



Harvard University: *Center for Nanoscale Systems*

NSF NNCI Annual Meeting

Fall 2018

Outline

- ✓ Node Overview (FY2018)
- ✓ Key New Staff/Tools/Instrumentation
- ✓ User Data
- ✓ Research Focus Areas
- ✓ Impact
- ✓ Education and Outreach
- ✓ Key Initiative: *Technological Sustainability*
- ✓ NNCI Cooperative Activities
- ✓ *Panel Charge Slide*

Epicenter for Interdisciplinary Nanoscience Research at Harvard: LABORATORY FOR INTEGRATED SCIENCE AND ENGINEERING (LISE)

CNS Activities: Overview 2018

- CNS serves as a one-stop shop for all things “Nano/Quantum”
- CNS serves as a important regional, nanoscience community resource.
- CNS serves to support the primary innovation thrusts within the Harvard research community and beyond.
- CNS are initiating new training and educational programs to engage larger numbers of undergraduates, non-traditional, and underserved external users, in nanofabrication, advanced characterization and advanced imaging techniques. New efforts in Quantum Material Science and Quantum Engineering.
- CNS is developing a number of new experimental platforms expanding our experimental capabilities; particularly to study Quantum systems (example, LT Scanning probe Microscopy/Spectroscopy and Low Energy Electron Microscopy (LEEM) platforms.)
- CNS now offering additional support for new Start-up companies and is establishing alliances with local incubators technology.



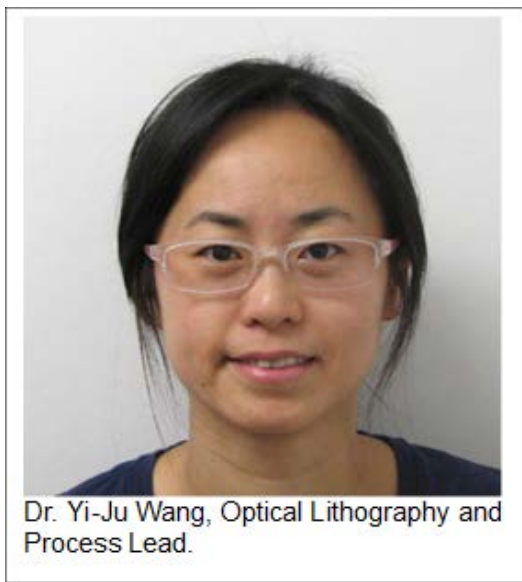
Robert Westervelt
Director



William L. Wilson
Executive Director

CNS Site overview

New Staff*



*This year we are supporting 3 REV Academic Year Interns

New tools:

- Wire bonder
- Oxford ICP- RIE
- PVD System
- Fusion Splicer

Driving renewal of workhorse tools

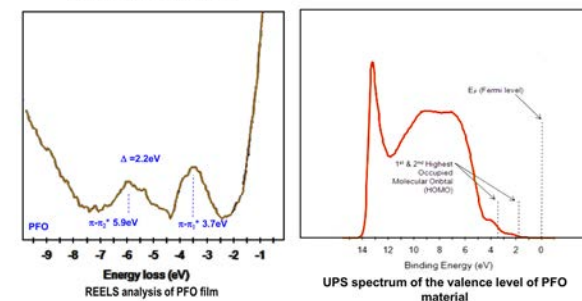
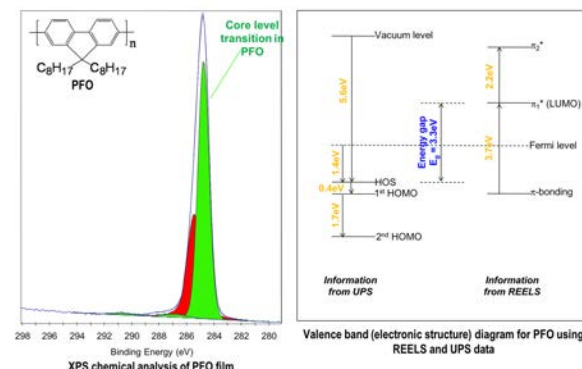


Oxford ICP-RIE

New Instruments:

- Thermo Electron NEXSA XPS/UPS
- Nicolet IS50 FTIR
- JEOL Analytical SEM

Exploring "greenfield" upgrade of SEM instrumentation



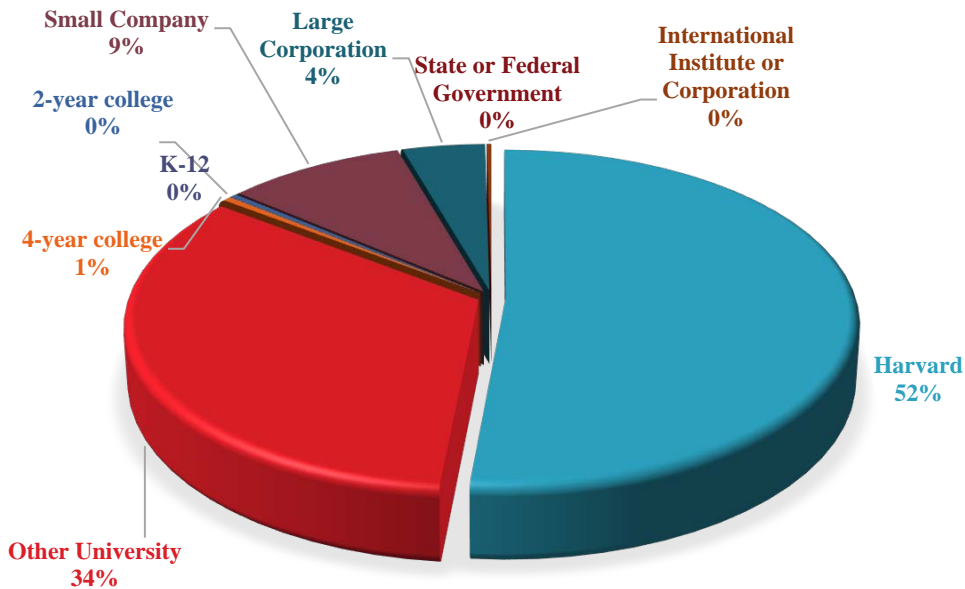
Harvard CNS User Data

| Yearly User Data Comparison | | | |
|-----------------------------------|--------------|--------------|-----------------------|
| | Year 1* | Year 2* | Year 3* (6 months) |
| Total Users | 1246 | 1357 | 944 |
| Internal Users | 673 | 697 | 538 |
| External Users | 573 (46%) | 660 (49%) | 406 (43%) |
| External Academic | 0 | 489 | 285 |
| External Industry | 0 | 170 | 120 |
| External Government | 0 | 0 | 0 |
| External Foreign | 0 | 1 | 1 |
| Total Hours | 174,710 | 183,117 | 87,003 |
| Internal Hours | 124,256 | 127,323 | 63,021 |
| External Hours | 50,454 (29%) | 55,794 (30%) | 28,982 (28%) |
| Average Monthly Users | 511 | 526 | 518 |
| Average Ext. Monthly Users | 201 (39%) | 204 (39%) | 195 (38%) |
| New Users | 415 | 429 | 203 |
| New External Users | 199 (48%) | 207 (48%) | 96 (47%) |

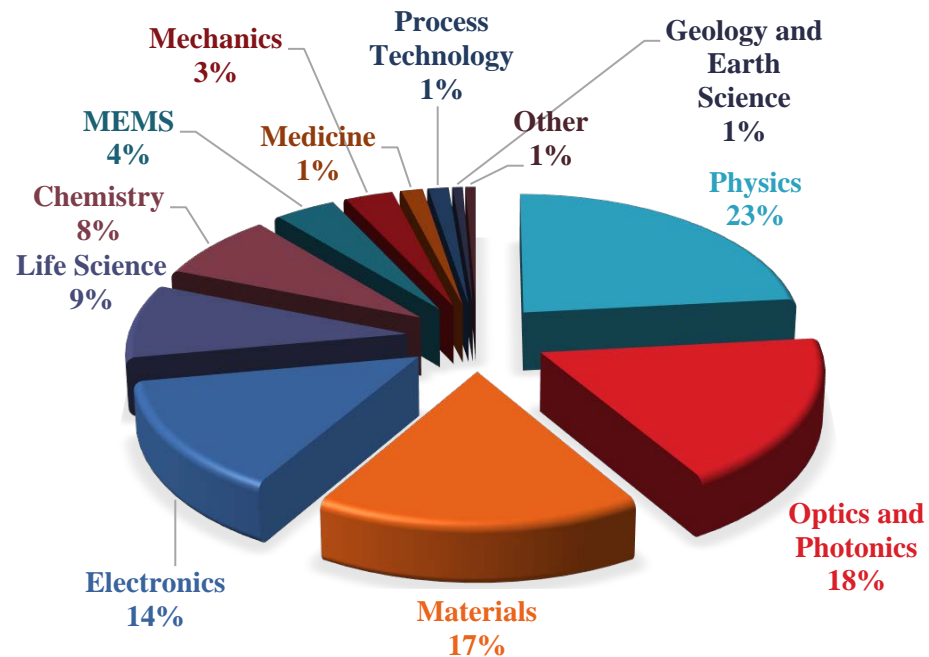
CNS has an annual Spring re-enrollment process (3/2018); Cumulative total is often not maximum active at the end of the grant year.

Harvard CNS User Data

Internal/External User Affiliations



All User Disciplines



CNS RESEARCH FOCUS AREAS

QUANTUM SCIENCE & ENGINEERING:

QUANTUM OPTICS; QUANTUM SPIN SYSTEMS, QUANTUM
INFORMATION SYSTEMS AND DEVICES

NANOOPTICS, NANOPHOTONIC DEVICES, NANOSPECTROSCOPY

QUANTITATIVE BIOLOGY:

NANOMECHANICS; NANOSCALE STRUCTURAL ANALYSIS

BIOENGINEERING (*TRANSLATIONAL BIOSCIENCE*):

ADVANCED IMAGING (CRYOEM)

CNS CORE FOCUS AREAS

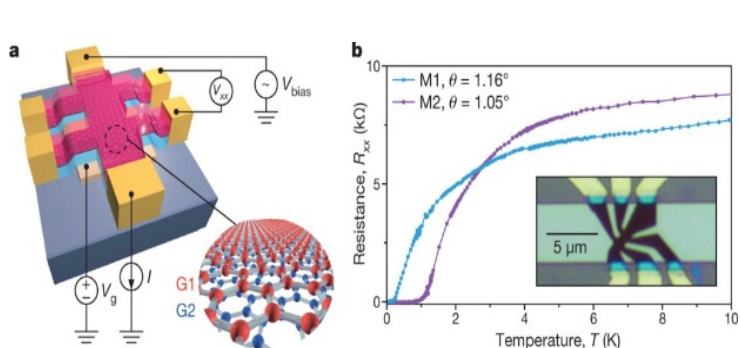
QUANTUM SCIENCE & ENGINEERING:

QUANTUM INFORMATION SCIENCE; QUANTUM MATERIAL SYSTEMS; ENGINEERED CONDENSED MATTER PHYSICS:

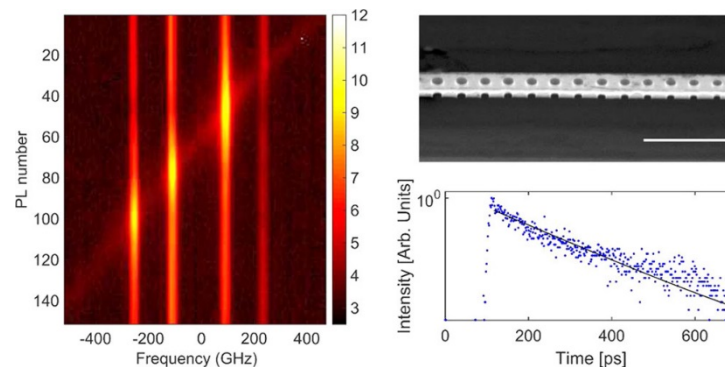
SUPPORTED WORK INCLUDES: *(in all work, CNS is enabling; training all researchers in tool and instrumentation use and often*

helping/supporting experimental design. CNS has strong synergy with the Center for Integrated Quantum Materials)

- STRAIN ENGINEERING IN NV-CENTER DIAMOND / NV-CENTER QUANTUM EMITTERS
- TOPOLOGICAL INSULATORS; 2D MATERIALS AND DEVICES
- UNCONVENTIONAL SUPERCONDUCTIVITY IN MAGIC-ANGLE GRAPHENE SUPERLATTICES



Bilayer Graphene Superlattice R vs T behavior;
Jarillo-Herrero et al, Nature V556, 43-50 (2018)



High-Q nanobeam photonic crystal cavity from
Loncar et al, Nano Letters, V18 (2) 1360 (2018)

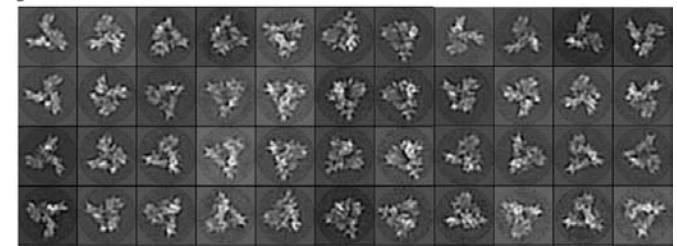
CNS CORE FOCUS AREAS

BIOENGINEERING (TRANSLATIONAL BIOSCIENCE):

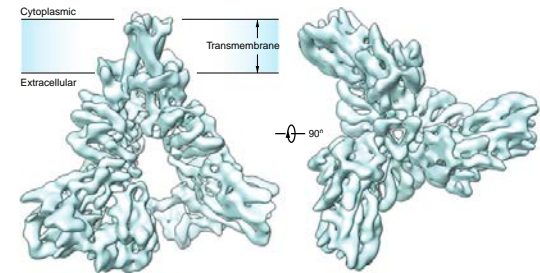
SUPPORTED WORK INCLUDES:

- MICROELECTRODES FOR SPATIALLY OVERSAMPLES NEURAL RECORDING
- CRYO-TEM OF INFLAMMOSOME
- STRUCTURAL ANALYSIS OF THE HIV TRIMER

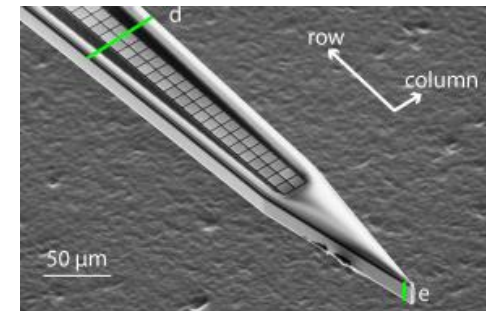
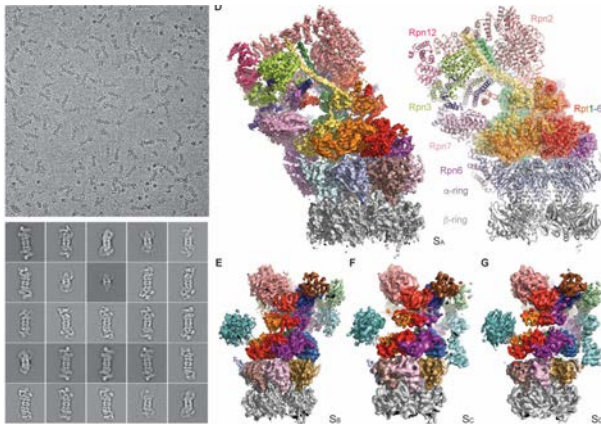
- ✓ CNS INSTRUMENTATION USED FOR ALL IMAGING AND SAMPLE PREP
- ✓ CNS STAFF CO-DEVELOPED AND ASSISTED PROCESSES/METHODS USED
- ✓ CNS FULLY TRAINS USERS FOR CRYO WORK



Structural analysis of HIV Trimer; Y. Mao et al., PNAS, 110 (2017) 12438



Structural analysis of human 26S proteasome; Wu et al., Proc. Natl. Acad. Sci. U S A 2016, 113, 12991-12996



Microelectrode for Neural Sampling; Boyden et. Al., IEEE TBME (2016), 10.1109/TBME.2015.2406113

During last year (Calendar 2017) 135 publications by CNS users
57 Conference Proceedings, 13 reported Patents



CNS Education Outreach Activities

REU program : Note: project offerings from entire userbase, both internal and external (*all participated in NNCI Convocation*);



Research Experience Veterans – *staff serves as mentors*
(*some interns carried through school year, all participated in NNCI Convocation*)

***REV activity has been Bunker Hill CC based** – Advanced training for returning Vets; research opportunities with Harvard Faculty (summer experiences identical to REU participants)



***CNS offers Summer Research Training and Program support for CIQM and other NSF funded efforts** – Advanced research opportunities for Ugrads from external, 2 and 4yr institutions; several summer students from Europe/ Costa Rica.

CNS: Impact on the Academic Mission and WorkForce Development

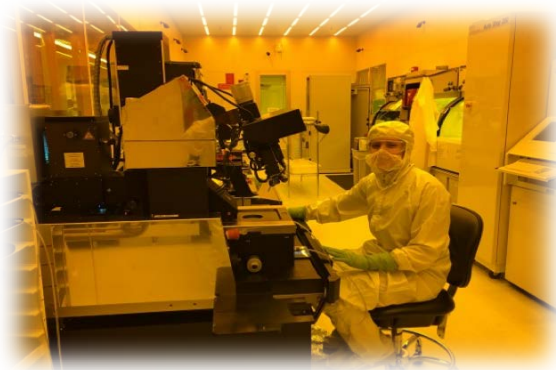
(training is an expanding part of our academic mission and a national priority)



Sarah McDonald and her mentor Daryl Vulis are fabricating zero-index metamaterials using RIE.



Mike Hoefft and Dr. Andrew Gross are crafting 3D nanostructures using NanoScribe



Isabel Castillo is doing photolithography for fabricating microfluidics devices.



CNS staff heavily engaged with students

CNS Start-up Community Outreach

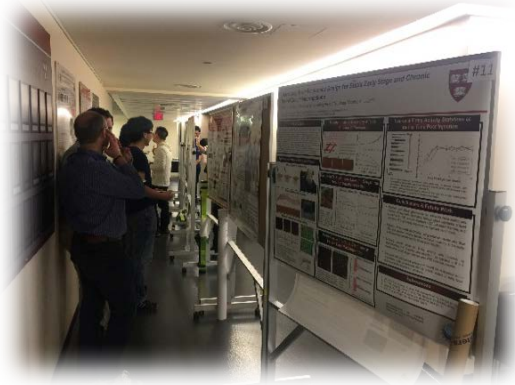


"Visiting local incubators developing relationships"

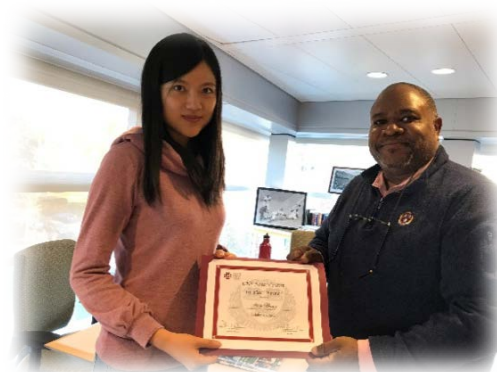


CNS "Start-up Boot Camp" planned for Spring 2019

Annual CNS Open House and Poster Session



Best Poster winners:
Anqi Zhang - Lieber
Srujan Meesala - Loncar



Renewed Focus on Technological Sustainability:

Problem: *Turnover of Workhorse Equipment*
Exploring ALL possibilities

Leasing for Sustainability:
Cleanroom Hitachi SEM
Hyperspectral Raman
Laser Cutter
Fab tools - (PECVD / RIE)
New XPS/UPS

Leveraging Start-up: New High Resolution,
Aberration Corrected Microscope
(PO submitted / room near completion / FY20)

Establishing Vendor Partnerships - Hitachi; Elionix

Proposals:

NIH High-end SIG Micro-CT (waiting)

MRI - LEEM (Bell) - Funded

MRI - LT Scan Probe System (Hoffman) - Funded

DURIP - LT Nanoscale Spectroscopy Platform (Submitted)

NNCI Cooperative Network Activities

Network-Wide

- Participation in subcommittees and working groups, resulting in shared reports and best practices; Key senior staff heavily involved in many technical information sharing efforts, *Imaging, Advanced ALD Processing, Photolithography*
- Attendance at REU convocation and NNCI annual conference

Multi-Site

- User project triage/support and staff technical interactions

On Behalf of the Network

- Hosting International NNCI Workshop on Scanning Probe Spectroscopy/Imaging (Oct. 2018)
- Electron Microscopy Summer School (completed first year)
- Planning “Start-up Boot Camp” this Spring (in planning stages)

NSF Center and other Scientific SYNERGIES

Programs to engage life science users:

Partnership with Catalyst offering instrumentation/ fabrication funding for Translational Bioscience Research using CNS

Partnership with NSF STC: CIQM, offering instrumentation/ complex fabrication expertise.



HARVARD CATALYST
THE HARVARD CLINICAL AND TRANSLATIONAL SCIENCE CENTER

Sponsored by Reactor, a Harvard Catalyst program
Up to \$50,000 in pilot funding

FUNDING OPPORTUNITY

**Big Ideas, Small Features:
Utilizing Advanced Microscopic
and Nanoscale Technologies**

Calling all researchers interested in utilizing state-of-the-art microscopes and/or nanoscale technologies at the Harvard Center for Biological Imaging (HCBI) and the Center for Nanoscale Systems (CNS) to innovate clinical healthcare.

TO LEARN MORE & APPLY

You *must* attend an educational event:
April 4 or April 11
2:30pm-5:30pm | Biological Laboratories, Cambridge

For more information & to register for an event:
bit.ly/hcmicronano

Established in 2009, Harvard Catalyst | The Harvard Clinical and Translational Science Center is dedicated to improving human health by enabling collaboration and providing tools, training, and mentorship to clinical and translational investigators. As a state enterprise of the University of Harvard, Catalyst is funded by the MIT, Harvard University, and the affiliated healthcare centers. Resources are freely available to all Harvard faculty and fellows, regardless of institutional affiliation or academic degree.

CNS RESEARCH FOCUS GROWTH AREAS

FUTURE RESEARCH DIRECTIONS

QUANTUM SCIENCE & ENGINEERING:

QUANTUM MATERIALS; QUANTUM SPIN SYSTEMS/DEVICES,

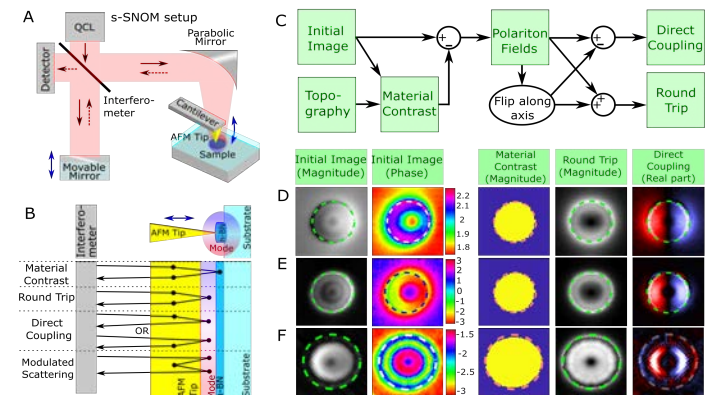
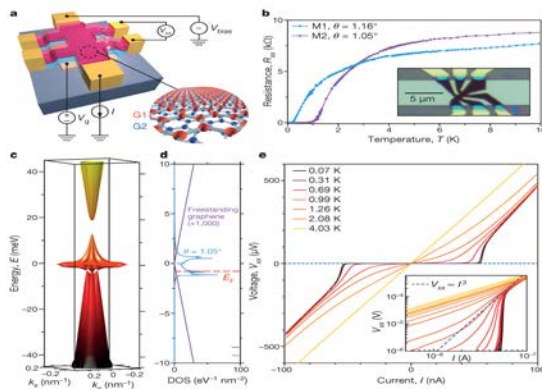
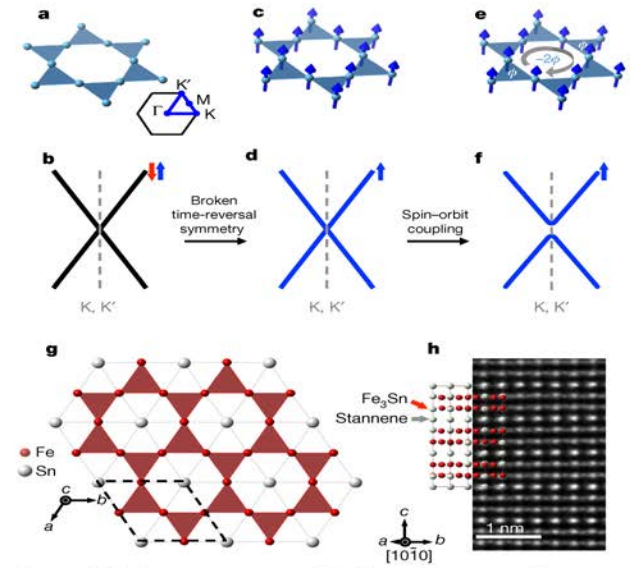
QUANTUM INFORMATION SCIENCE AND DEVICES

QUANTUM SENSING

QUANTITATIVE BIOLOGY:

NANOMECHANICS; NANOSCALE STRUCTURAL ANALYSIS

BIOENGINEERING (TRANSLATIONAL BIOSCIENCE):





Thank you!
Questions?

