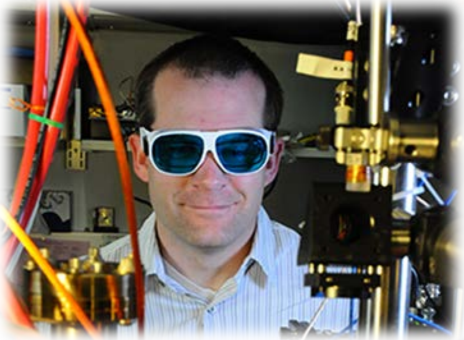
Partnership Models:
JILA
&
Joint Quantum Institute (JQI)



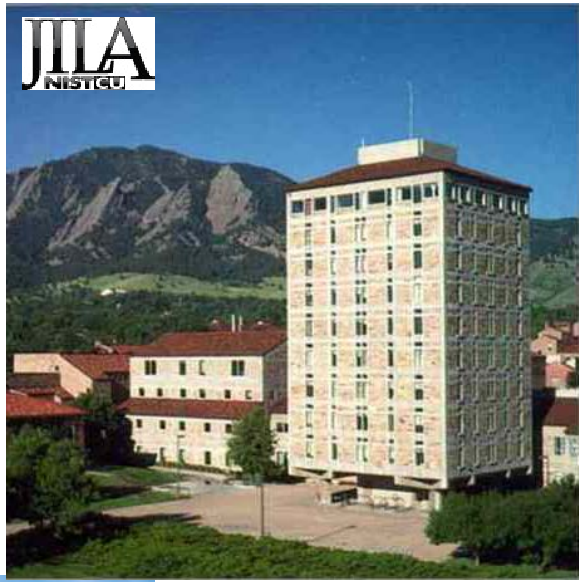
Dr. James K. Olthoff
PML Director

October 7, 2015

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

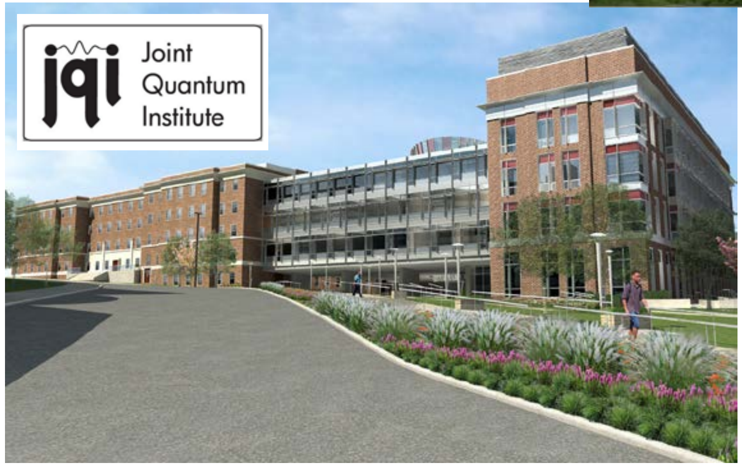
PML
Physical Measurement Laboratory

PML: Two (Three?) Collaborative Institutes



Outline

- JILA
- Joint Quantum Institute (JQI) / Joint Center for Quantum Information in Computer Science (QuICS)
- Benefits
- “Secrets of success”
- Future



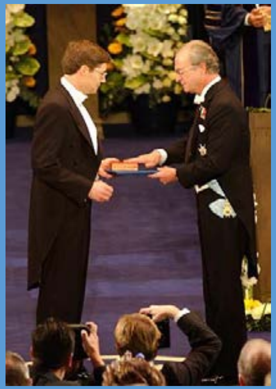
JILA

Among the 25 JILA Fellows are:

- 3 Physics Nobel Laureates
- 3 MacArthur Foundation Fellows (“Genius grant” winners)
- 8 members of the National Academy of Sciences
- 5 members of the Academy of Arts and Sciences

JILA Scientist receiving Nobel Prizes from King Carl XVI Gustaf of Sweden

2001 Cornell

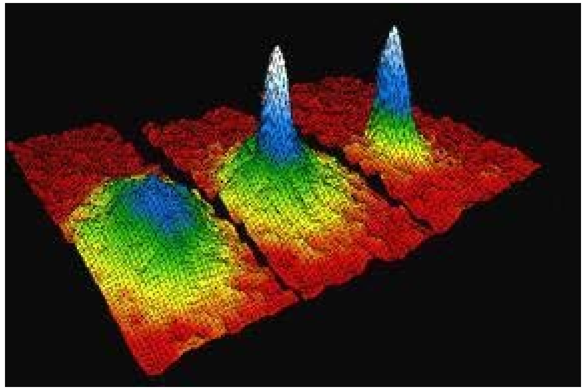


2001 Wieman

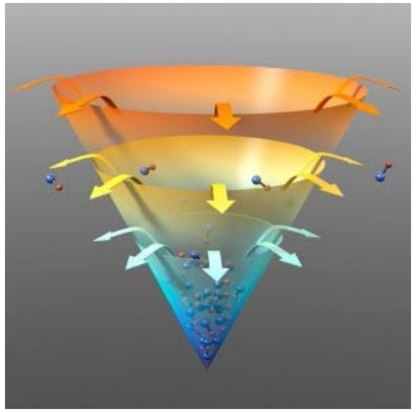
2005 Hall

World-First breakthroughs in AMO physics:

- First Bose-Einstein Condensate
- First Fermi condensate
- First self-referenced laser frequency comb
- First evaporative cooling of molecules
- First quantum degenerate gas of polar molecules
- First cooling to the quantum ground state of a macroscopic object



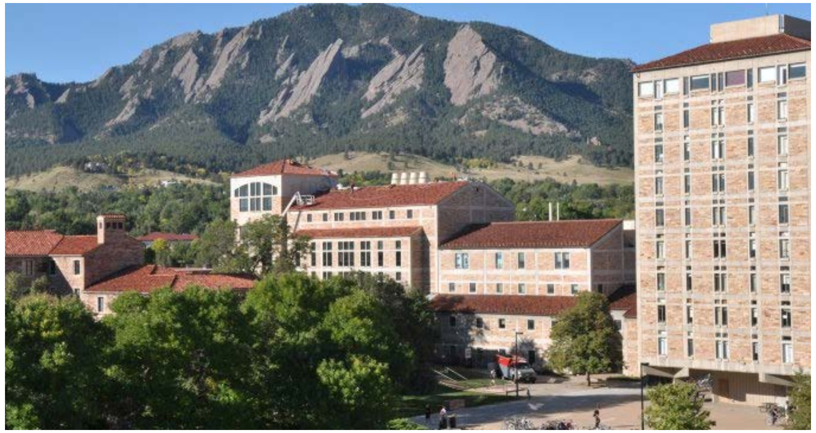
First quantum degenerate gas (BEC) Eric Cornell and Carl Wieman



First evaporative cooling of molecules (OH), Jun Ye

JILA: Facts and Figures

- Joint institute of NIST and the University of Colorado (CU)
- First government/university full partnership
- Founded 1962 as the "Joint Institute for Laboratory Astrophysics"
- Name changed to just "JILA" in 1995
- Physically located on CU campus (Boulder)
- 25 JILA Fellows (11 NIST and 14 CU)
  - NIST JILA Fellows hold Adjoint CU faculty appointments
- 250 personnel, including Fellows, Research Associates, graduate and undergraduate students, staff
- Today known as a leading center for
  - Atomic, Molecular, and Optical (AMO) Science
  - Leveraging AMO experience in nanoscience, bioscience, etc.
  - Measurement science



Labs of JILA
Boulder, Colorado

Fellows of JILA from NIST

John Bohn
Theorist: Cold Mole-cules and quantum many-body systems

Eric Cornell
Bose-Einstein condensates; Precision measurement

Ralph Jimenez
Biophysics; Ultrafast lasers; Chemical physics; Microfluidics

Deborah Jin
Fermi degenerate atoms; Cold molecules; Bose-Einstein Conden.

Konrad Lehnert
Quantum nano-mechanics; Microwave quantum optics

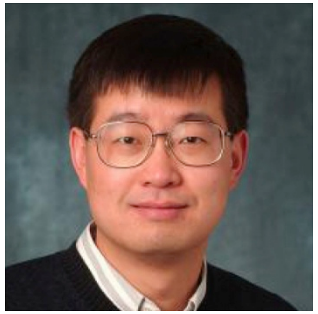
Judah Levine
Distributing precise time and frequency information

David Nesbitt
Chemical physics; Biophysics; Molecular Ions

Thomas Perkins
Biophysics; AFM; Optical tweezers; Single molecule

Ana Maria Rey
Theorist: Cold atoms, molecules; Quantum many-body systems

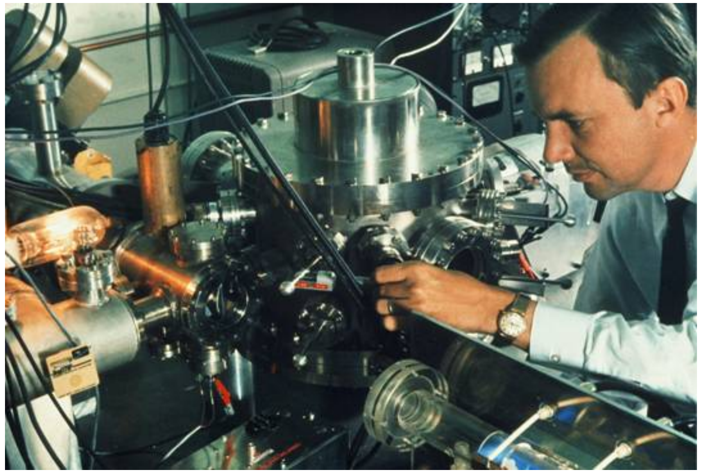
James Thompson
Cold atoms; Quantum optics and Information; Precision measurement



Jun Ye
Cold atoms, molecules; Frequency combs; Ultrastable lasers

JILA: Original Purpose

- In late 1950s, the new emphasis on the space program revived interest in plasma and hence atomic physics
  - Together with aerodynamics and nonequilibrium thermodynamics, these disciplines were combined into what was then loosely called "Laboratory Astrophysics"
- NBS staff Lewis Branscomb (atomic physics), Dick Thomas (aerodynamics), and John Jefferies (non-equilibrium thermodynamics) envisioned an institute to bolster NBS's research activities in Laboratory Astrophysics
- Idea was strongly encouraged by the Space Science Board and the Federal Council for Science and Technology



Lewis Branscomb
First Chairman of JILA (1962–1969)
NBS Director (1969–1972)

JILA: Original Objectives

1. Provide a means of bringing into the laboratory astrophysics program outstanding individuals who could not be hired with normal Civil Service procedures and salary limitations
2. Link the NBS programs to the astronomers and astrophysicists in universities, who were the primary users of the type of data that the NBS program provided
3. Train young scientists in the techniques important for laboratory astrophysics, providing stature for what was then a less fashionable field of physics
4. Pioneer a new approach to university-government cooperation that might establish precedent for additional cooperation in other areas

JILA: Evolution Over Time

1962

- Research in basic atomic physics
  - Emphasis on stationary and interaction properties of atoms and molecules needed for a microscopic description of a gaseous ensemble
- Research on cooperative behavior of gaseous ensembles
  - For example: plasma physics, aerodynamic problems involving excitation of internal degrees of freedom of a gas and subsequent radiation, atomic-resonance phenomena such as lasers and optical pumping
- Research in those areas of stellar astrophysics applying the above

Source: Physics Today*, Nov. 1962, pp. 42–46*

2015

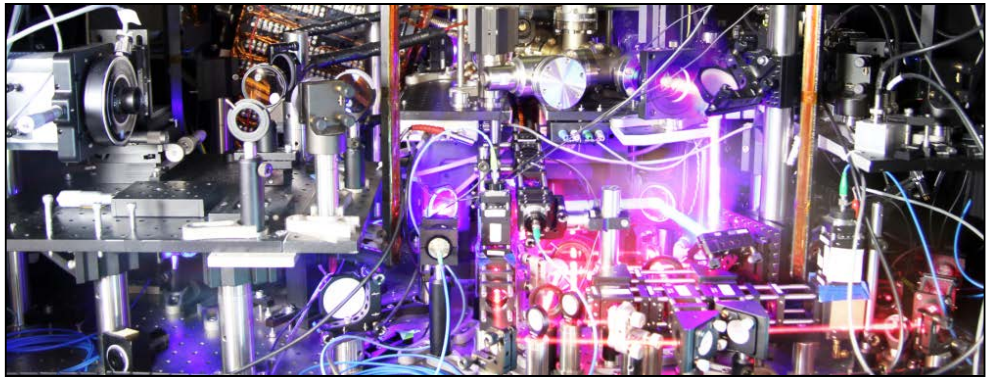
- Lasers as measurement tools
- Chemical kinetics
  - Quantum chemistry
- New frequency standards
  - Extending freq. comb spectrum
- Measurement science at the nanoscale
- Quantum degenerate gases
  - Bose-Einstein Condensation
  - Fermi gases
- Ultrafast science
- Biophysics

JILA's "Biggest Impact": Highly Trained Innovators

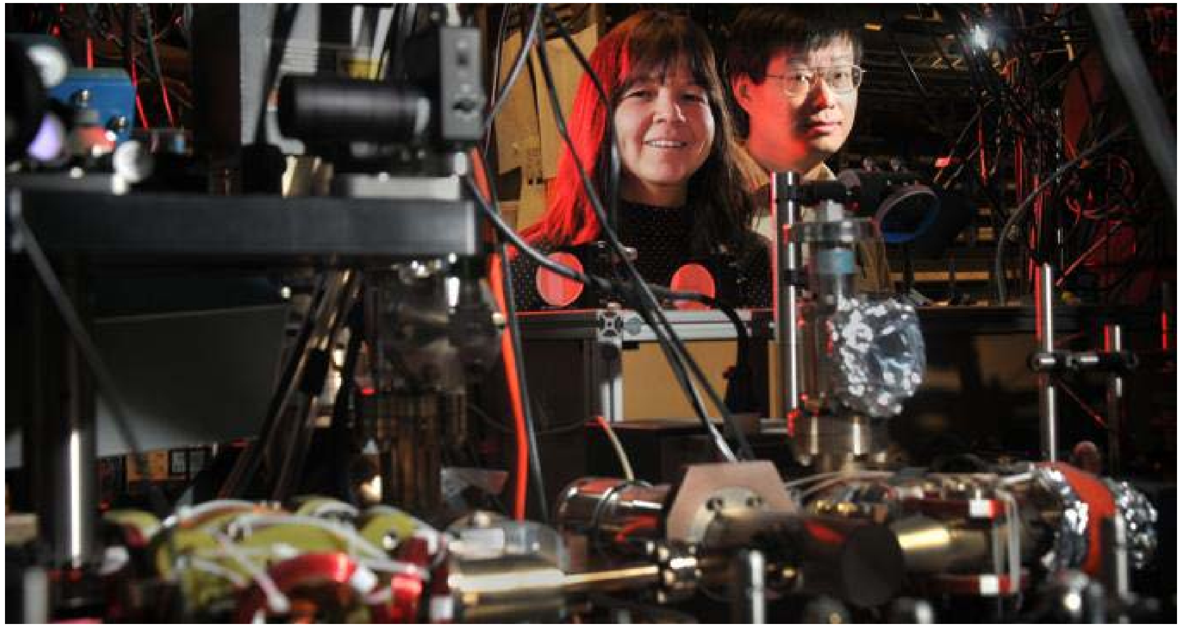
Over 400 JILA "graduates" have taken positions within NIST

Recent JILA Accomplishments

- Strontium optical lattice clock, world's best atomic clock
  - 2×10^{-18} accuracy and rapidly improving
  - 100x improvement over 5 years

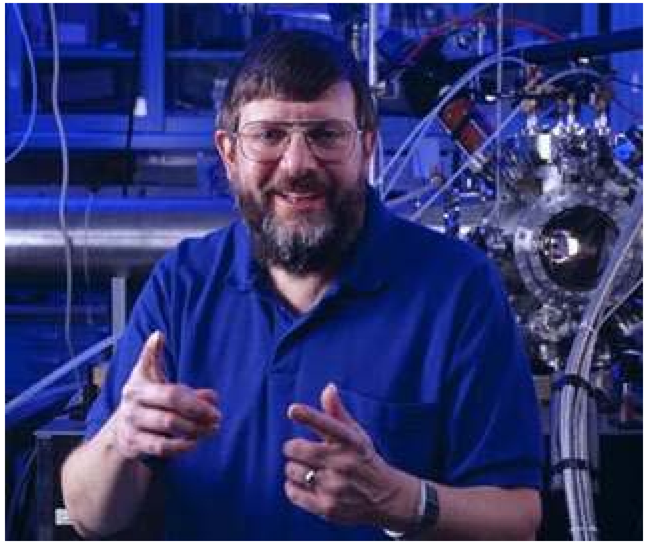


- Ultracold molecules and ultracold chemistry



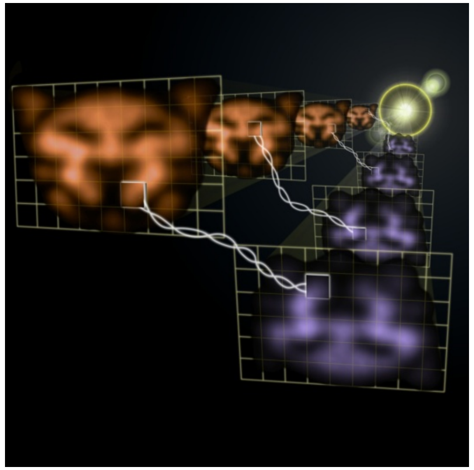
Debbie Jin and Jun Ye

JQI



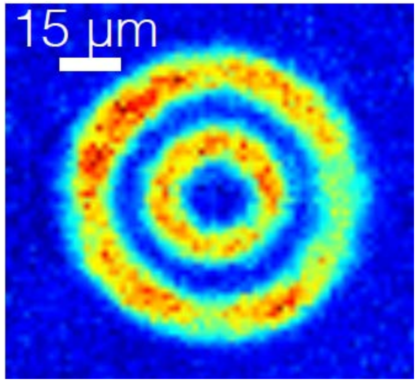
Among the 24 JQI Fellows are:

- 3 of the 38 2015 APS award recipients
  - Competed among hundreds of U.S. physics institutions!
- 1 Physics Nobel Laureate
- 1 recipient and 2 finalists: Service to America “Call to Service”
- 8 Arthur S. Flemming award winners



World’s largest institute in quantum coherent phenomena & quantum information science

- World’s first quantum simulation
- World’s first pixel-by-pixel entangled images
- World’s first controllable “atomtronic” circuit, where atoms flow like electrons through wires of light
- Laid the theoretical foundation for interactions between cold atoms



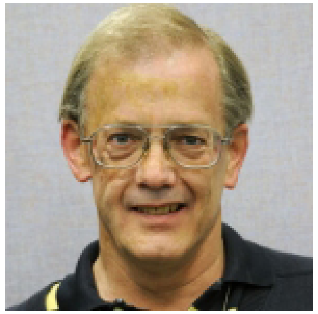
JQI: Facts and Figures

- Joint institute of NIST and the University of Maryland (UMD)
- Modeled in part on JILA
- Established 2006
  - After several years of discussion and effort
- Physically located on UMD campus (College Park)
- 31 JQI Fellows (14 NIST, 16 UMD, and 1 LPS)
  - NIST JQI Fellows hold Adjunct UMD faculty appointments
- 180 people, and still growing
- Today known as a leading center for quantum mechanical science, including:
  - Cold quantum matter (AMO Physics)
  - Quantum matter and materials (Condensed Matter Physics)
  - Quantum Information

jqi JOINT QUANTUM INSTITUTE

Labs of the JQI
College Park, Maryland

Fellows of the JQI from NIST

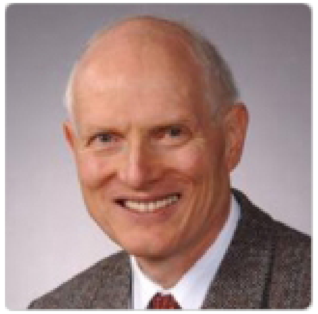


Garnett Bryant
Theoretical condensed matter physics; Nano-structures and devices

Gretchen Campbell
Atom circuits: super-fluidity and analogs to superconductivity

Charles Clark
Atomtronics; Quantum telecommunications; Neutron studies

Alexey Gorshkov
Intersection of AMO and condensed matter physics, and QI science

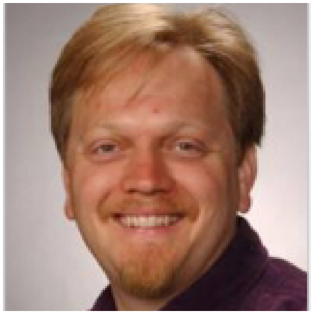


Paul Julienne
Theory of ultracold atomic collisions, scattering resonances

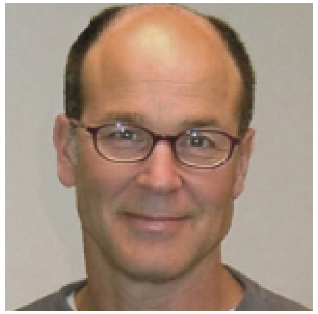
Paul Lett
Laser cooling, trapping; Quantum, non-linear optics, squeezed light

Alan Migdall
Nonlinear optics, correlated photons, single-photon sources

William Phillips
Laser cooling, trapping of neutral atoms; Atomic-gas BEC



Trey Porto
Ultracold atoms in optical lattices; Neutral atom quant. computing



Glenn Solomon
Semiconductor-based materials physics, quantum optics

Ian Spielman
Bose-Hubbard model for ultra-cold rubidium atoms in optical lattice

Jacob Taylor
Fundamental and practical limits to building QI devices

Eite Tiesinga
Interferometry with interacting ultra-cold atomic matter

Carl Williams
Quantum computing with neutral atoms; Ultracold collisions

Joint Center for Quantum Information in Computer Science (QuICS)

- Established 2014
- Physically located on UMD campus (College Park)
- 12 QuICS Fellows (6 NIST, 5 UMD, and 1 NSA)
  - NIST QuICS Fellows hold Adjunct UMD faculty appointments
- 30 people, and still growing
- Goal to become a leading center for quantum information in computer science:
  - How does quantum mechanics inform the theory of computation and communication?
  - What insight does computer science shed on quantum computing?
  - What are the consequences of quantum information theory for fundamental physics?
  - How can theoretical advances in computation and communication be applied?

JOINT CENTER FOR QUANTUM INFORMATION AND COMPUTER SCIENCE

QuICS
College Park, Maryland

Fellows of QuICS from NIST

Alexey Gorshkov (PML)

Interface of AMO (atomic, molecular, optical) physics, condensed matter physics, and quantum information

Stephen Jordan (ITL)

Quantum information, especially algorithms, complexity, and post-quantum cryptography

Yi-Kai Liu (ITL)

Quantum computation, in particular, quantum algorithms and complexity, quantum state tomography and cryptography

Jacob Taylor (PML)

Fundamental and practical limits to building quantum information devices; novel approaches to entangling atomic, photonic, and solid state systems

Eite Tiesinga (PML)

Quantum information theory with ultra-cold-atom and Josephson-junctions; interactions and collisions between ultra-cold atoms and molecules

Carl Williams (PML)

Quantum computing with neutral atoms; quantum computing architectures; ultracold atomic collisions; Bose Hubbard and Fermi Hubbard models

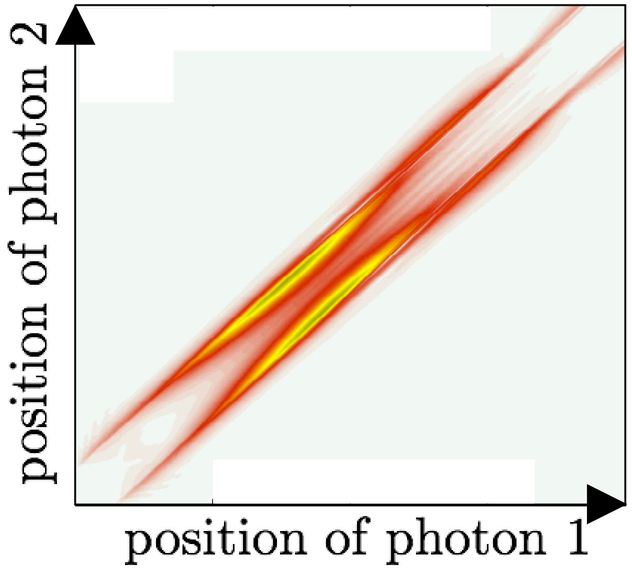
JQI: Objectives

1. Serve as a world-class research institute, conducting fundamental investigations of coherent quantum phenomena and thereby laying the foundation for engineering and controlling complex quantum systems capable of using the coherence and entanglement of quantum mechanics
2. Maintain and enhance the nation's leading role in high technology through a powerful collaboration among NIST, UMD and LPS
3. Provide a unique, interdisciplinary center for the interchange of ideas among atomic physics, condensed matter and quantum information scientists

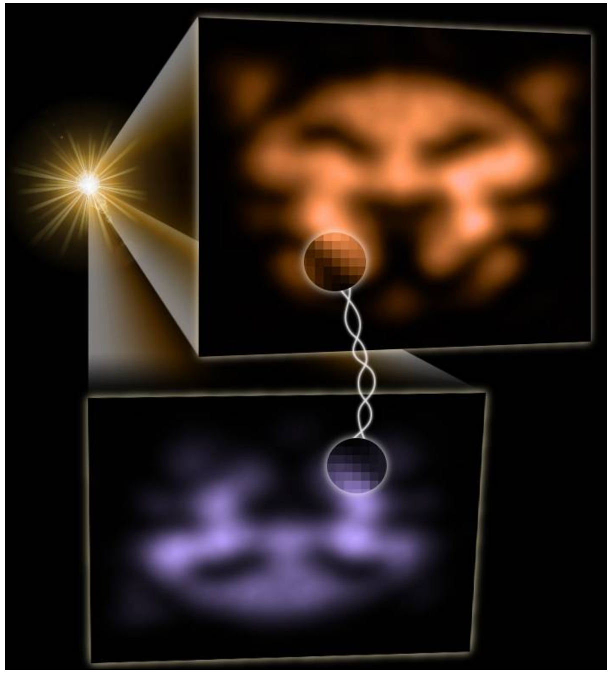
Source: http://jqi.umd.edu/about

Recent JQI Accomplishments

- Theoretical description of "molecule of light"
  - Binding photons a specific distance apart

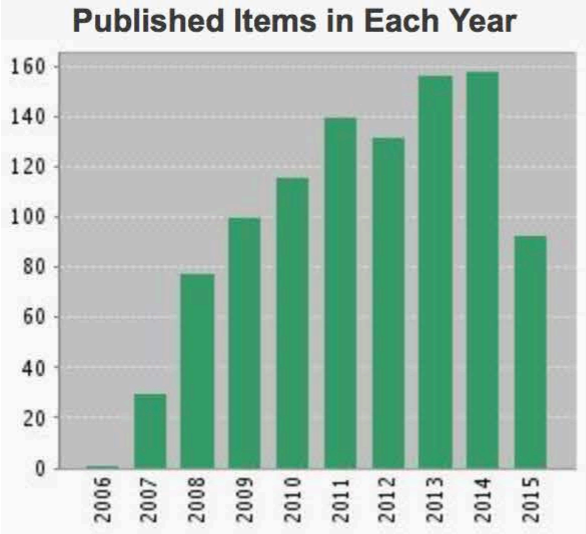


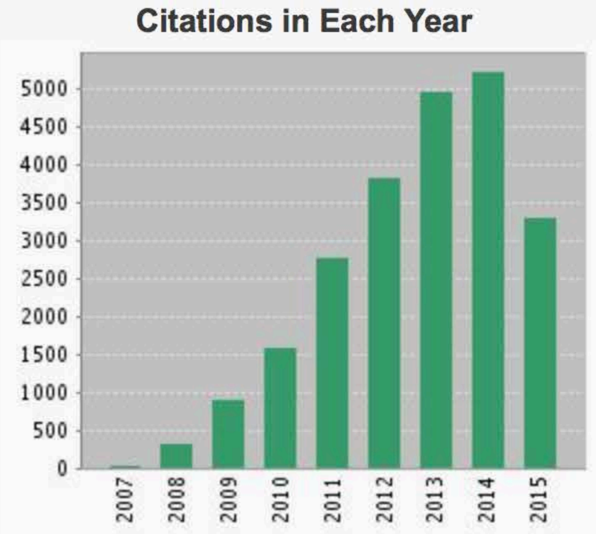
- Quantum correlations of noise in twin images should allow beyond-classical image resolution and quantum memory



Growing Reputation of the JQI

- Currently publishing more than 150 papers per year
- Accruing more than 5,000 citations per year
- Has 43 papers with more than 100 citations





Results found:	1005
Sum of the Times Cited [?] :	23043
Sum of Times Cited without self-citations [?] :	20744
Citing Articles [?] :	13156
Citing Articles without self-citations [?] :	12433
Average Citations per Item [?] :	22.93
h-index [?] :	68

Benefits to NIST

JILA and JQI contribute significantly to NIST and PML's core mission, by:

- Being world-class research institutes for exploiting coherent quantum phenomena and ensuring the benefits of revolutionary new technology for the nation
  - Innovating new, transformational measurement tools and technologies for NIST, industry, Government, and basic research
  - Investigating new ways of precisely directing and controlling light, atoms, and molecules
  - Extending mastery of light and atoms to other fields, such as biophysics and nanoscience
- Providing credibility for our services through the breadth, vigor, and excellence of our research programs
- Providing access to academic-based research environments
- Producing fresh generations of scientists dedicated to precision and novel measurement, at NIST and elsewhere
  - Significantly increases students and post-docs working at NIST

Benefits to the Host Universities

- Extraordinary environments for basic and applied research
  - Innovation engines, jobs and economic impact affecting host regions
- Shared culture of the institute is pre-eminent over disparate, departmental cultures
  - Genuinely empowers interdisciplinary research
- Unique opportunities for students (graduate, undergraduate, and post-doctoral)
  - Focus on national priorities, NIST measurement-science culture/collaborations
- Creates durable, state-of-the-art infrastructure
- Access to long term stable funding
- Ability to attract world-leading faculty

These impacts are integral to NIST's mission, too.

What has contributed to success?

- Strong Joint-Institute-centric culture which demands collaboration and cooperation among Fellows
  - Internal shared governance. Key strategic and operational decisions made by Fellows.
  - Substantial independence from parent organizations (NIST, CU, UMD) in scientific decision-making.
  - Joint Institute internal decisions consistent with broad goals of parent organizations.
- High expectations for research, training, support services
  - JQI associated with 13^{th} top ranked Physics Department in U.S.
  - JILA consistently the #1 ranked AMO program in the U.S.
- Fund for success
  - Strong investment in JILA infrastructure. World-class Instrument shop (JILA), Electronics shop, IT support.
  - High performance administrative support.
  - Limited number of well-supported Fellows.
  - Long-term stable NIST and University investment

Lessons Learned

- Co-location, with differences between government and university staff minimized
  - Unlike a government-funded, university-based center (GOCO)
- Continual evolution in scientific subjects, operations, structure, and culture
  - Latitude for self-determination and self-governance
- Strong commitment to recruiting and retaining the best and brightest people
  - Sharp scientific focus, all contribute to a “critical mass”
  - Requires expected and planned sustainability
- Strong training mission
  - With network of alumni and visitors for continuing partnerships

Challenges

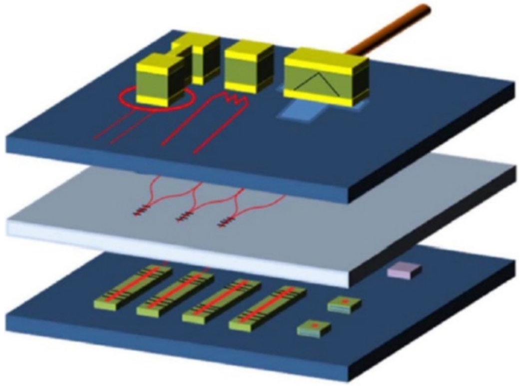
- Intellectual property
  - e.g., University entrepreneurship vs. Government ethics
- Inherent cultural/operational differences between Government and Academia

Opportunities

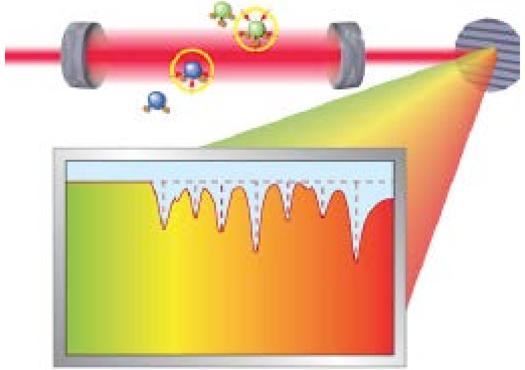
- Pioneer extension of JILA/JQI model to include private industry as a partner
  - Creation of the first, true Government-University-Industry partnership (Leverages NIST's experience with JILA/JQI)
  - Applicable to national priorities that span research to commercialization ("Lab to Market")
  - Increase NIST focus on industry needs and opportunities

Plans for the Future

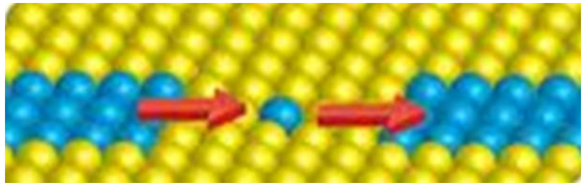
- JILA and JQI are good fits and excellent resources for portions of all five of the PML priority research areas



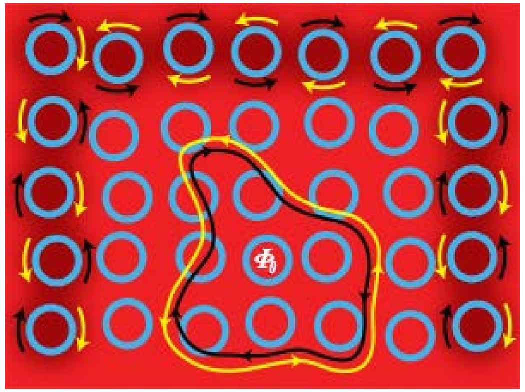
Advanced Measurement Dissemination
Embedded Sensors ("NIST on a Chip")



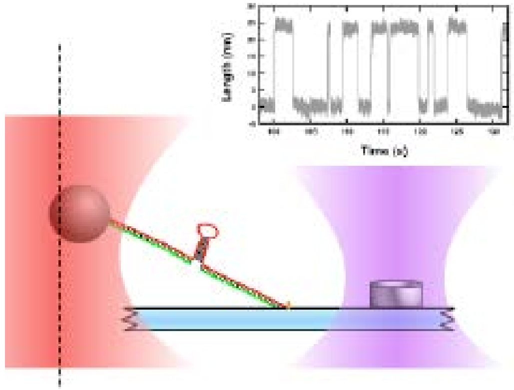
Photonics
Advanced Photonics for Health Care



Future Computing Devices
Atomic Scale Metrology



Quantum Information Science
Complex Quantum Systems



Measurements of Living Systems
Force and Mass Metrology

National Institute of Standards and Technology

U.S. Department of Commerce