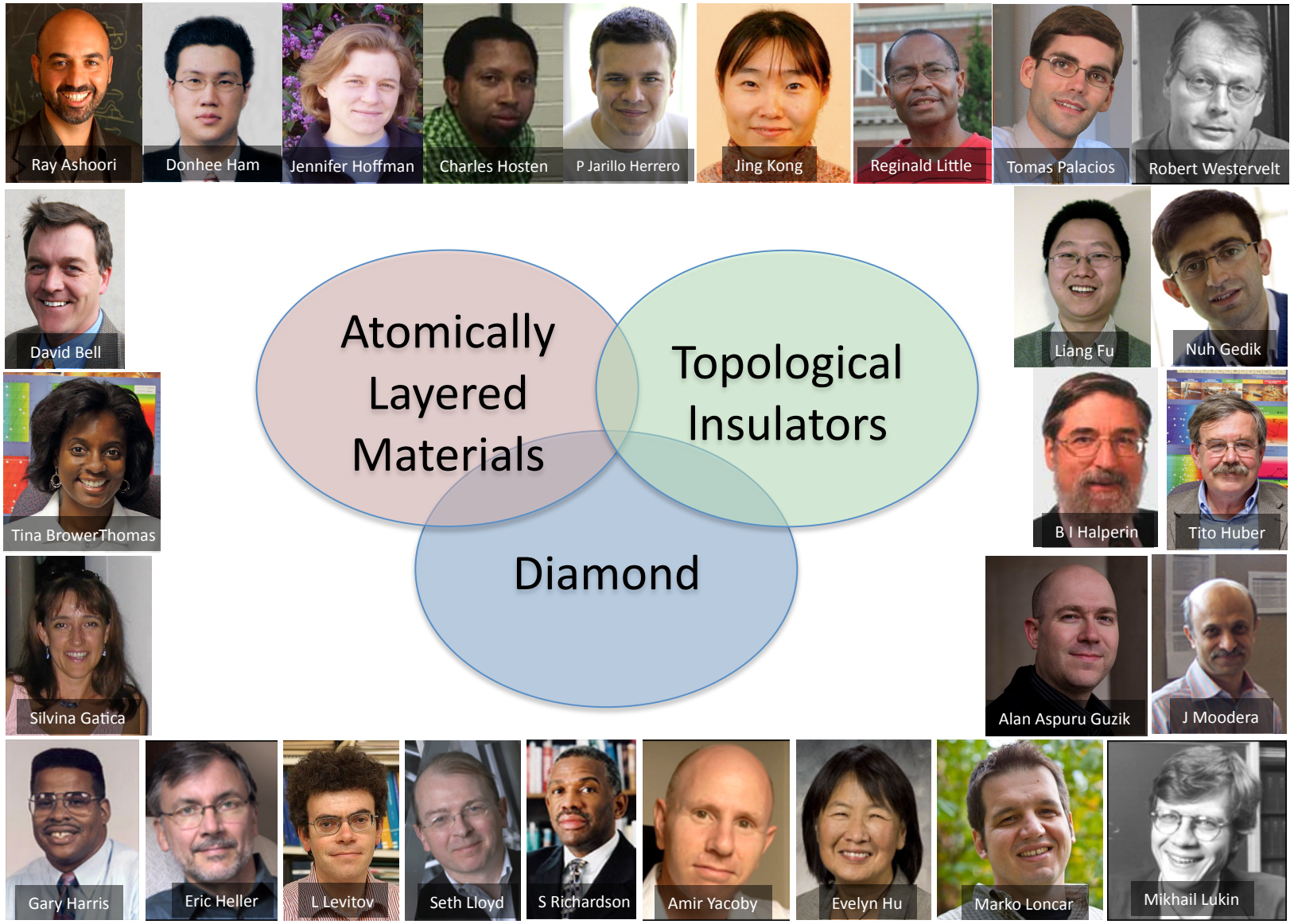
Quantum Materials

Atomic Layers: Graphene, BN, MoS_2 - *ultrafast devices*
Topological Insulators – *protected data*
Nitrogen Vacancy Center Diamond – *atomic memory*

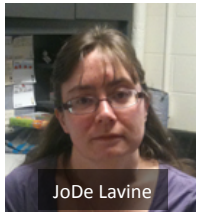
Broader Impact

Attract young students to careers in science & engineering.
Engage public audiences in the quest for new frontiers.
Commercialize sciences - new technologies & products

Quantum Materials Research

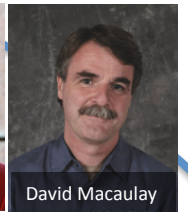


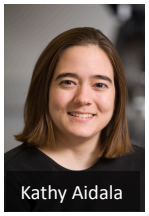
Science & Education Community



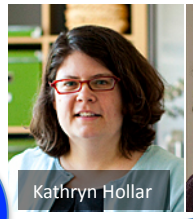
Bunker Hill CC

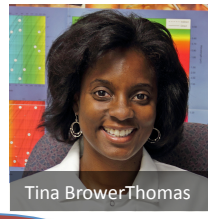
NISE Network





Museum of Science





Mt Holyoke College

Prince George's CC

MIT

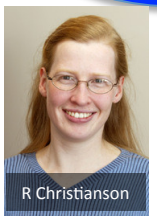
Harvard

Howard

Olin College

Gallaudet University

Harvard Innovation Lab



Wellesley College

Industrial & Venture Partners

$120 round trip

Museum of Science™ A non-profit, community organization

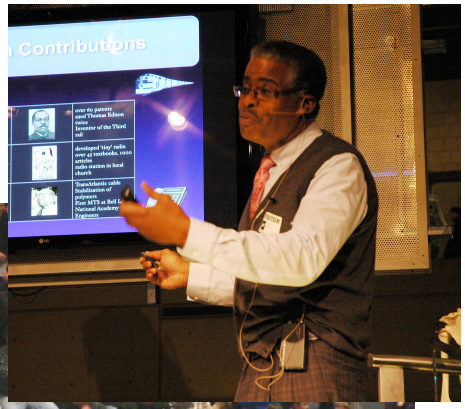
Headquarters:

National Center for Technological Literacy
Nanoscale Informal Science Education Network
Intel Computer Clubhouse Network

Bringing public and school audiences face-to face with leading scientists and engineers…

Award winning Current Science & Technology (CS&T) Center developed by CIQM Co-PI Carol Lynn Alpert

Gary Harris
on CS&T Stage

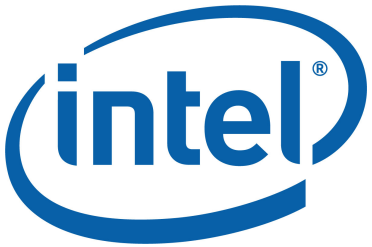


Center for Nanoscale Systems

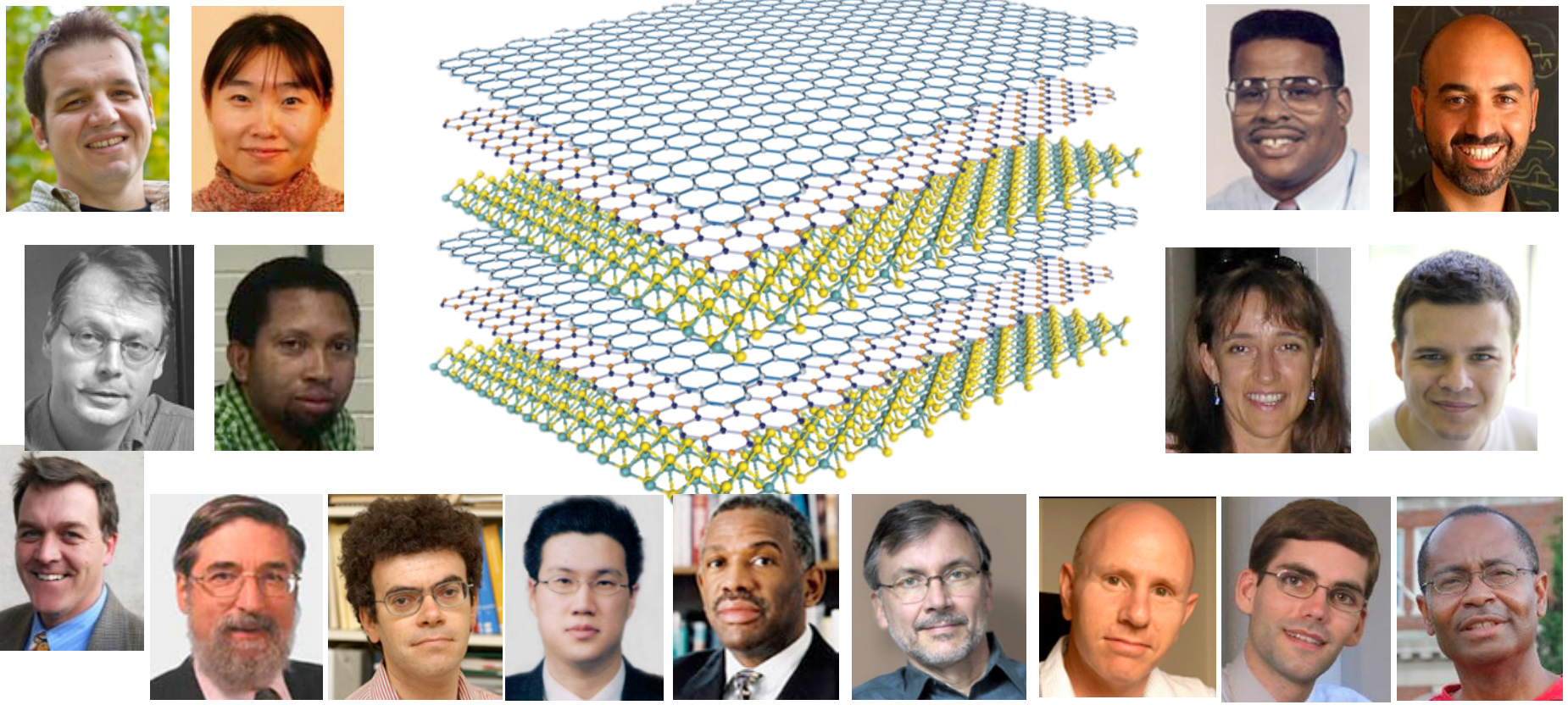
1500+ Users
academic & industry
NNIN member

Nanofabrication
Electron Imaging
Materials Synthesis

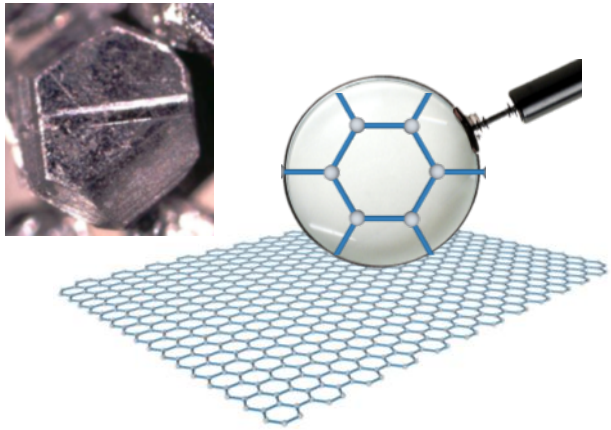
CIQM Industrial Partners



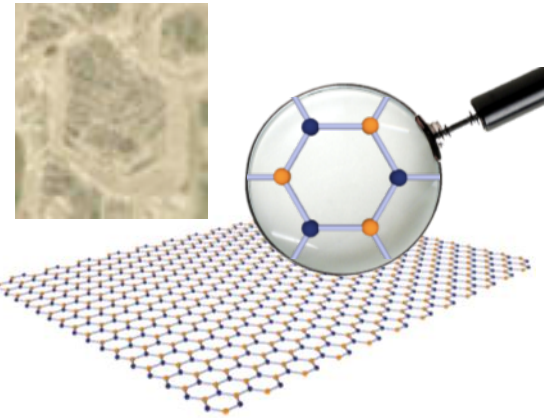
Graphene and other Atomically-Thin Layered Materials



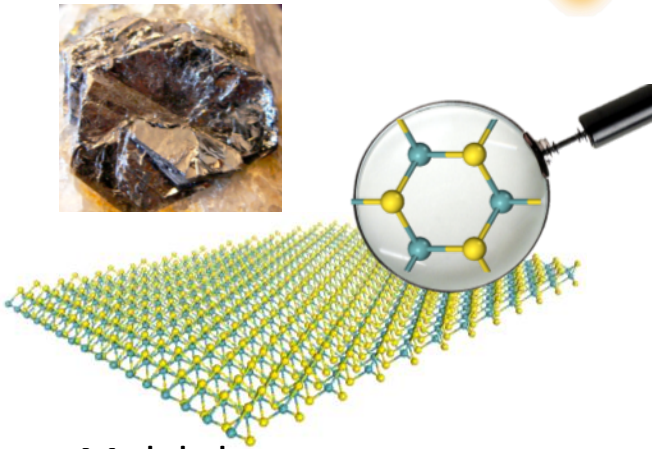
The World of Atomically-thin 2D-Layered Materials



Graphene (G)



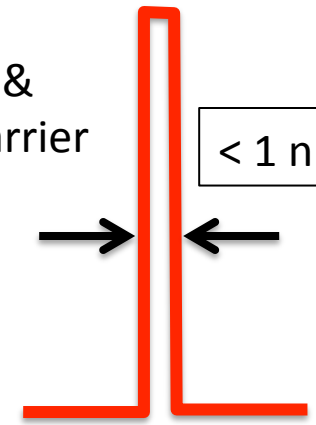
Hexagonal Boron Nitride (hBN)



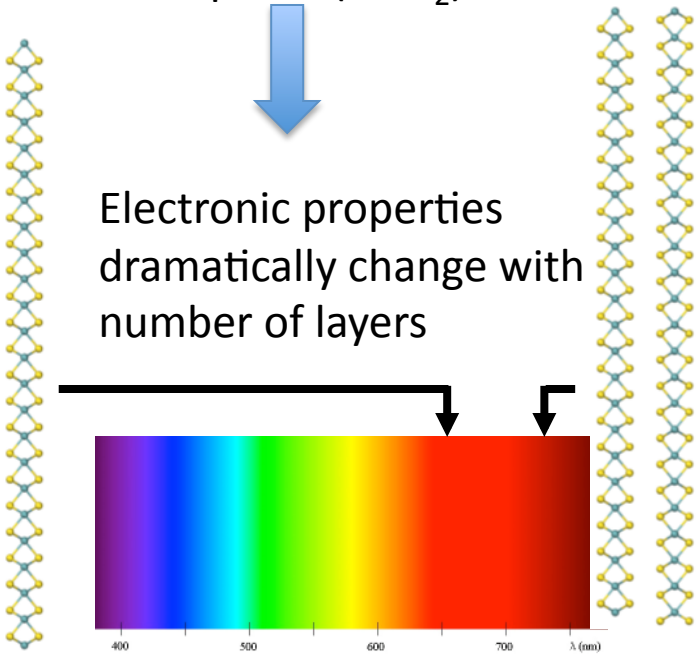
Molybdenum Disulphide (MoS_2)

Tabletop Relativistic Physics

Thinnest Insulator & tunnel barrier

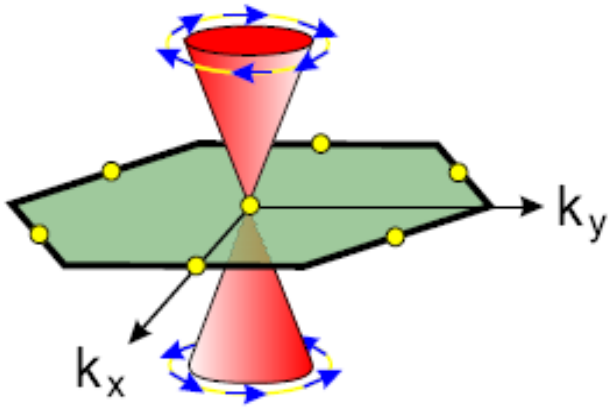


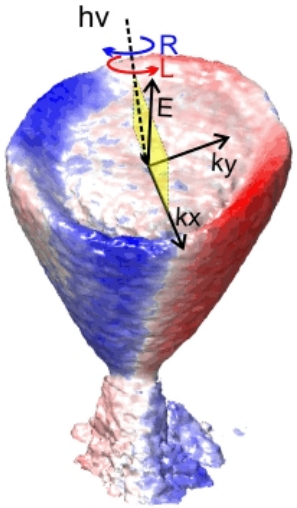
Electronic properties dramatically change with number of layers

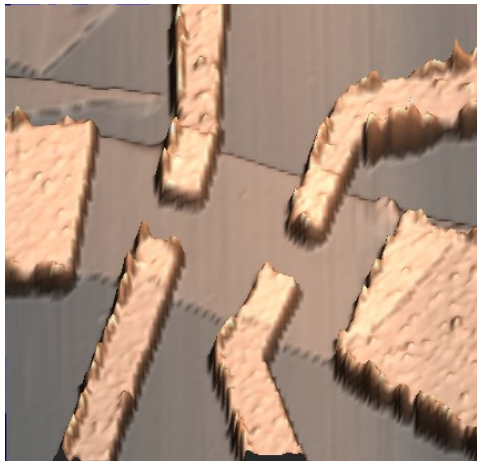


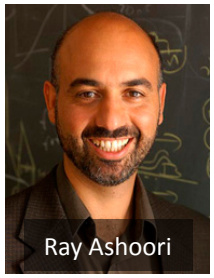
Topological Insulators

Nuh Gedik







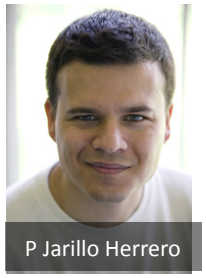

Ray Ashoori


David Bell


Liang Fu


Nuh Gedik

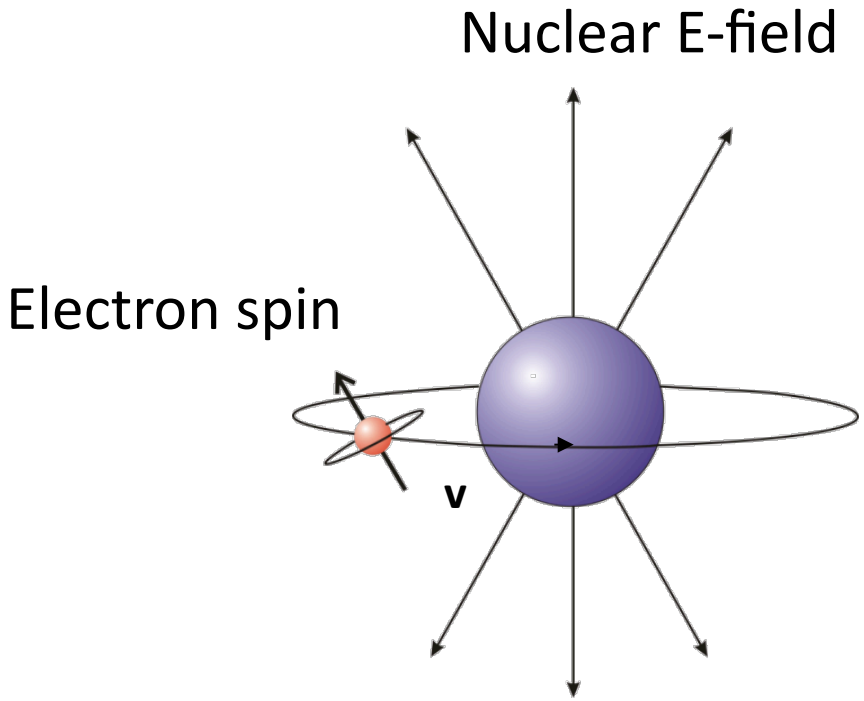

Jennifer Hoffman

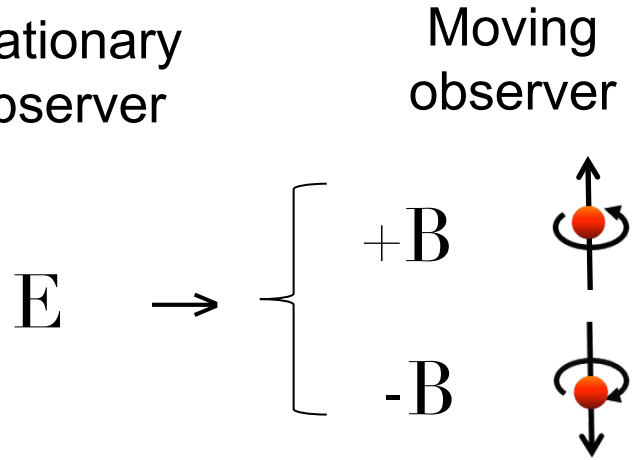

P Jarillo Herrero

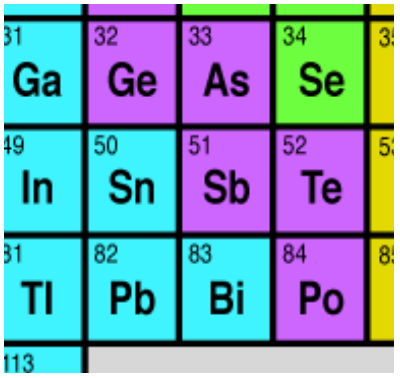

J Moodera

Can quantum Hall physics occur without a magnetic field?

Spin-orbit coupling



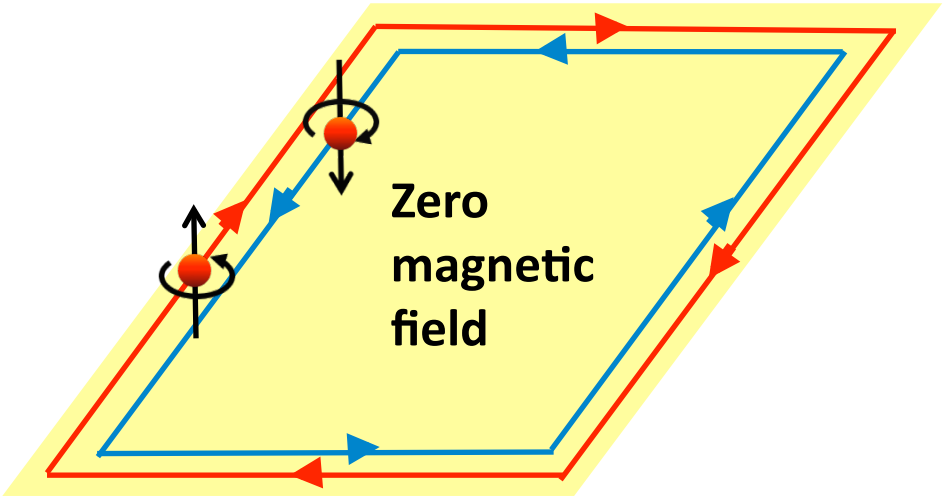


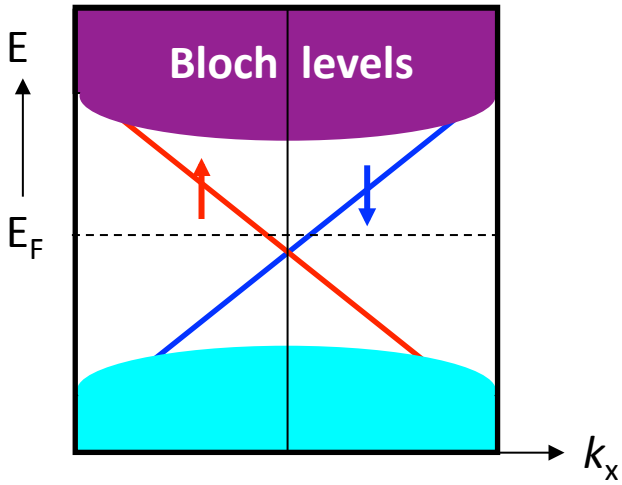


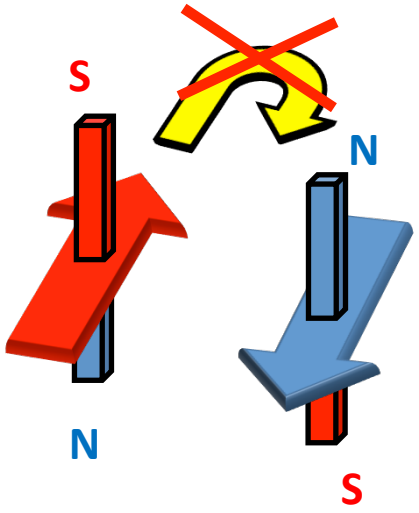
Largest effect in heavy elements

The 2D quantum spin Hall insulator

Theoretical prediction (Kane and Mele 2005)

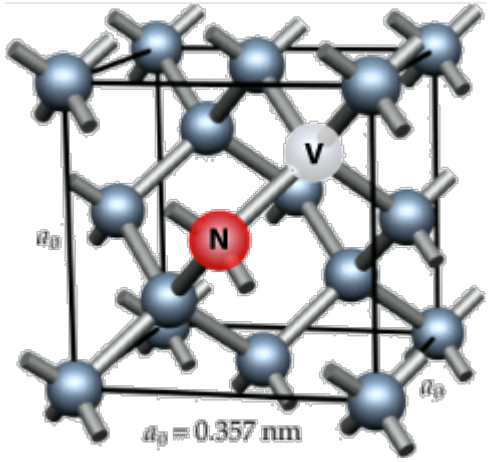


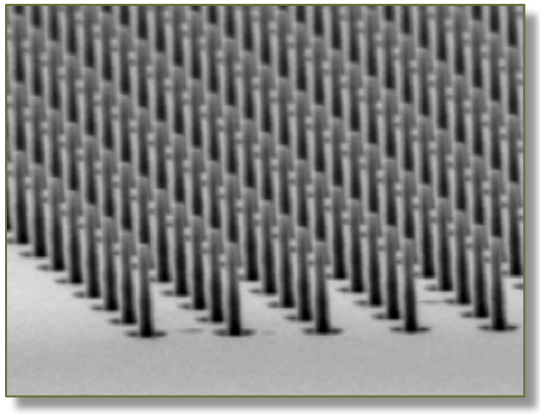




First realistic materials proposal
HgTe/CdTe (Bernevig, Hughes, Zhang 2006)

Experimental confirmation
(Konig, Molenkamp et al. 2007)

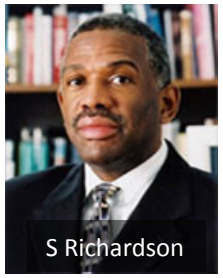


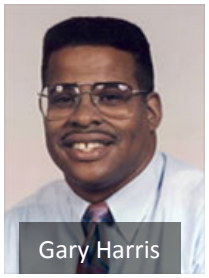


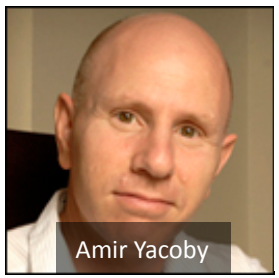
Diamond Nitrogen-Vacancy Centers

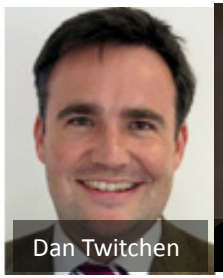

Evelyn Hu


Mikhail Lukin


S Richardson


Gary Harris


Amir Yacoby


Dan Twitchen

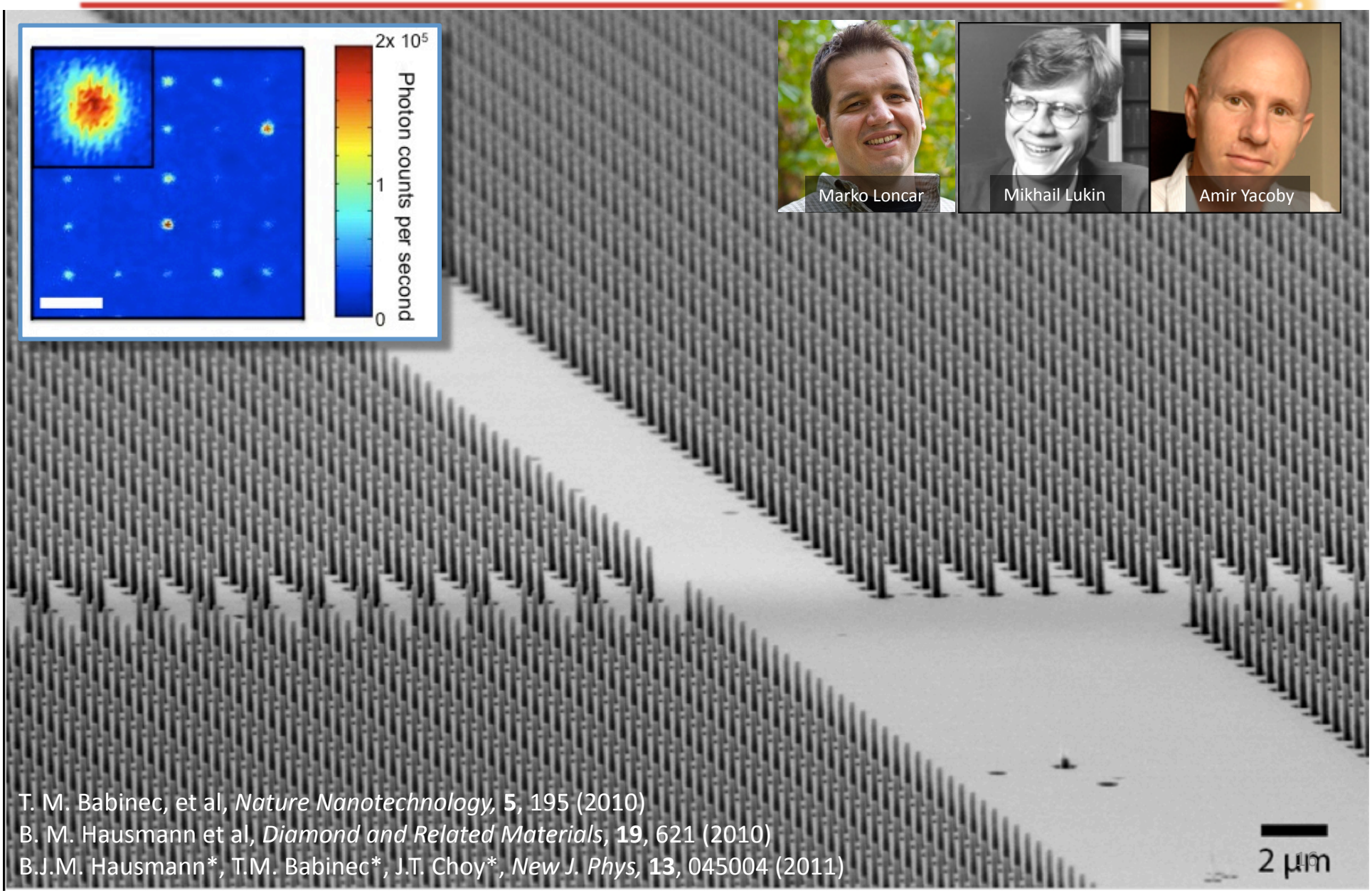

Alan Asparu Guzik


Marko Loncar

Its color centers make diamond excellent

Quantum Material

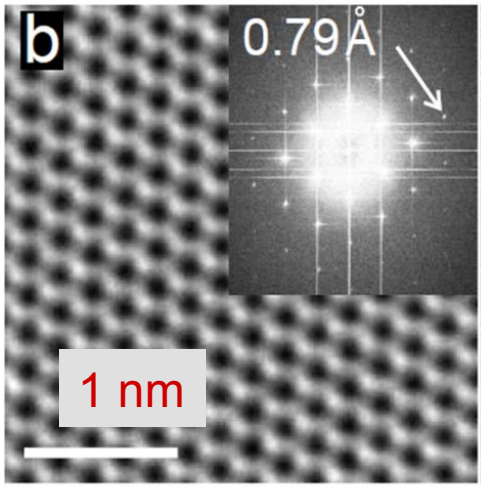
Diamond Nanowire Single Photon Source:

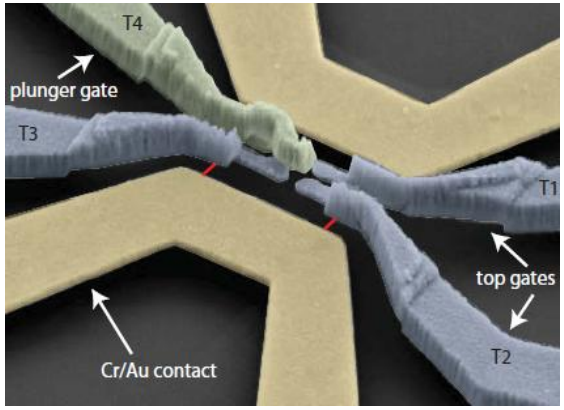


T. M. Babinec, et al, *Nature Nanotechnology,* **5**, 195 (2010)
B. M. Hausmann et al, *Diamond and Related Materials*, **19**, 621 (2010)
B.J.M. Hausmann*, T.M. Babinec*, J.T. Choy*, *New J. Phys,* **13**, 045004 (2011)

Wrap Up

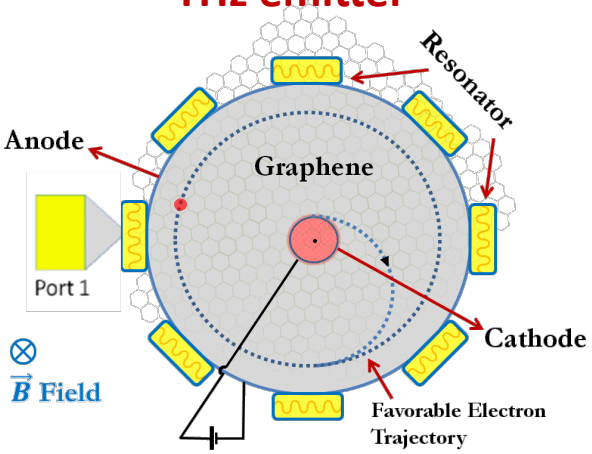
Graphene & Atomic Layer Materials

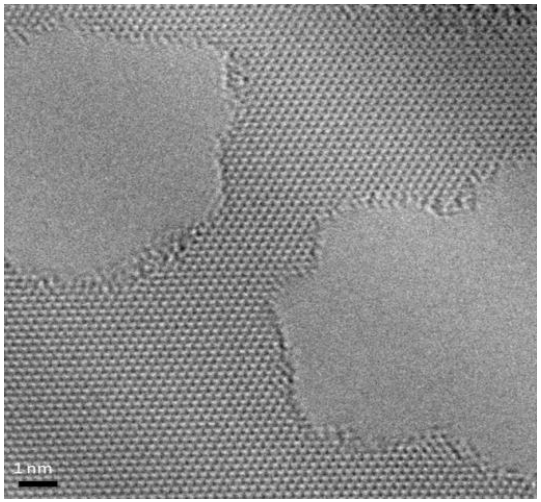


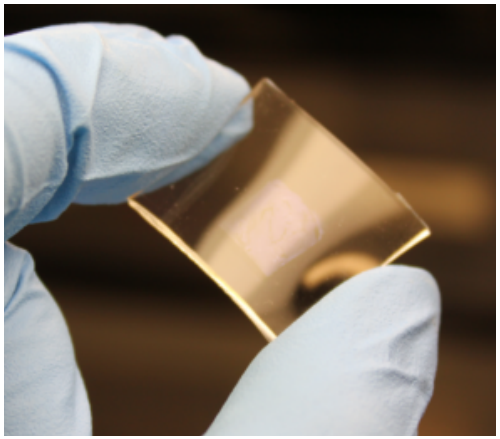


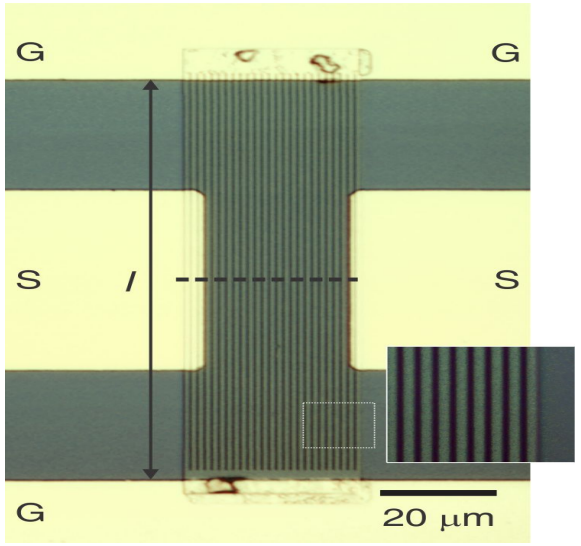
Quantum Confinement

THz emitter



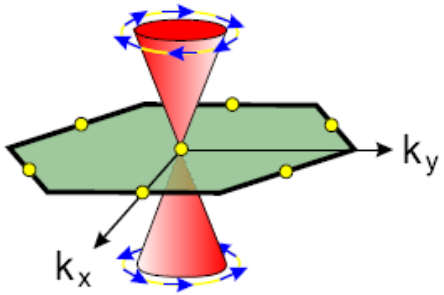




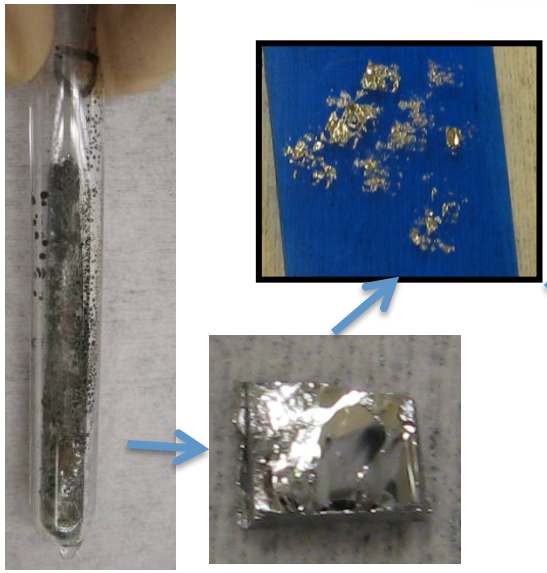


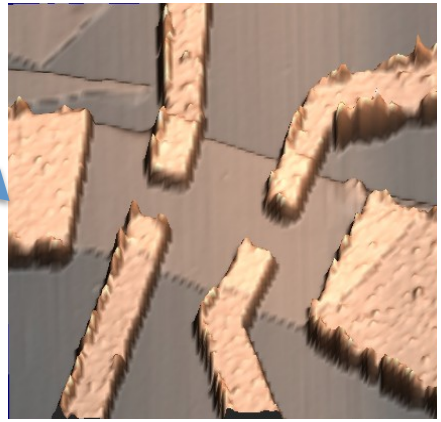
Graphene plasmonics

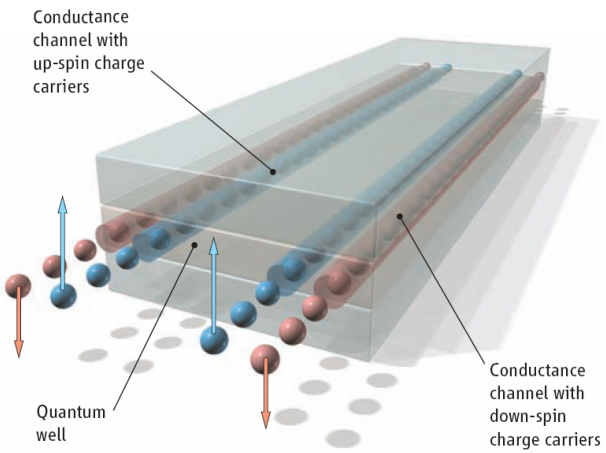
Topological Insulators



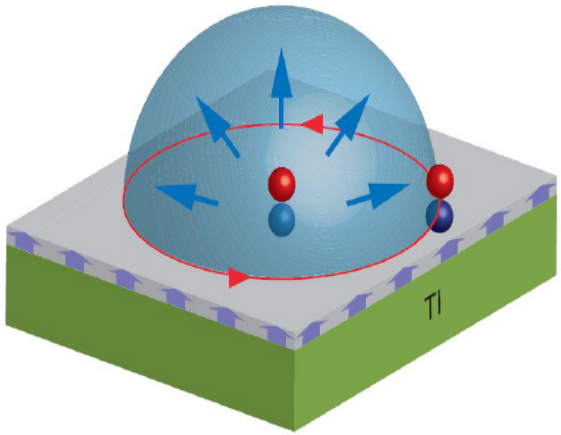
TI crystal growth





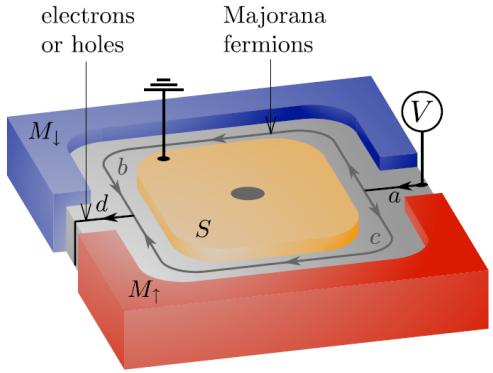


Create magnetic monopole!

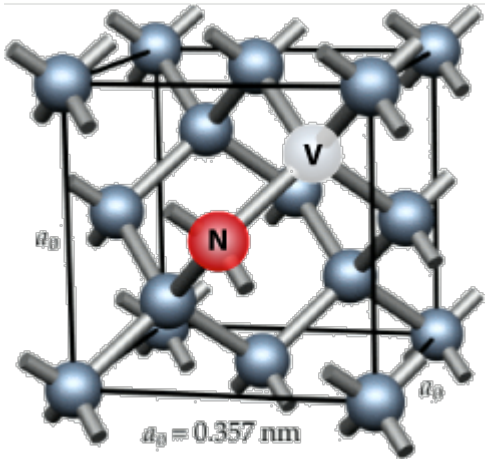


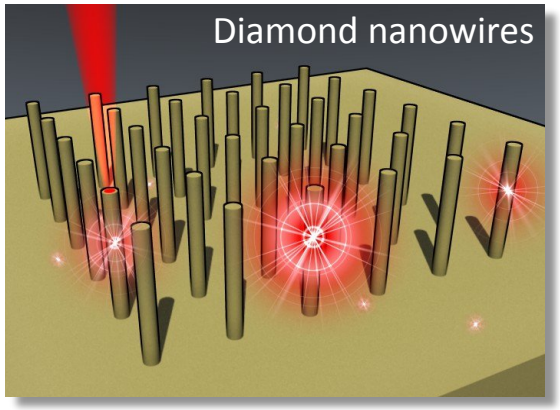
Qi et al, Science 323, 1184 (2009)

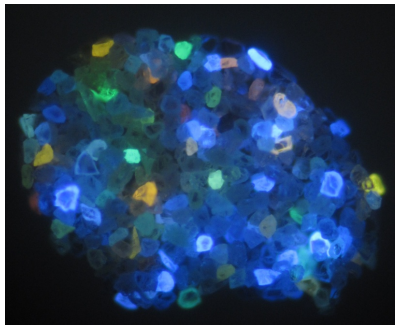
Majorana fermions
Topological quantum computing

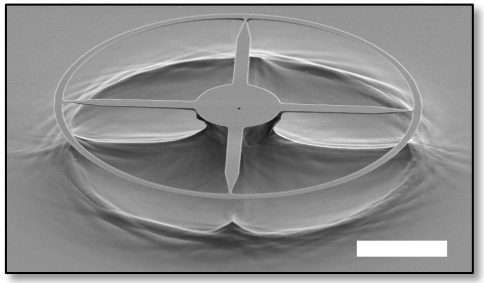


NV Centers in Diamond

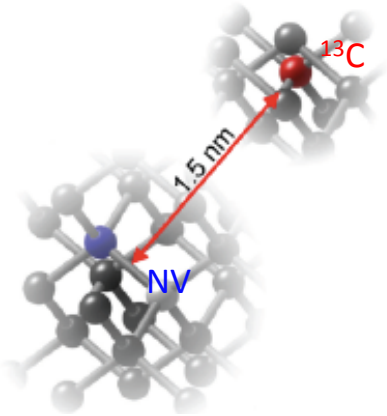








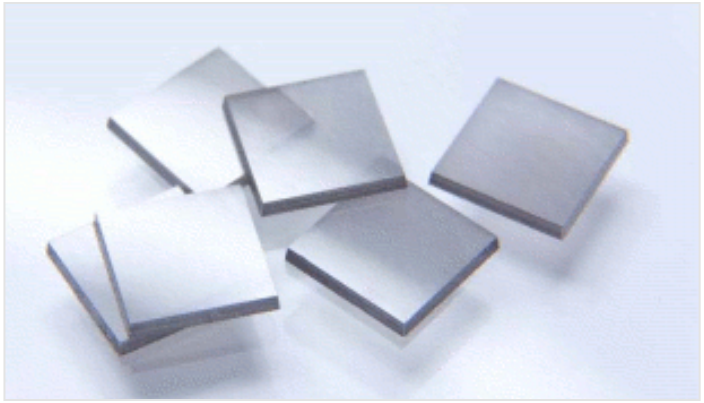
NV diamond magnetic imager

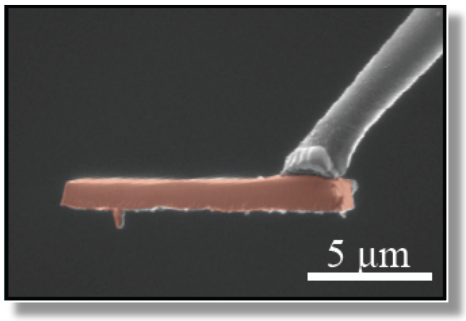


1 bit on 1 spin at RT

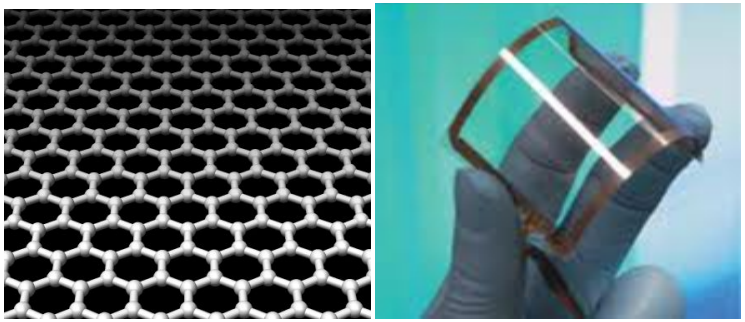
single crystal diamond growth

elementsix

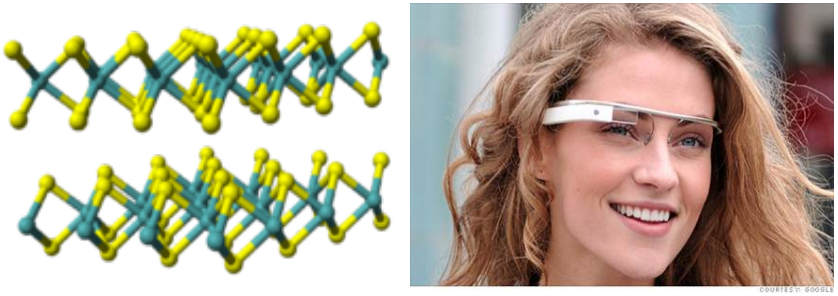




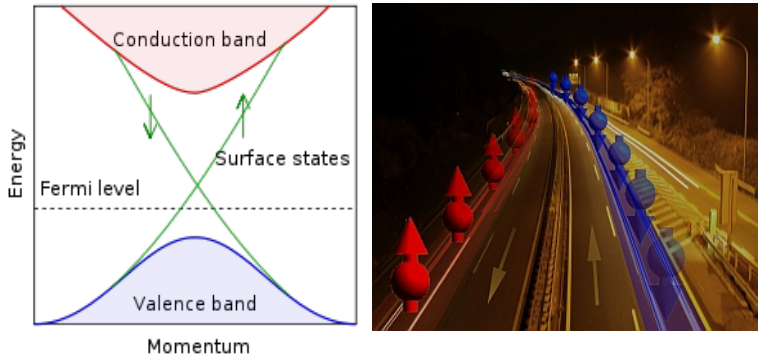
Low Dimensional Materials for 21st Century



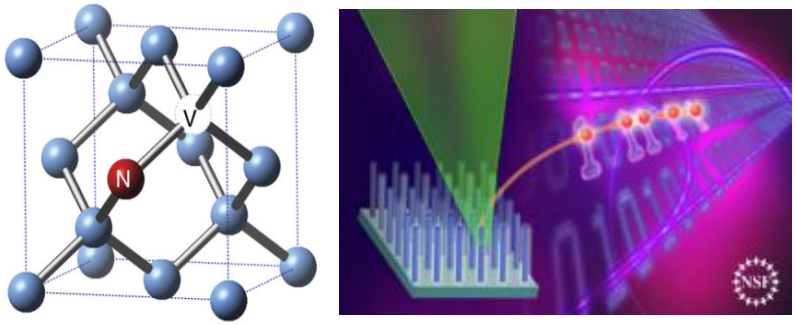
Graphene: High mobility, transparent
Flexible Displays, RFID Tags



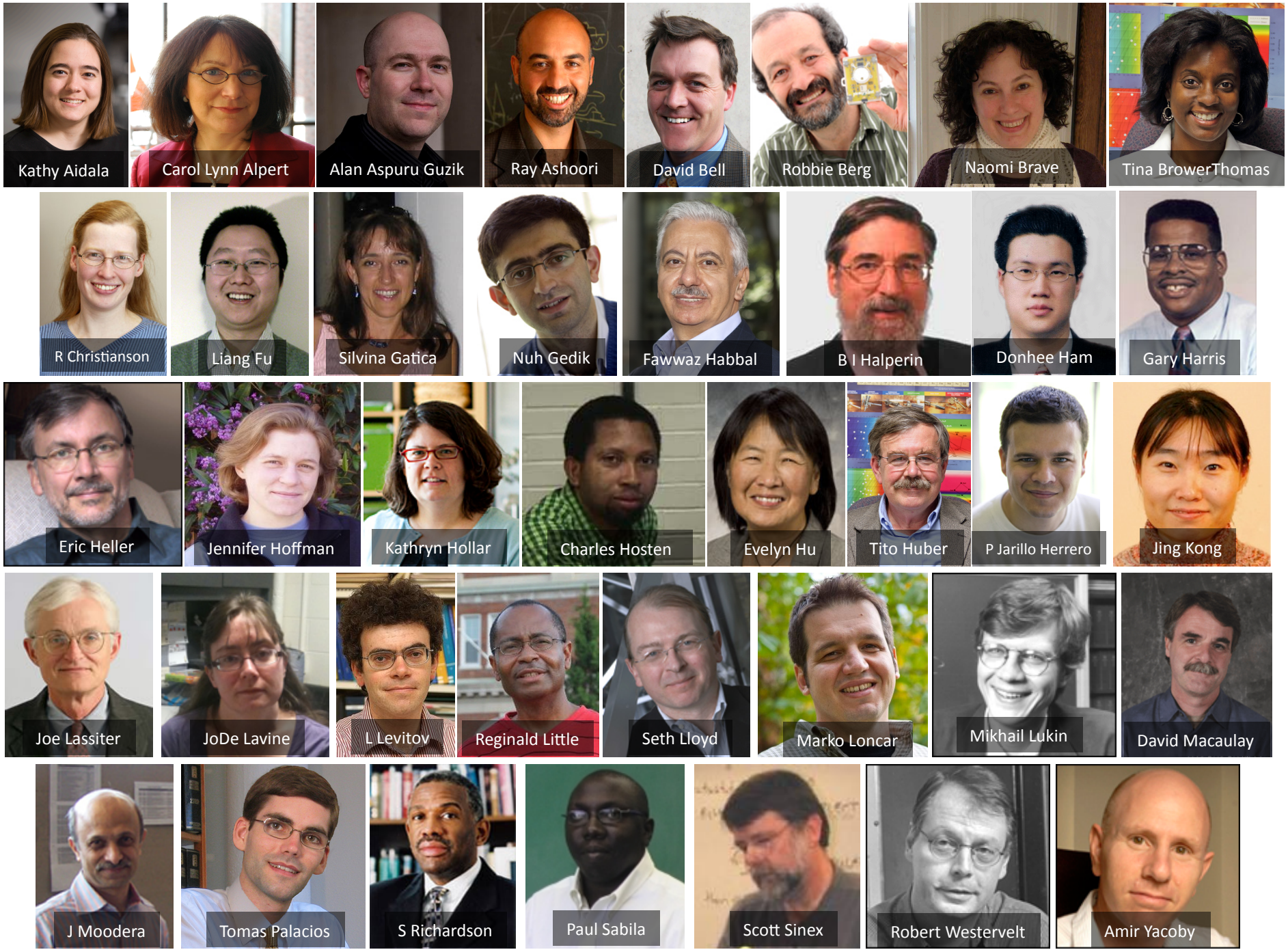
MoS_2 family: Thinnest semiconductors
Ultra-Low-power Flexible (Opto-Electronics)



Topological Insulators: Protected metallic surface state.
Manipulate the spin, no heat generation in the device



Nitrogen-vacancy Diamond:
Transduction and Spintronics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