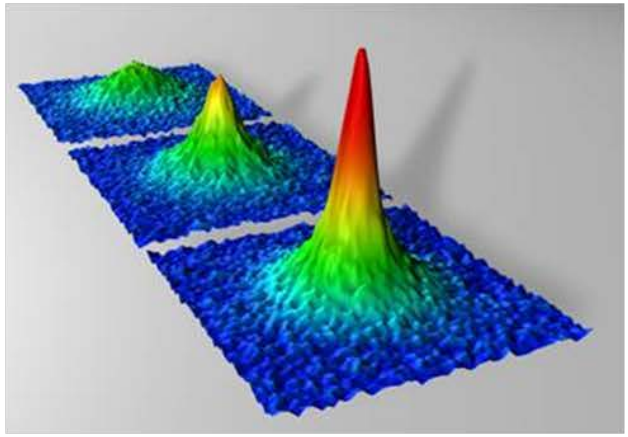
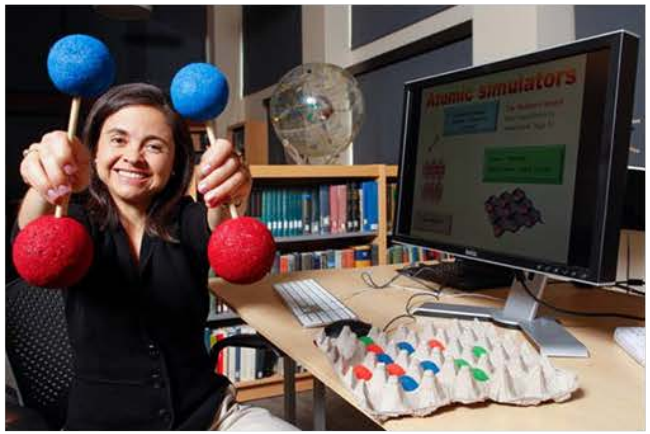
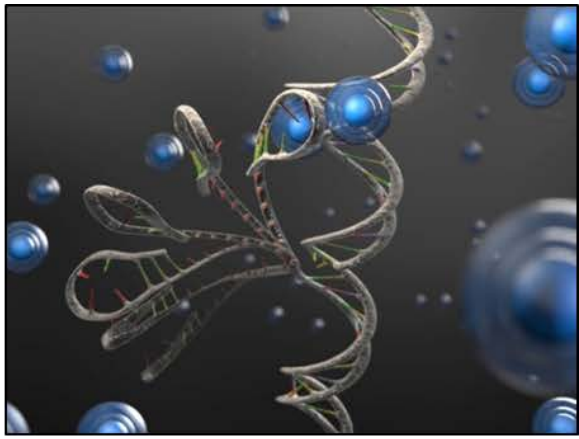


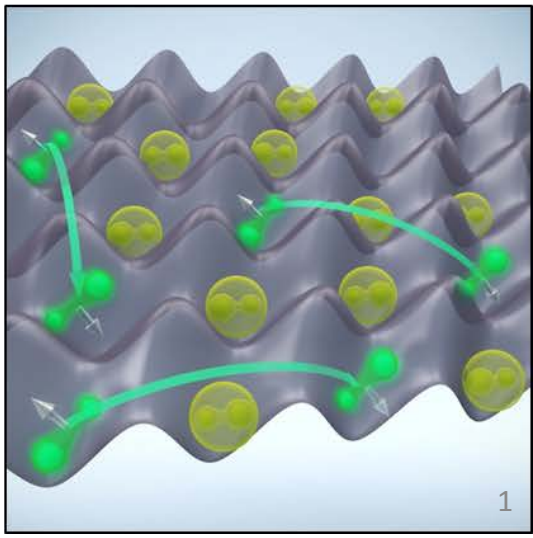




jila.colorado.edu

JILA: NIST/CU Partnership for Research, Innovation and Training

JILA
NIST CU



Assessment of the NIST Quantum Physics Division

THANK YOU!

For your service in helping to assess the Quantum Physics Division, Physical Measurement Lab, and NIST.

A lot of work, and distraction from your regular responsibilities.

We find the formal and informal interactions very helpful as we continually strive to improve our programs.

Assessment of the NIST Quantum Physics Division

Charge to the NRC Board on Assessment of NIST Programs from the NIST Director through contract with NRC (*paraphrased*):

1. Technical programs.
   - Quality of research compared to rest of world.
   - Are technical programs adequate to achieve stated mission?

2. Scientific expertise.
   - Quality of technical staff compared to rest of world.
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3. Infrastructure.
   - Are quality of facilities, equipment, human resources adequate to achieve stated mission?

4. Dissemination of outputs.
   - How effectively does the organization disseminate/transfer its outputs?

Assessment of the NIST Quantum Physics Division

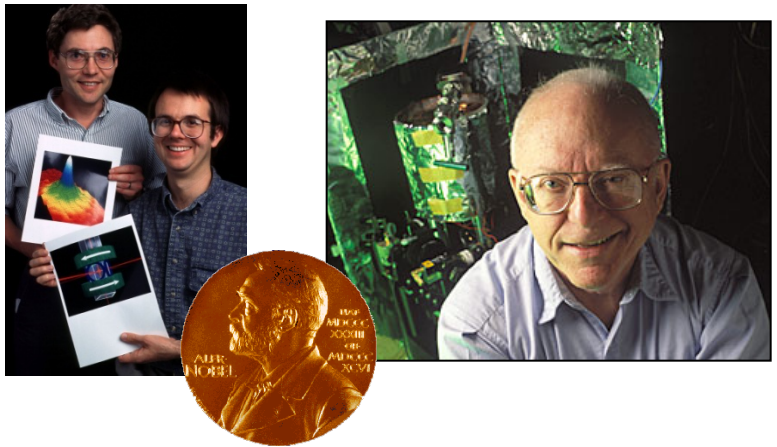
Strategic planning, external review of plans, input for planning for Quantum Physics Division, Physical Measurement Lab, NIST:

- Visiting Committee on Advanced Technology.
  - Industry, academia, government agencies.
- Department of Commerce (parent agency of NIST).
- Congress of the United States.
- Multiple internal strategic planning exercises.
  - Division, Laboratory, NIST-wide.
- JILA Cooperative Agreement External Review.
- NSF Physics Frontier Center reviews.
- Other reviews by funding agency program managers.

JILA

- Joint institute of NIST and University of Colorado (CU).

- Founded 1962 as “Joint Institute for Laboratory Astrophysics.”
- Physically located on CU campus.
- 26 JILA Fellows (CU and NIST).
  - NIST employee JILA Fellows hold Adjoint CU faculty appointments.
- 250 personnel, including Fellows, Research Associates, graduate and undergraduate students, staff.
- Leading center for:
  - AMO physics.
    - With applications in bio, nano.
  - Measurement science.



NIST Investments in JILA

- NIST supports through the JILA Cooperative Agreement (financial arrangement) the following activities at JILA:
  - Research led by NIST employees and associates at JILA (members of NIST Quantum Physics Division).
  - Training at JILA (grad students, postdocs, etc.).
  - JILA Visiting Fellows program broadly benefiting all of JILA.
  - JILA infrastructure broadly benefiting all of JILA.
    - Administrative support.
    - Technical support (instrument shops, electronics shops, IT, etc.).
    - Facilities.

Quantum Physics Division Scientific Focus Areas

- Cold atoms and molecules.
- Precision measurement.
- Ultrafast phenomena.
- Biophysics.
- Nanotechnology.

Substantial overlap and synergy among all these scientific areas.

Much research conducted in collaboration with CU JILA groups, and external partners.

"Ultra-Cold, Ultra-Precise, Ultra-Fast, Ultra-Small."

Quantum Physics Division Scientific Focus Areas

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Major new area evolving at Quantum Physics Division/JILA: Quantum many-body phenomena (collective quantum phenomena)

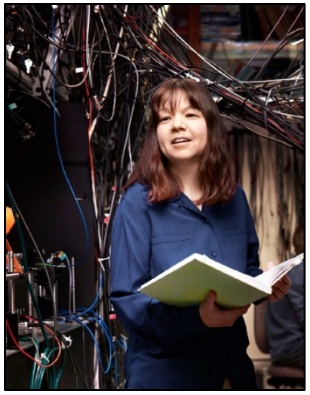
Quantum Physics Division Scientists (JILA Fellows)

John Bohn
Cold atoms & molecules
Quantum many-body

Eric Cornell
Cold atoms & molecules
Precision measurements

Steve Cundiff
Ultrafast phenomena
Precision measurements

Ralph Jimenez
Biophysics
Ultrafast phenomena



Debbie Jin
Cold atoms & molecules
Quantum many-body

Konrad Lehnert
Nanoscience
Precision measurements

Quantum Physics Division Scientists (JILA Fellows)

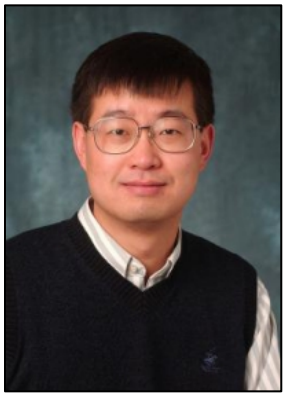
Judah Levine
Precision measurements

David Nesbitt
Chemical physics
Biophysics

Tom Perkins
Biophysics
Precision measurements

Ana Maria Rey
Ultracold atoms & molecules
Quantum many-body

James Thompson
Ultracold atoms & molecules
Quantum many-body
Precision measurements



Jun Ye
Ultracold atoms & molecules
Quantum many-body
Ultrafast phenomena
Precision measurements

Quantum Physics Division Scientists (JILA Fellows): Special Cases

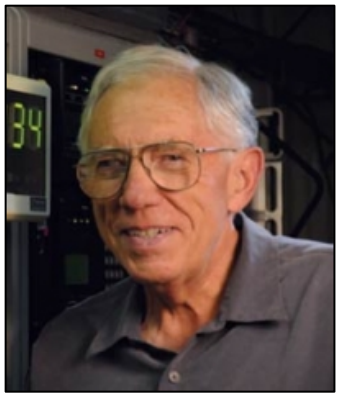
Ana Maria Rey

John Bohn

Cold atoms & molecules

Quantum many-body

CU research faculty fully paid by NIST



Judah Levine

Precision measurements

Joint appointment with

Time & Frequency Division

Steve Cundiff

Ultrafast phenomena

Precision measurements

University of Michigan as of Fall 2015

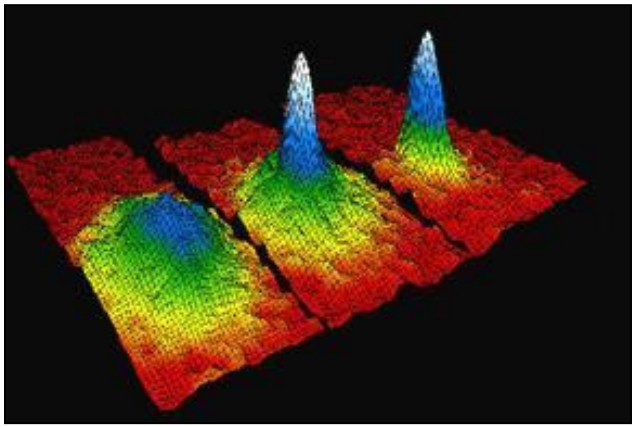
CU (Non-NIST) JILA Fellows, Indirectly Benefit through Cooperative Agreement

- Dana Anderson, CU Physics, quantum sensors, precision measurements
- Phil Armitage, CU Astrophysics, black holes, galaxy/planet formation
- Andreas Becker, CU Physics, ultrafast phenomena
- Mitch Begelman, CU Astrophysics, astrophysical gas & magnetohydrodynamics
- Andrew Hamilton, CU Astrophysics, black holes, cosmology
- Murray Holland, CU Physics, ultracold atoms & molecules, quantum optics
- Agnieszka Jaron-Becker, CU Physics, ultrafast phenomena
- Henry Kapteyn / Margaret Murnane, CU Physics, ultrafast phenomena, quantum optics
- Heather Lewandowski, CU Physics, ultracold molecules, chemical physics
- Carl Lineberger, CU Chemistry, chemical and molecular physics
- Cindy Regal, CU Physics, quantum nanomechanics
- Juri Toomre, CU Astrophysics, solar/stellar structure and evolution
- Mathias Weber, CU Chemistry, chemical and molecular physics

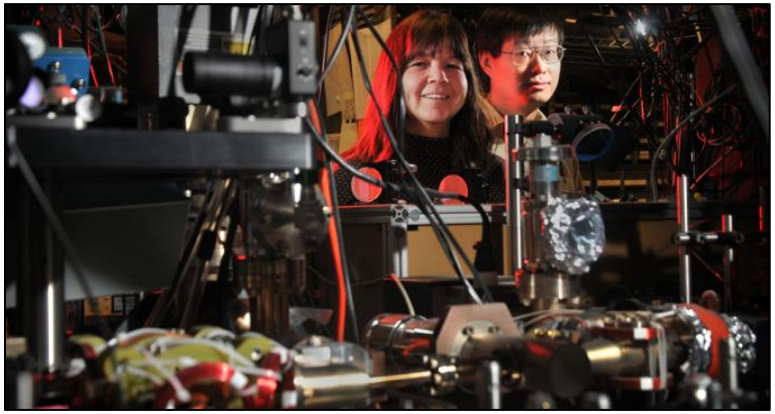
Cold Atoms and Molecules

A leading center for research and measurement on cold atoms and molecules.

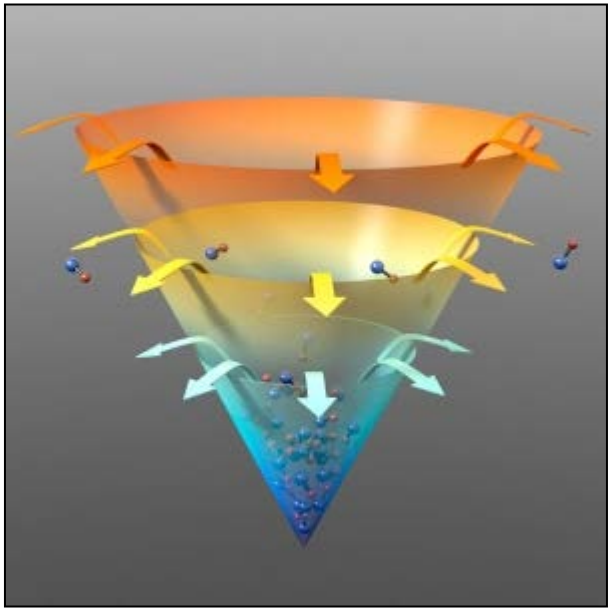
- First Bose-Einstein condensate.
- First Fermi condensate.
- First quantum control of cold molecular reactions.
- Much more…



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



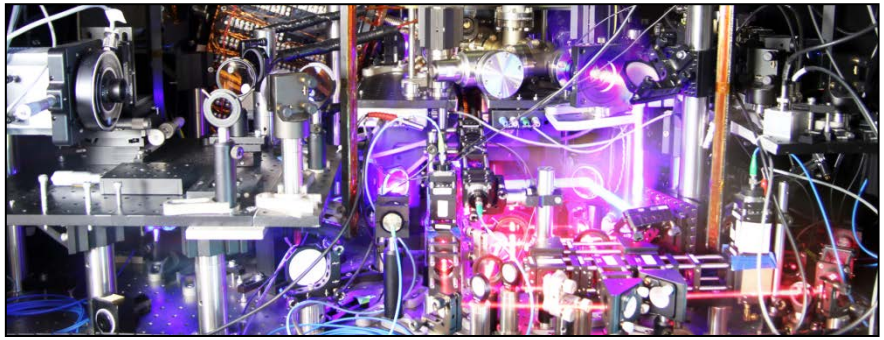
Ultracold molecules and ultracold chemistry,
Debbie Jin and Jun Ye



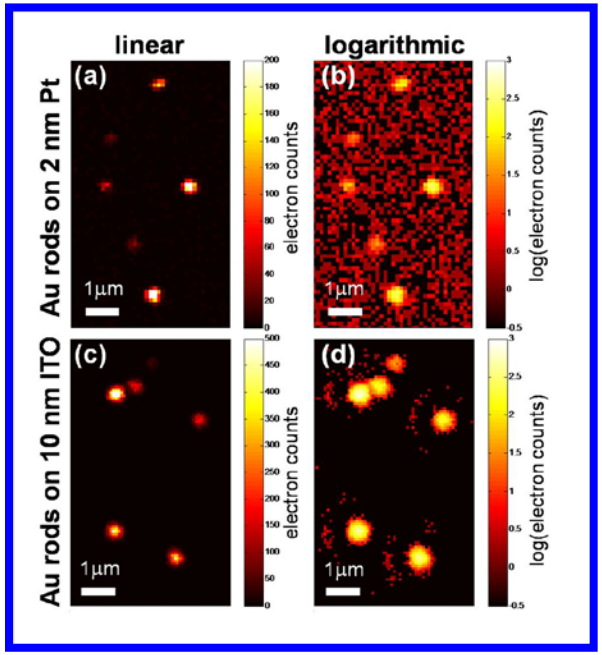
First evaporative cooling of molecules (OH), Jun Ye

Precision Measurement

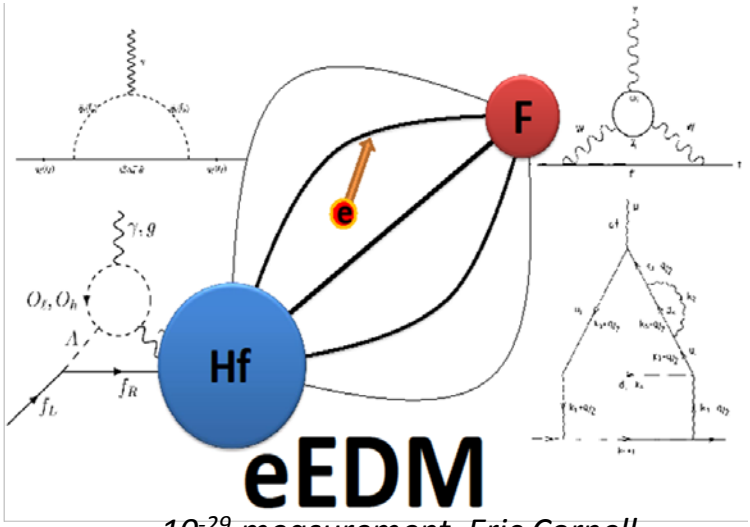
- Optical lattice atomic clock.
- Electric dipole moment of electron.
- Single molecule microscopy.



Sr optical lattice clock, world's best atomic clock (2×10^{-18} accuracy and rapidly improving), Jun Ye



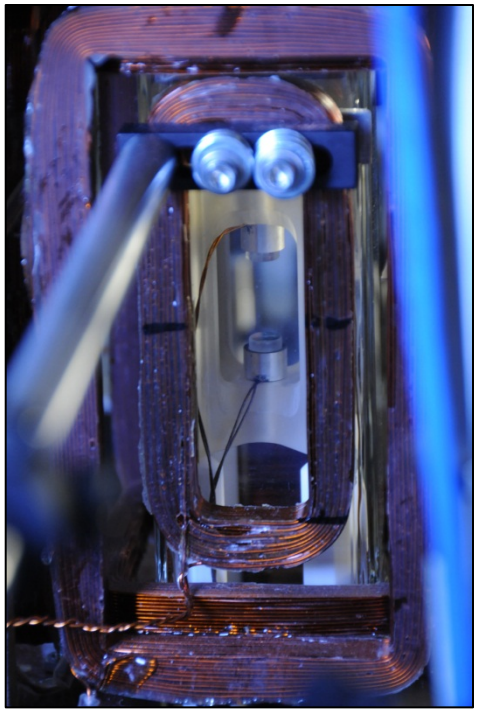
Tools for single molecule imaging and measurement, David Nesbitt



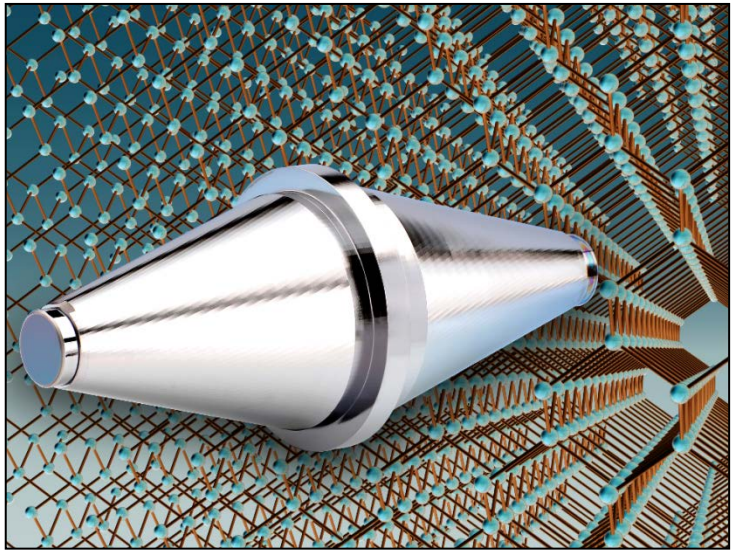
10^{-29} measurement, Eric Cornell

Precision Measurement

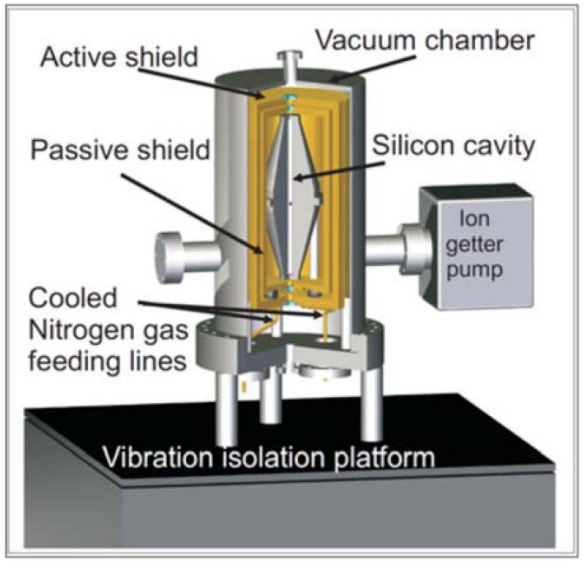
- World's most stable laser.
- Super-radiant laser.
- Much more...



Super-radiant laser, potentially 100x more stable, James Thompson

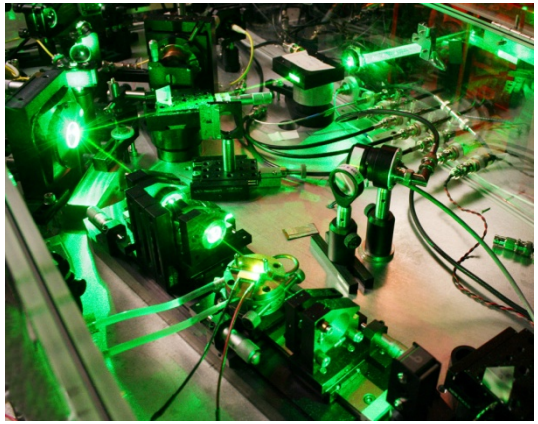


Unique silicon laser cavity for the world's most stable laser, Jun Ye

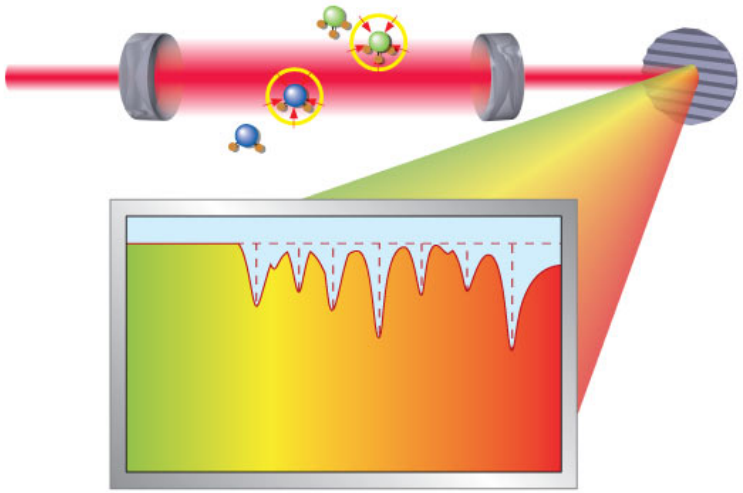


Ultrafast Phenomena

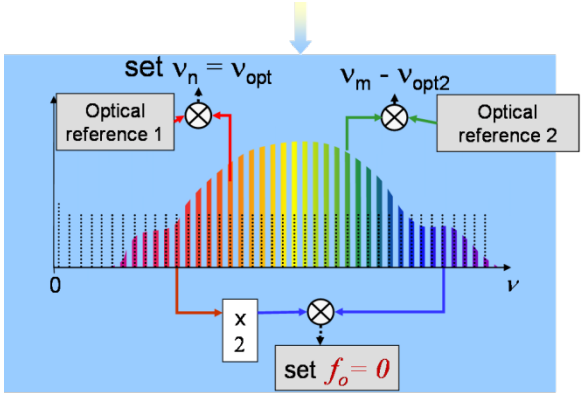
- Innovative frequency comb development and applications.
- Light/semiconductor interactions.

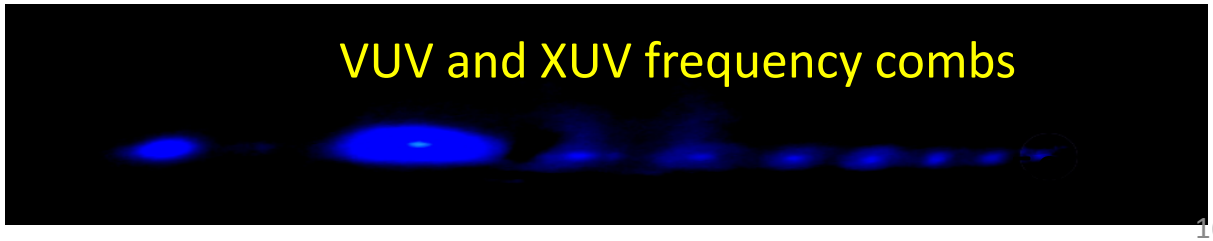


Semiconductor metrology for improved photovoltaics, optical processing, etc., Steve Cundiff



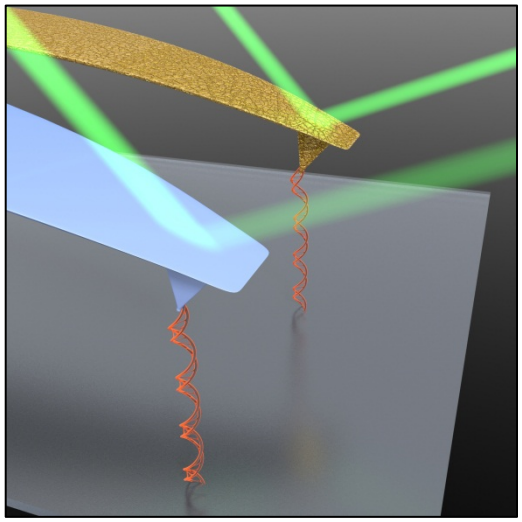
*Frequency comb development and applications to atomic clocks, electron dipole moment, medical diagnostics, massively parallel spectroscopy, ultracold molecules, **much** more, Jun Ye.*

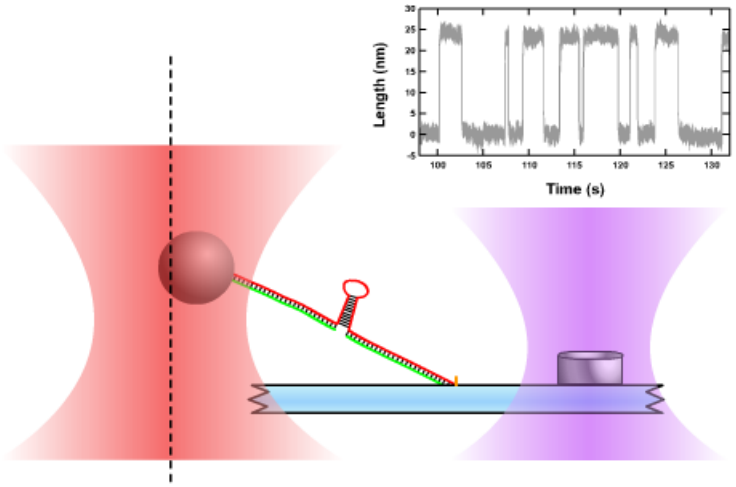




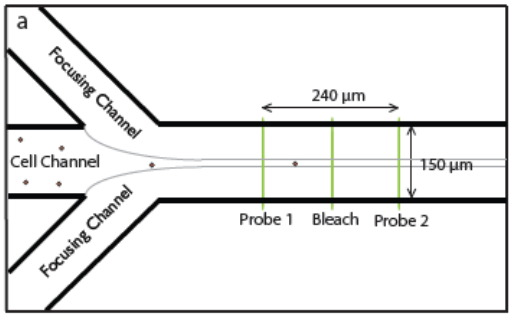
Biophysics

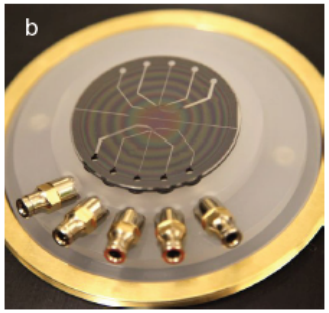
- Leverage AMO physics expertise.

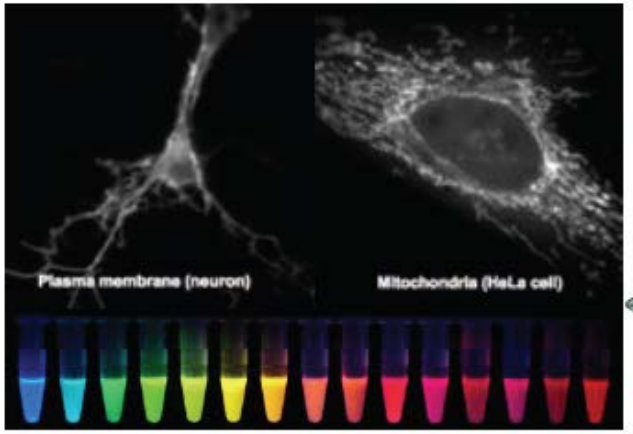


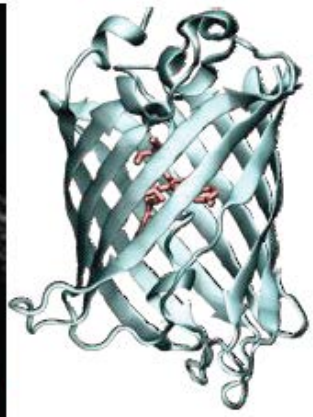


Ultraprecise AFM and laser trapping measurements of single biomolecules for structure/function determination, precision picoNewton force standards, etc., Tom Perkins





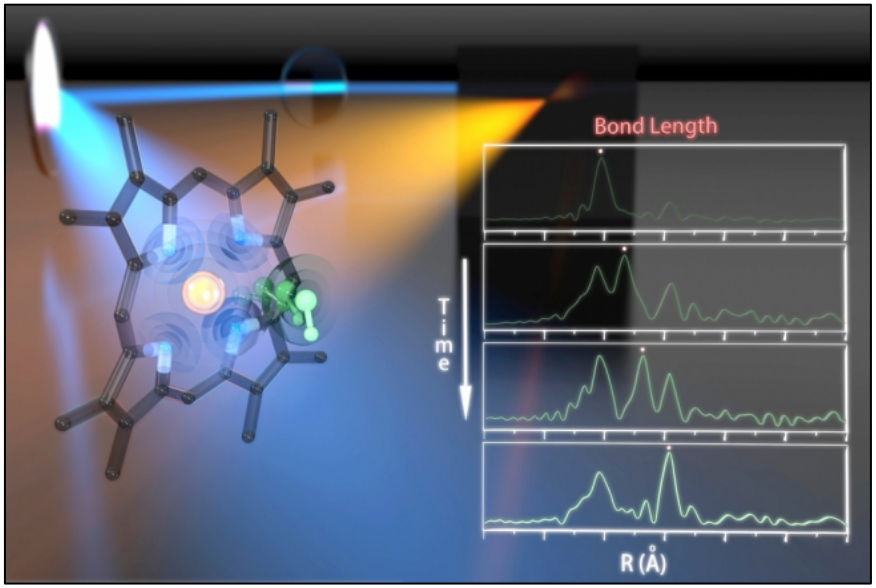




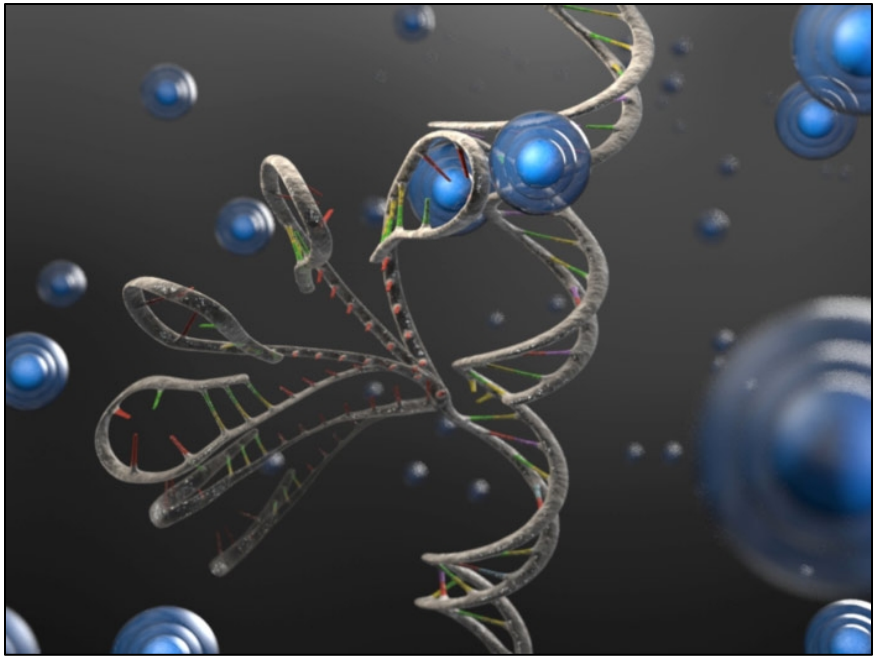
Rapid structure/function/genetic analysis with ultrafast lasers and microfluidics, Ralph Jimenez

Biophysics

- Leverage AMO physics expertise.



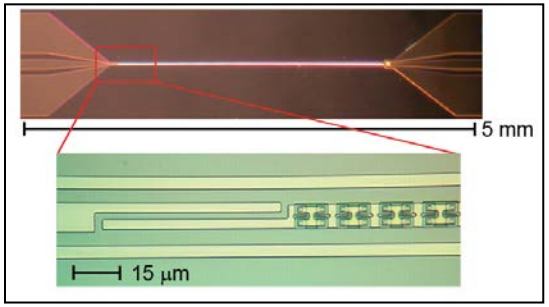
Molecular movies based on ultrafast x-ray sources to monitor real-time changes in conformation, etc.
Ralph Jimenez



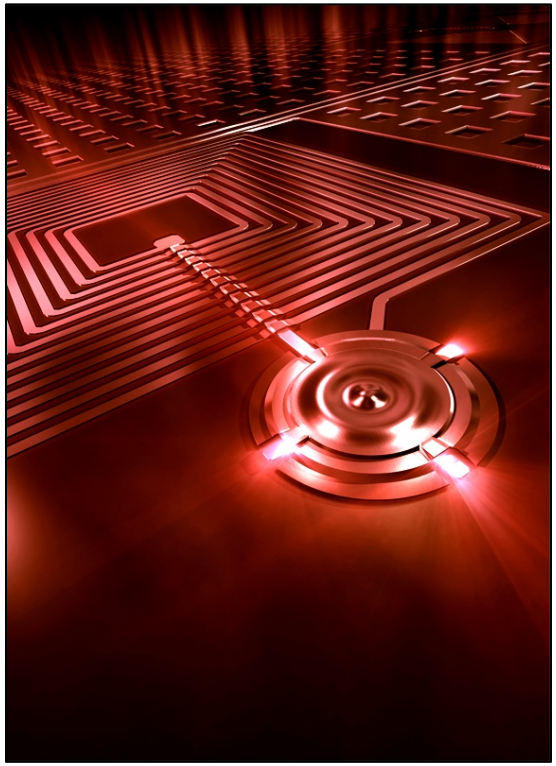
Single-molecule dynamics and kinetics with optical probes.
David Nesbitt

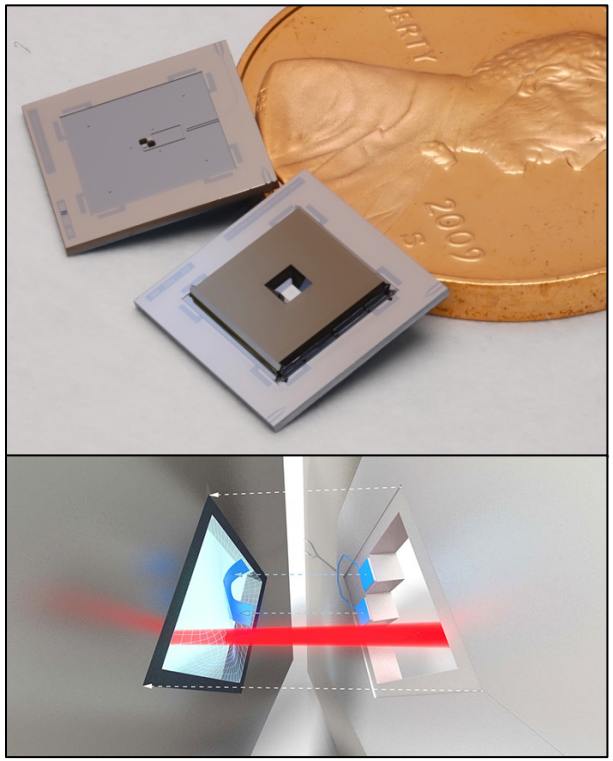
Nanoscience

- Quantum-based metrology.



Noiseless Josephson parametric amplifier,
search for axions (dark matter)
Konrad Lehnert





Opto-electro-mechanical quantum transduction.
Quantum mechanics in macroscopic objects (microresonators).
Quantum-based measurements.
Quantum networks.
Konrad Lehnert

What is the Value of Quantum Physics Division/JILA *To NIST*

- NIST mission: Promote US economic growth and national security through measurements, standards, technology and innovation.

- Why should NIST invest in JILA?

- Not a question about the intrinsic value of JILA research and training to broad scientific goals.

- A question about the specific roles that JILA plays within the NIST mission as an agency of the Federal Executive Branch.

Assessment of the NIST Quantum Physics Division

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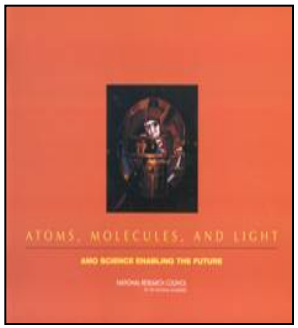
What is the Value of Quantum Physics Division/JILA *To NIST*

Develop unique measurement science tools and techniques.



- Yields a "bumper crop of innovations."
- Produces fundamental new "tools of science."
- Measurement science technology transfer through new companies, intellectual property, exchange of scientists.
- Broad economic impact.

Provide new generations of uniquely trained innovators and measurement scientists to work at NIST and other organizations.

Trains top scientists, engineers, and technical staff for NIST (>400 currently), industry, universities, other organizations.

"Increase our number of science and engineering graduates and encourage undergraduates studying math and science to pursue graduate studies"
- President Obama's Technology Agenda

"Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit and retain the best and brightest students, scientists and engineers from within the United States and throughout the world."
- Recommendation C in National Academy of Science report "Rising Above The Gathering Storm"

Measurement science research in national priority areas.

Advanced Manufacturing, Biosciences/Health Care, Energy, Environment, Nanotechnology, etc.

What is the Value of Quantum Physics Division/JILA *To NIST*

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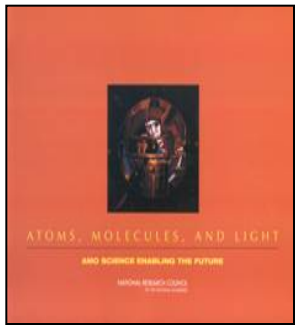

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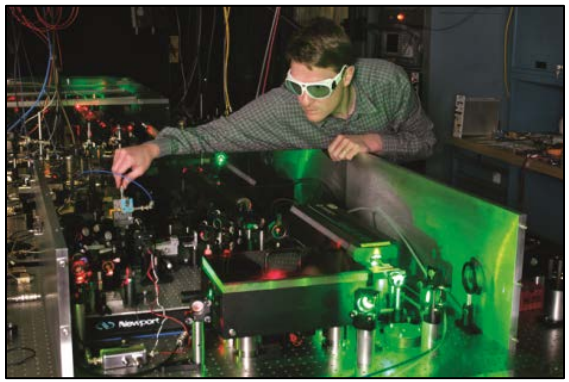
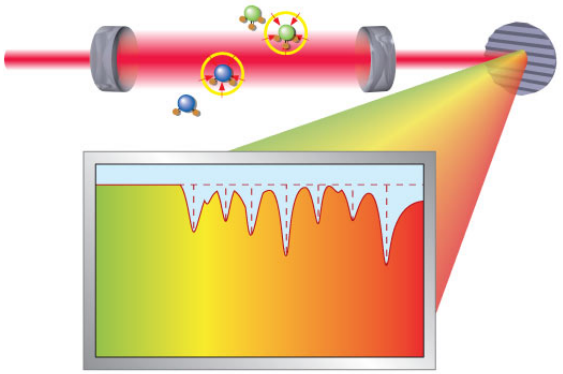
Quantum Physics Division Technologies Supporting NIST Metrology Mission

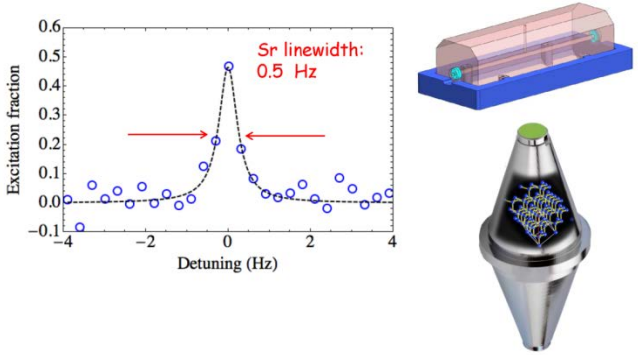
A few examples:

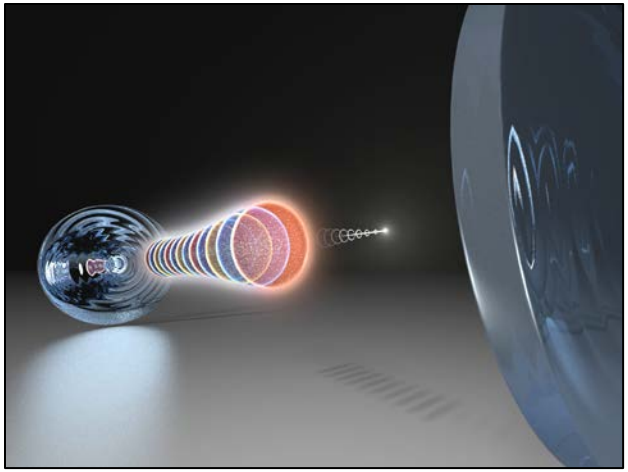
Femtosecond laser frequency combs





Ultrastable lasers

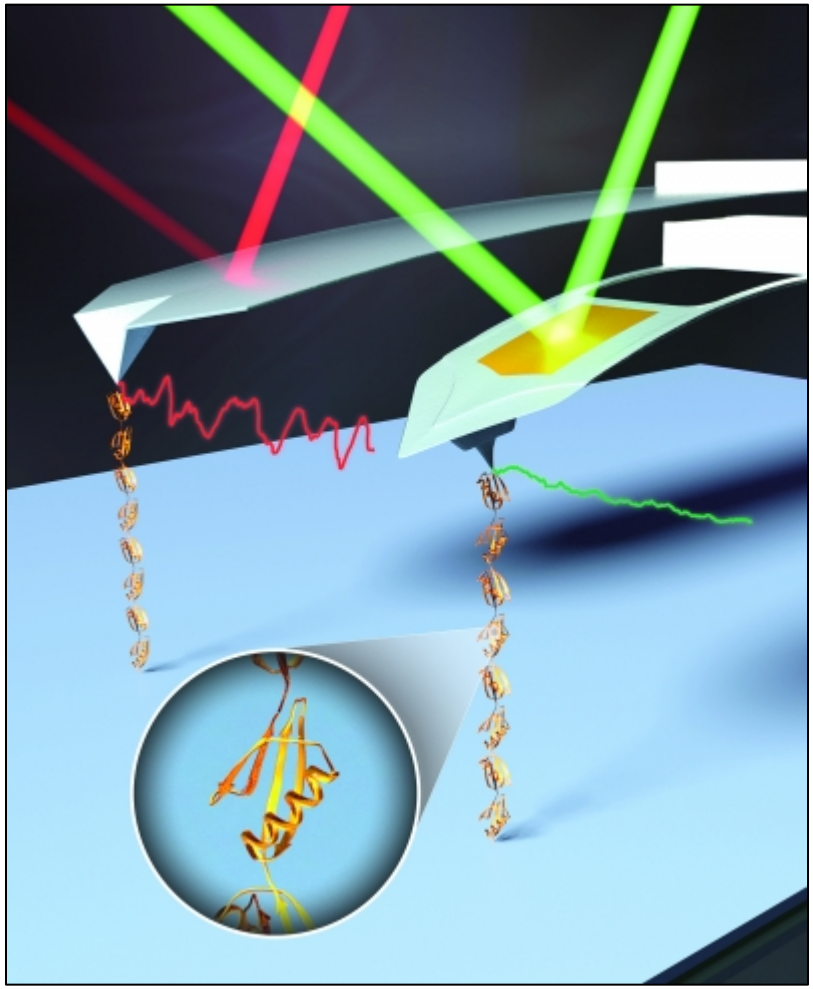




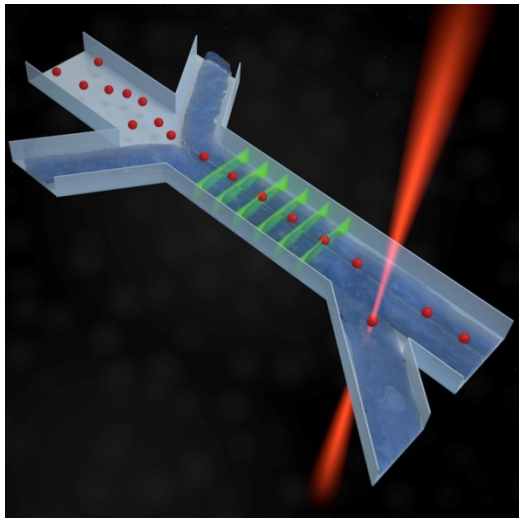
Quantum Physics Division Technologies Supporting NIST Metrology Mission

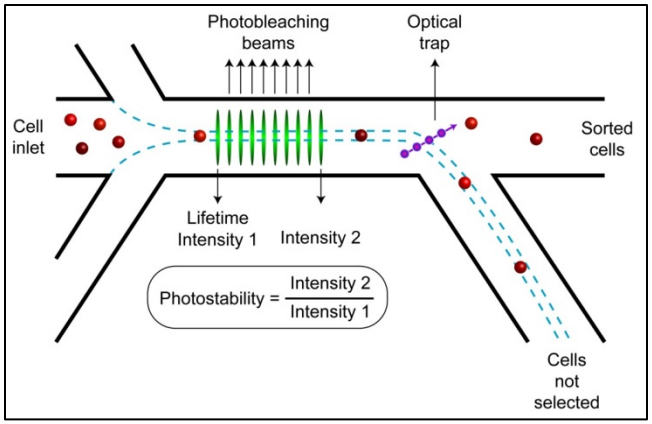
A few examples:

Ultrastable AFM



High speed cell/biochemical analysis and selection

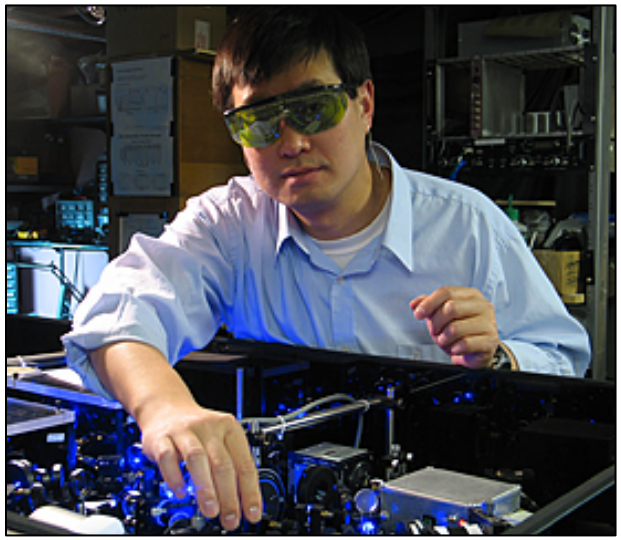


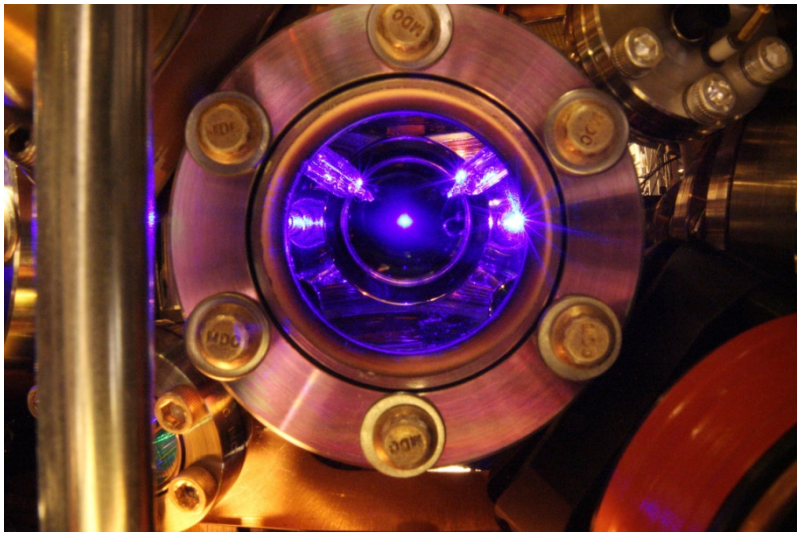


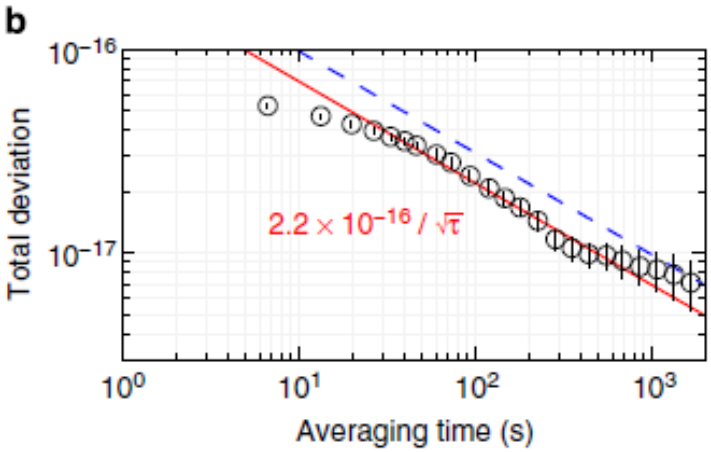
Quantum Physics Division Technologies Supporting NIST Metrology Mission

A few examples:

Sr optical lattice clock





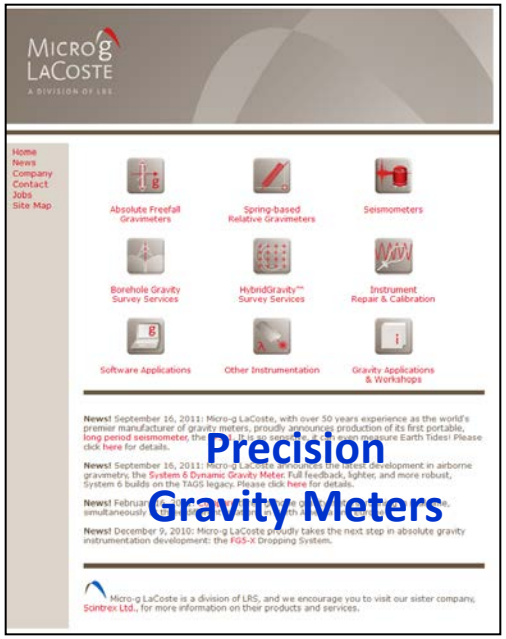


Quantum Physics Division Technologies Supporting NIST Metrology Mission

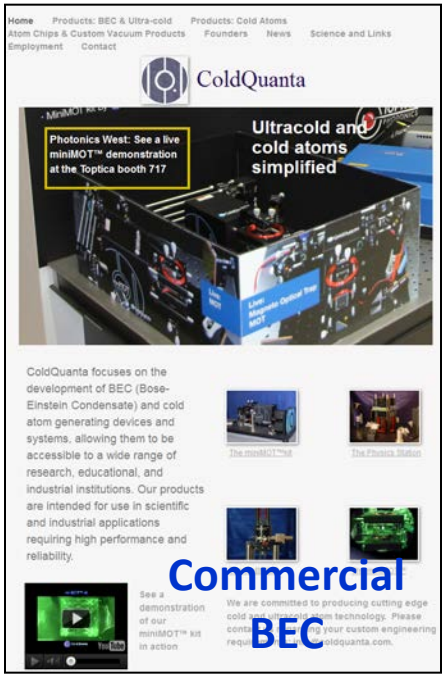
- More that 20 patents supported by NIST investment in JILA:
  - Technologies to generate and stabilize frequency combs.
  - Frequency comb applications, including medical diagnostics.
  - Monolithic silicon optical cavity for ultrastable laser.
  - Advanced cytometer for high speed identification and sorting of living cells with particular properties.
  - World's most stable AFM (operating in wet, warm environment).
  - Many more…

JILA Spinoff Companies (Partial Sample)

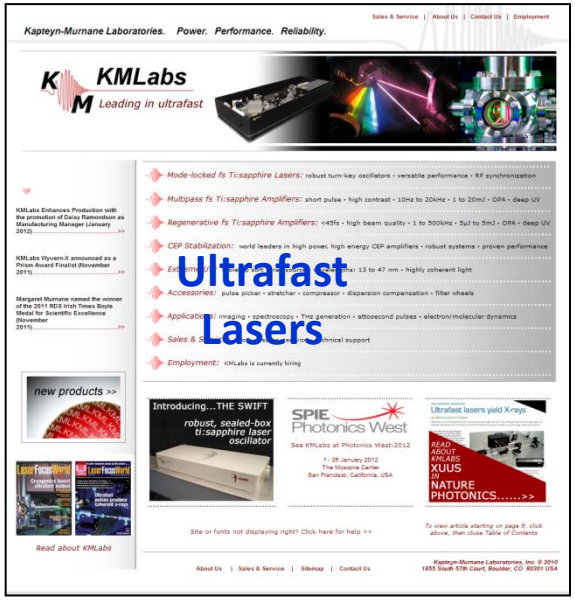
Advanced Photonics



Precision Gravity Meters



Commercial BEC



Ultrafast Lasers

What is the Value of Quantum Physics Division/JILA *To NIST*

Develop unique measurement science tools and techniques.

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"Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit and retain the best and brightest students, scientists and engineers from within the United States and throughout the world."
- Recommendation C in National Academy of Science report "Rising Above The Gathering Storm"

Measurement science research in national priority areas.

Advanced Manufacturing, Biosciences/Health Care, Energy, Environment, Nanotechnology, etc.

JILA's Biggest Impact: Highly Trained Innovators

JILA Training Supporting NIST Mission

- NIST investment in JILA supports:
  - Training of about 25 graduate students each year.
  - Training of about 15 postdocs each year.
  - About four Visiting Fellows each year.

- People trained at JILA go on to high impact careers in academia, industry, national labs, start up companies, etc.
  - ~400 people trained at JILA currently work at NIST in some capacity.
    - Gaithersburg and Boulder campuses.
    - NIST employees.
    - NIST associates (guest researchers, contractors, etc.).
    - Typically among the scientific leaders at NIST.

JILA Training Supporting NIST Mission

High impact of JILA training

Outstanding Doctoral Thesis Research in Atomic, Molecular, or Optical Physics

To recognize doctoral thesis research of outstanding quality and achievement in atomic, molecular, or optical physics and to encourage effective written and oral presentation of research results. The award to be given annually consists of $2,500 and a certificate citing the contribution made by the recipient. All finalists will receive a travel stipend of $500.

Establishment & Support

The award was established in 1992 by the Division of Atomic, Molecular and Optical Physics and is sponsored by members and friends of the Division of Atomic, Molecular and Optical Physics.

Rules & Eligibility

With exceptions noted below, doctoral students at any university in the United States or abroad who have passed their thesis defense for the Ph.D. in the disciplines of atomic, molecular, or optical physics any time during the two calendar years preceding the DAMOP Annual Meeting at which the award is to be presented are eligible for the award. For the 2015 meeting, a person is eligible if the Ph.D. is completed in 2013 or 2014. A student who has won a thesis prize in another division or whose thesis advisor serves on the current Selection Committee is not eligible for an award. The student's thesis advisor nominates the student, and must be a member of the APS and DAMOP. A student may be a finalist in the competition only once. Eligible non-finalists may only be renominated by submitting an entirely new package, even if it is the same as the original package. Renominations are NOT made automatically.

Nomination & Selection Process

Serving a diverse and inclusive community of physicists worldwide is a primary goal for APS. Nominations of qualified women, members of underrepresented minority groups, and scientists from outside the United States are especially encouraged.

The deadline for submitting nominations has past. All applications must be submitted to the chair of the DAMOP thesis prize committee by **December 1** of the year proceeding the award.

2014 Outstanding Doctoral Thesis Research in AMO Physics Recipient:
Thibault Peyronel
Massachusetts Institute of Technology

Past Recipients:

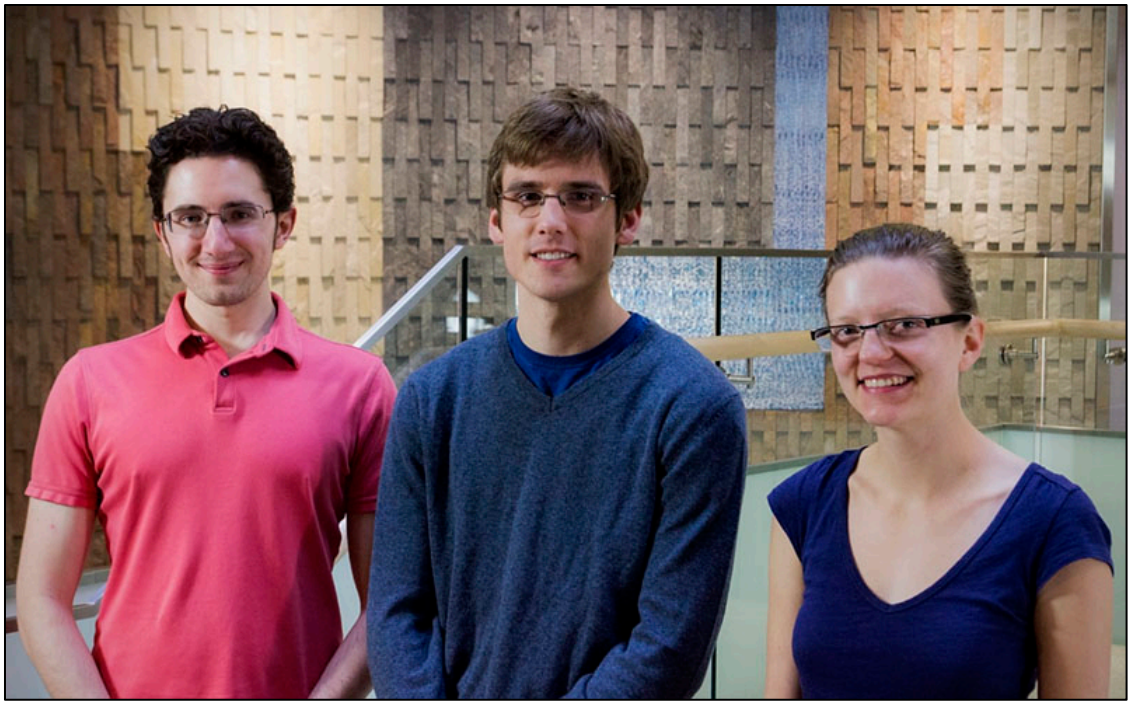
2013: Michael Foss-Feig, Yaroslav Dudin
2012: Waseem Bakr
2011: Elmar Haller
2010: Kang-Kuen Ni
2009: Andrew Ludlow, Javier von Stecher
2008: David Moehring
2007: Cindy Regal
2006: Brian Odom
2005: Ana María Rey
2004: James Thompson, Markus Greiner
2003: Daniel Steck
2002: Brian DeMarco
2001: Thomas Weinacht
2000: Dan M. Stamper-Kurn

Completed PhD at JILA, and/or became JILA Fellows

JILA Training Supporting NIST Mission

High impact of JILA training

Three JILA grad students win 2015 NSF Graduate Research Fellowships
All working on NIST projects, with NIST advisors



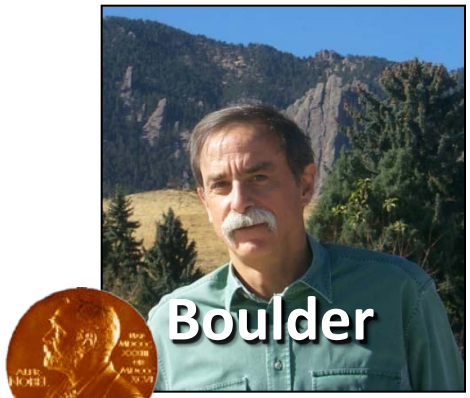
Steve Okoniewski
Perkins Group
DNA dynamics with precision AFM

Jake Pettine
Nesbitt Group
Gold/silver nanoparticle interactions with light

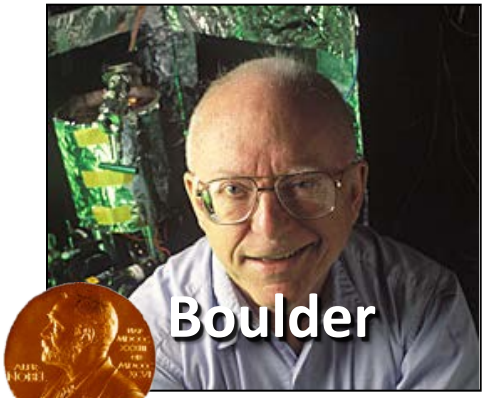
Lindsay Sonderhouse
Ye Group
Improve Sr lattice clock to 10^{-19} level

NIST Technical Staff: Members of the National Academy of Sciences

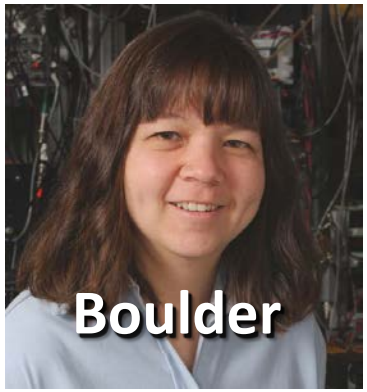
Anneke Sengers
Thermodynamics



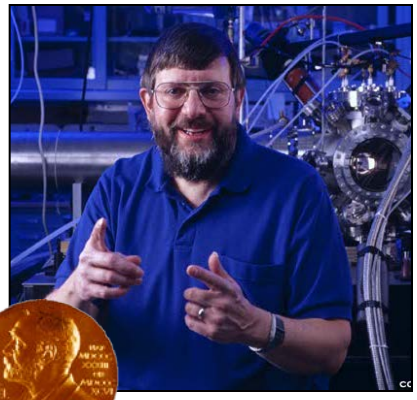
Dave Wineland
Quantum computing
Nobel Prize in Physics



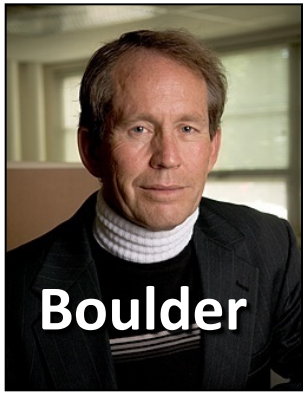
Jan Hall
Precision laser measurements
Nobel Prize in Physics



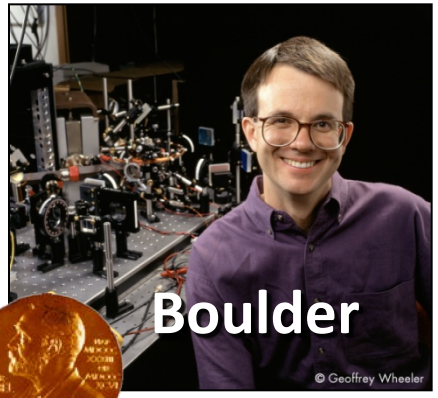
Debbie Jin
Ultracold atoms
MacArthur "Genius" Award



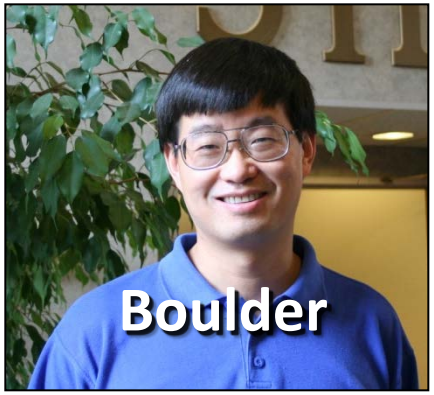
Bill Phillips
Laser cooling
Nobel Prize in Physics



Jim Bergquist
Atomic clocks



Eric Cornell
Bose-Einstein condensate
Nobel Prize in Physics



Jun Ye
Laser applications
Newest NIST NAS Member

JILA NIST|CU

What is the Value of Quantum Physics Division/JILA *To NIST*

Develop unique measurement science tools and techniques.

- Yields a "bumper crop of innovations."
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Trains top scientists, engineers, and technical staff for NIST (>400 currently), industry, universities, other organizations.

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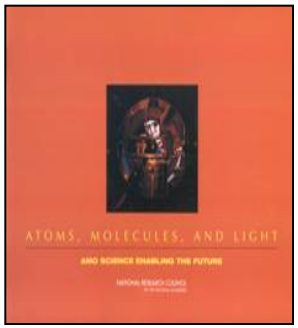

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Measurement science research in national priority areas.

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General Recognition for Quantum Physics Division and JILA

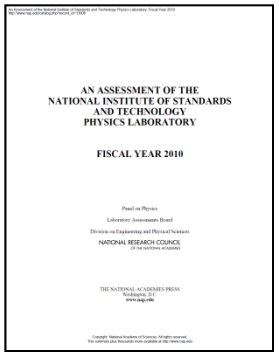
Quality of JILA Fellows (26 total):

- Three Nobel Prizes in Physics
- Three MacArthur "Genius" Awards
- Eight Members of the National Academy of Sciences
- Five Members of the Academy of Arts and Sciences

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

National Academy of Sciences Evaluation of JILA

- "Undeniable world leader in many areas of quantum optics."
- "Students in JILA receive an outstanding education in fundamental measurement science"
- "Provides a stream of young talent for future needs."


AN ASSESSMENT OF THE
NATIONAL INSTITUTE OF STANDARDS
AND TECHNOLOGY
PHYSICS LABORATORY

FISCAL YEAR 2010

U.S. News

- Consistently top-ranked AMO Physics Graduate Program.

BEST GRAD SCHOOLS
U.S.News & WORLD REPORT
RANKINGS

JILA Activities Supported by the NIST Cooperative Agreement

- Research and training.
  - ~$6.3 million per year. Primarily supporting JILA Fellows who are NIST employees or NIST associates.
  - Graduate students.
  - Postdocs.
  - Visiting Fellows.
  - Equipment and supplies.
  - Highly flexible distribution among these categories.

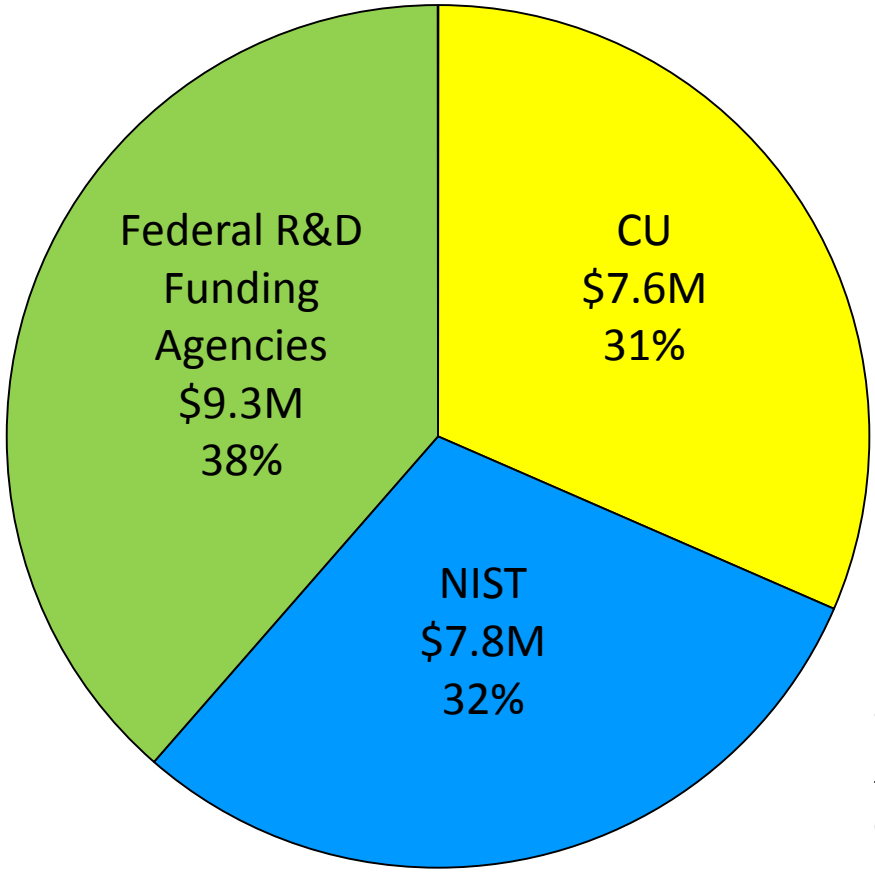
- Support services.
  - ~$1.5 million per year. Supporting all JILA Fellows (NIST and CU).
  - Administrative support.
    - ~9 FTE, roughly half of total JILA administrative support.
  - Technical support.
    - Instrument shop, electronics shop, IT support.
    - ~9 FTE, roughly half of total JILA technical support.

- Facilities support.
  - ~$1.4 million per year. Supporting all JILA Fellows (NIST and CU).
  - Maintenance, renovation, utilities, etc.
  - Roughly half the total JILA facilities investment.

JILA Resources: Funding

Annual Operating Budget: $24.7 million (FY2014)

Approximate data

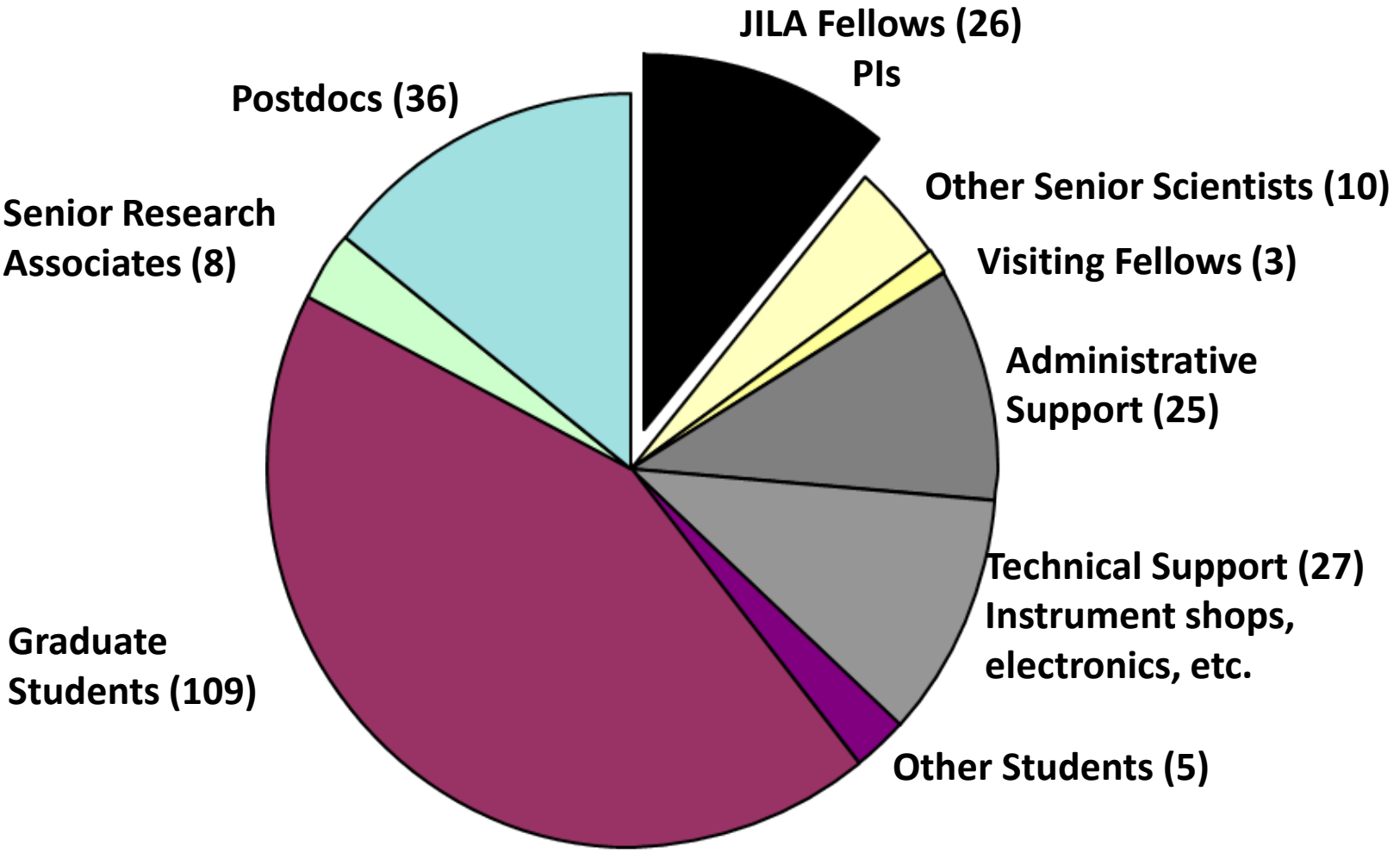


For JILA scientific programs and admin/technical support.
Does not include funds for facilities maintenance, utilities, etc.

Mutual leverage of:

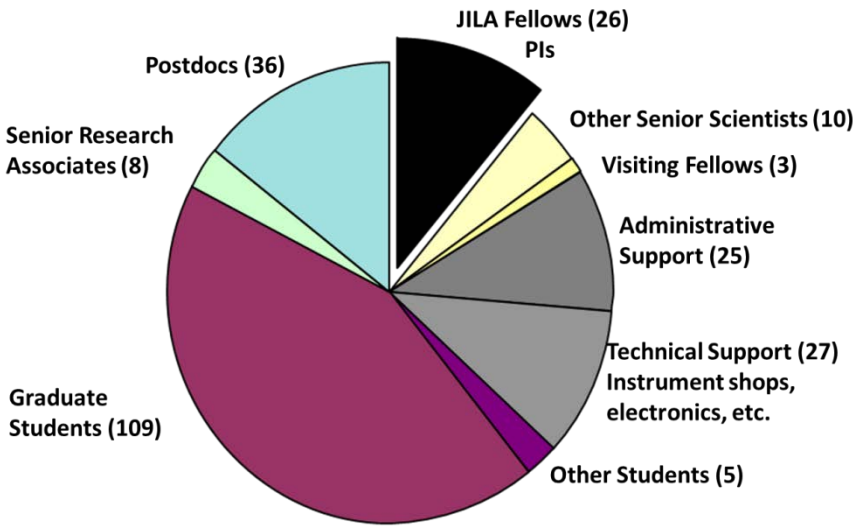
NIST investment
CU investment
Federal funding agency investment

JILA Resources: People



"Snapshot" Total = 249
Many categories vary throughout the year
(students, postdocs, visitors, etc.)

JILA Resources: People Supported by NIST Cooperative Agreement



Supported by Cooperative Agreement:

- Direct funding of research activities for 12 NIST-supported Fellows.
- Grad students (~25 per year).
- Postdocs (~15 per year).
- Broad benefits to all of JILA:
  - Visiting Fellows (~4 per year).
  - Administrative staff (~9 FTE).
  - Technical support staff (~9 FTE).
- Roughly 1/3 of total JILA people supported by Cooperative Agreement.
- Most of these are CU employees, NOT NIST employees.
- JILA Overall: ~7% NIST / ~93% CU

Quantum Physics Division JILA Fellows (PIs)

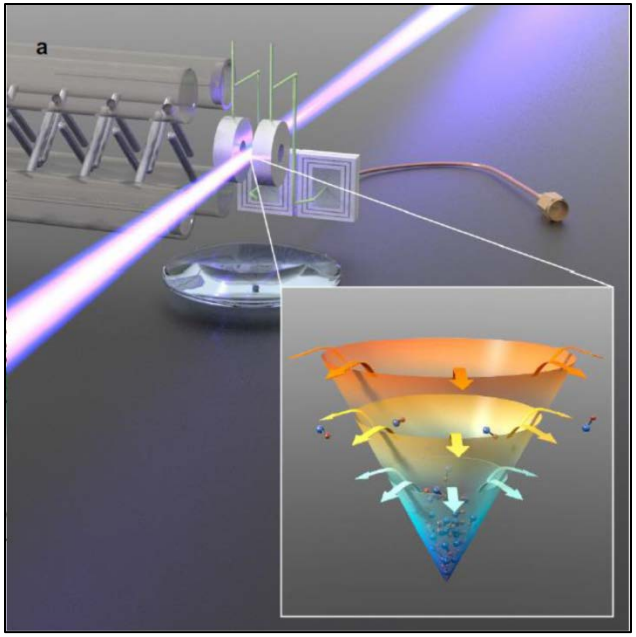
- Funding for NIST-supported JILA Fellows.
  - Average research group size is ~10:
    - Led by NIST-supported JILA Fellow PI.
    - Grad students, postdocs, visitors, senior scientists, technicians, undergrads, etc.
    - Group size varies from ~5 to ~25.
  - Each group very roughly half funded by NIST (through Cooperative Agreement) and half funded by grants from other Federal agencies (NSF, NIH, DoD agencies, etc.).
    - Mostly individual PI grants, with NSF Physics Frontier Center grant.
    - Small but increasing amount of funding from private foundations.
    - Distribution between NIST and external funds varies by group, varies year to year, etc.
  - Long-term NIST funding provides continuity and flexibility to JILA Fellow PIs.
    - PI decides best research investments, rather than what can be funded from external grants.
    - Ability to tackle hard projects that may take years to show results.
    - Ability to ride out ups and downs of grant cycles with less disruption to group.

Quantum Physics Division JILA Fellows (PIs)

- NIST funding to JILA Fellows through Cooperative Agreement.
  - Balance stability and predictability of NIST funding to supported JILA Fellows with some flexibility in re-distributing NIST funding among the JILA Fellows as needed.
    - Bridge temporary gaps in external grant funding.
    - Support one-time high cost investments in equipment, visitors, etc.
    - Provide “start up” funding for transitions into new scientific areas when external grants not available.
    - Deal with natural evolution of research group growth and ebbing over career of JILA Fellow.
    - Etc.

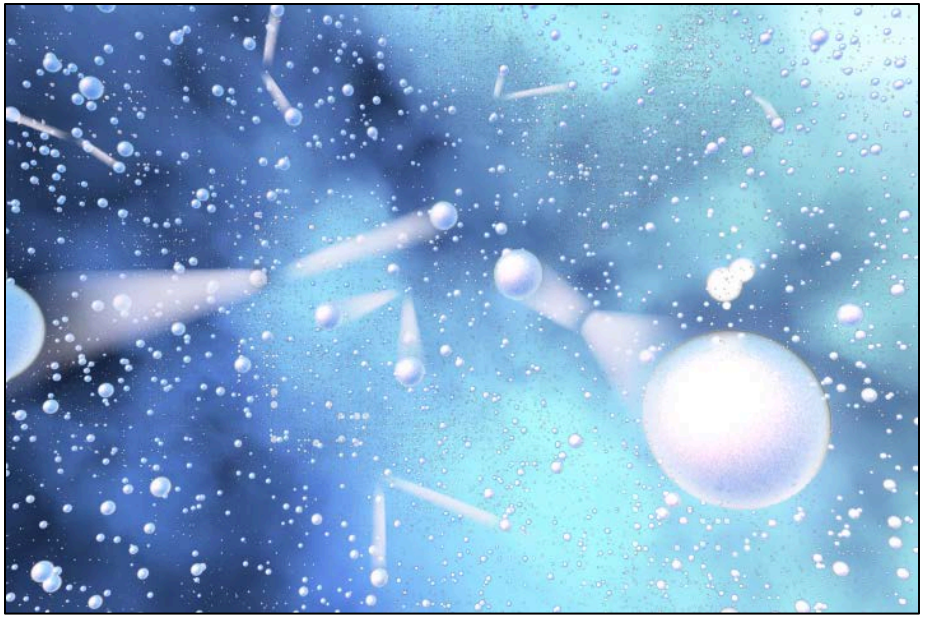
A Few Examples: Quantum Physics Division Accomplishments

Ultracold Molecules



First evaporative cooling of molecules (OH)
Jun Ye

B. K. Stuhl, Hummon, M. T. , Yeo, M. , éméner, G. , Bohn, J. L. , and Ye, J. , "Evaporative cooling of the dipolar hydroxyl radical", ***Nature***, vol. 492, no. 7429, pp. 396 - 400, (2012)

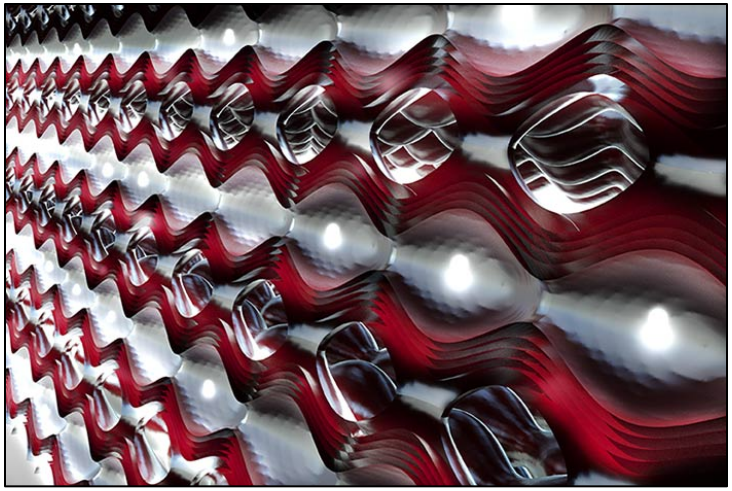


First observation of Tan's Contact in bosons (^{85}Rb)
Debbie Jin, Eric Cornell

Measurements of Tan's Contact in an Atomic Bose-Einstein Condensate, R. J. Wild, P. Makotyn, J. M. Pino, E. A. Cornell, and D. S. Jin, ***Phys. Rev. Lett.*** 108, 145305 (2012)

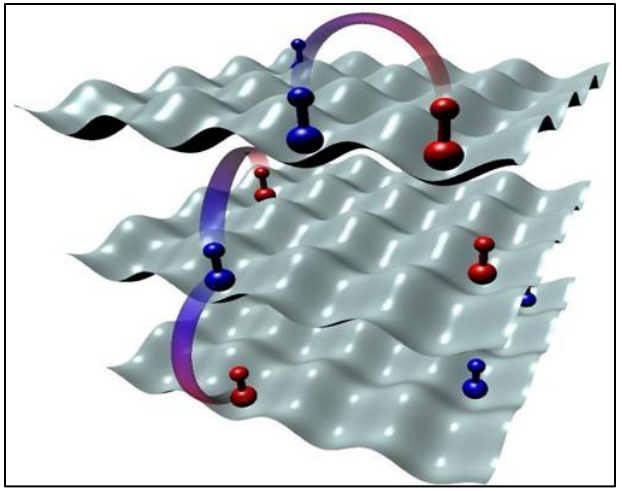
A Few Examples: Quantum Physics Division Accomplishments

Ultracold Molecules



Suppressing K-Rb loss through Quantum Zeno Effect
Debbie Jin, Ana Maria Rey

Suppressing the Loss of Ultracold Molecules Via the Continuous Quantum Zeno Effect. B. Zhu, B. Gadway, M. Foss-Feig, J. Schachenmayer, M. L. Wall, K. R. A. Hazzard, B. Yan, S. A. Moses, J. P. Covey, D. S. Jin, J. Ye, M. Holland, and A. M. Rey, ***Phys. Rev. Lett***. 112, 070404 (2014)

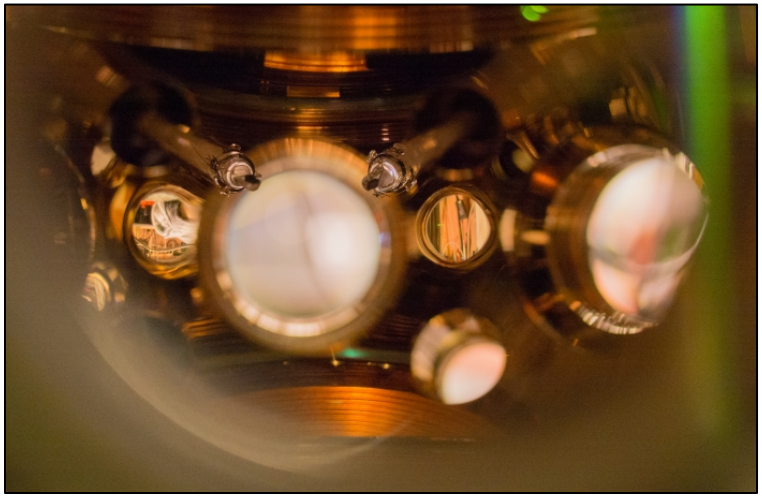


Spin-exchange among ultracold molecules in a lattice
Jun Ye, Debbie Jin, Ana Maria Rey

Observation of dipolar spin-exchange interactions with lattice-confined polar molecules, Bo Yan, Steven A. Moses, Bryce Gadway, Jacob P. Covey, Kaden R. A. Hazzard, Ana Maria Rey, Deborah S. Jin Jun Ye, ***Nature*** 501, 521–525(2013)

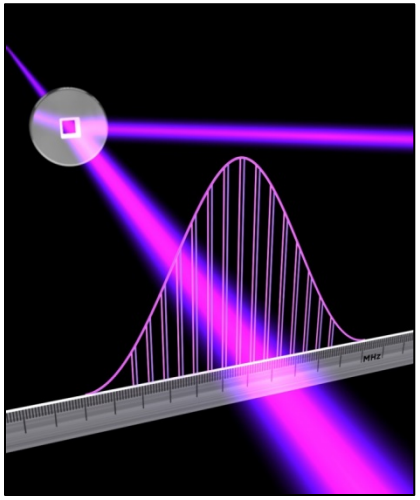
A Few Examples: Quantum Physics Division Accomplishments

Precision Measurement



Latest of several world records for Sr optical lattice clock
2 x 10^{-18} uncertainty, 100x improvement in 5 years
Jun Ye, Ana Maria Rey

Systematic evaluation of an atomic clock at 2 × 10^{-18} total uncertainty. T.L. Nicholson, S.L. Campbell, R.B. Hutson, G.E. Marti, B.J. Bloom, R.L. McNally, W. Zhang, M.D. Barrett, M.S. Safronova, G.F. Strouse, W.L. Tew J. Ye , ***Nature Communications*** 6, 6896 (2015)

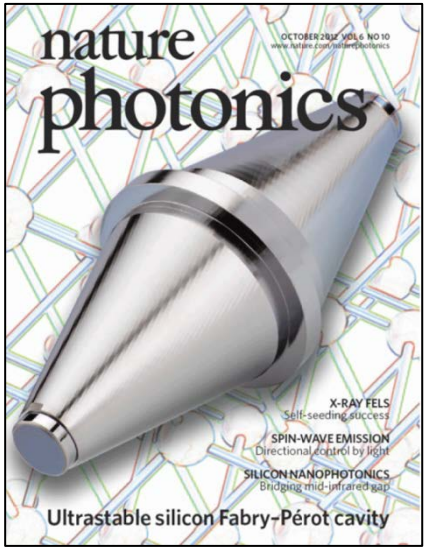


High coherence XUV light
Jun Ye

C. Benko, Allison, T. K. , Cingöz, A. , Hua, L. , Labaye, F. , Yost, D. C. , and Ye, J. , "Extreme ultraviolet radiation with coherence time greater than 1 s", **Nature Photonics,** vol. 8, pp. 530 – 536 (2014)

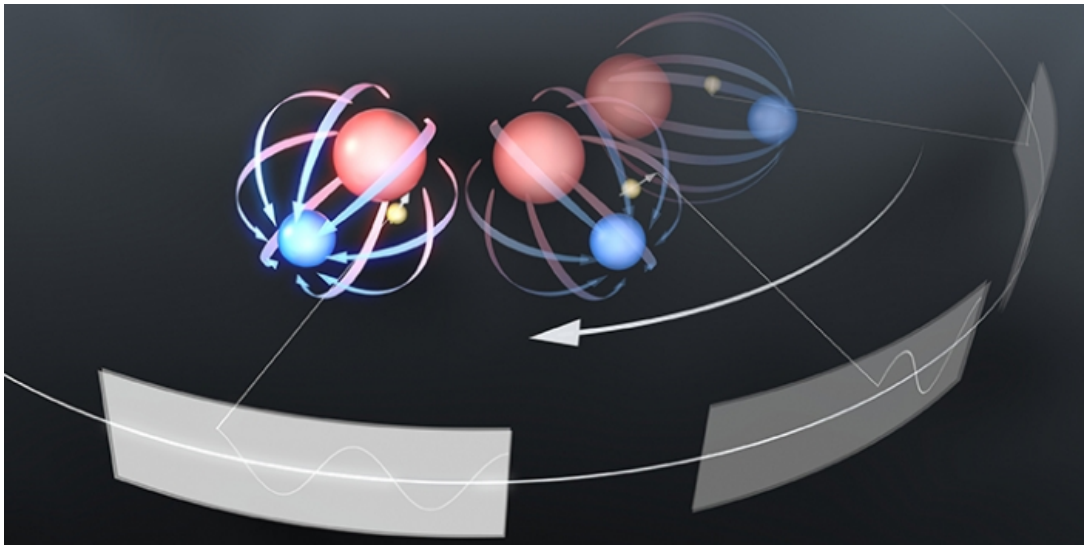
A Few Examples: Quantum Physics Division Accomplishments

Precision Measurement



Ultrastable (1 x 10^{-16}) monolithic Si laser cavity
Jun Ye

T. Kessler, Hagemann, C. , Grebing, C. , Legero, T. , Sterr, U. , Riehle, F. , Martin, M. J. , Chen, L. , and Ye, J. , "A sub-40-mHz-linewidth laser based on a silicon single-crystal optical cavity", ***Nature Photonics*****,** vol. 6, no. 10, pp. 687 – 692 (2012)

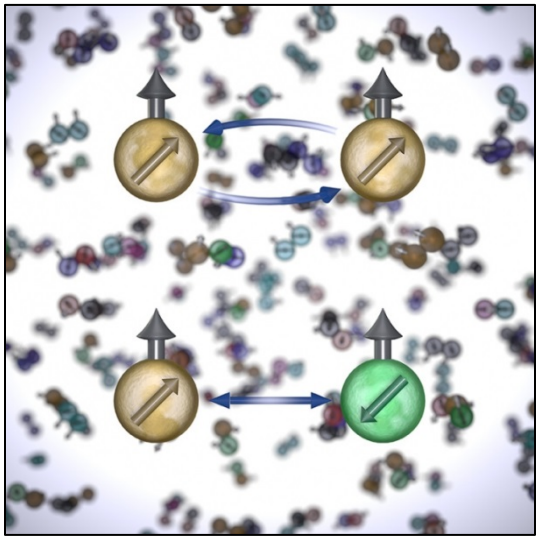


Electric dipole moment of electron measurements
Eric Cornell, Jun Ye

H. Loh, Cossel, K. C. , Grau, M. C. , Ni, K. -K. , Meyer, E. R. , Bohn, J. L. , Ye, J. , and Cornell, E. A. , "Precision Spectroscopy of Polarized Molecules in an Ion Trap", ***Science*****,** vol. 342, no. 6163, pp. 1220 – 1222 (2013).

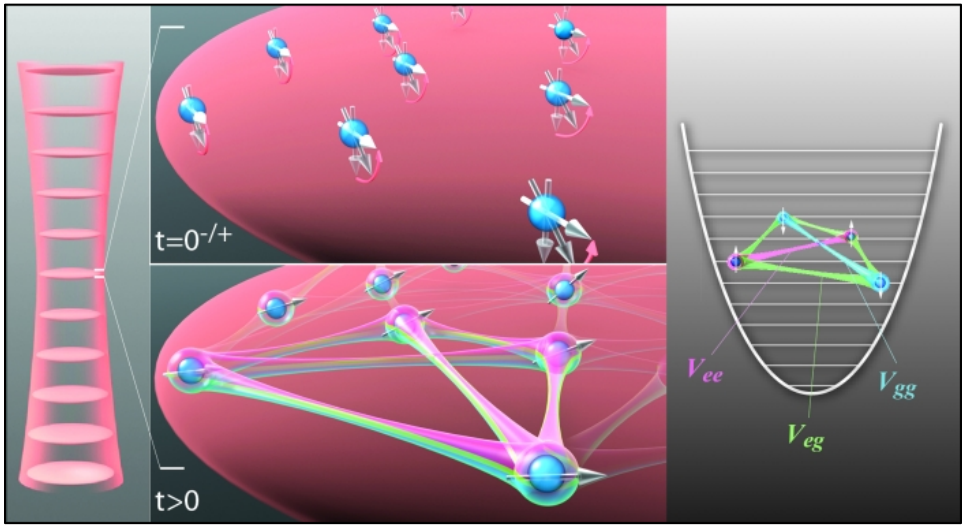
A Few Examples: Quantum Physics Division Accomplishments

Collective (Many-Body) Quantum Phenomena



First SU(N) symmetry observation in atomic system
Jun Ye, Ana Maria Rey

X. Zhang, Bishof, M. , Bromley, S. L. , Kraus, C. V. , Safronova, M. S. , Zoller, P. , Rey, A. M. , and Ye, J. , "Spectroscopic observation of SU(N)-symmetric interactions in Sr orbital magnetism", ***Science***, vol. 345, no. 6203, pp. 1467 – 1473 (2014)

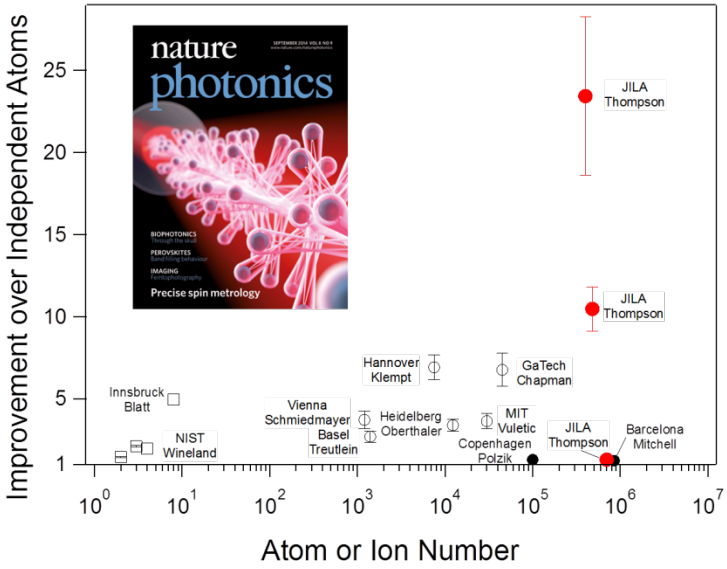


Quantum many-body spin system in Sr lattice clock
Jun Ye, Ana Maria Rey

M. J. Martin, Bishof, M. , Swallows, M. D. , Zhang, X. , Benko, C. , von-Stecher, J. , Gorshkov, A. V. , Rey, A. M. , and Ye, J. , "A Quantum Many-Body Spin System in an Optical Lattice Clock", ***Science***, vol. 341, no. 6146, pp. 632 – 636 (2013)

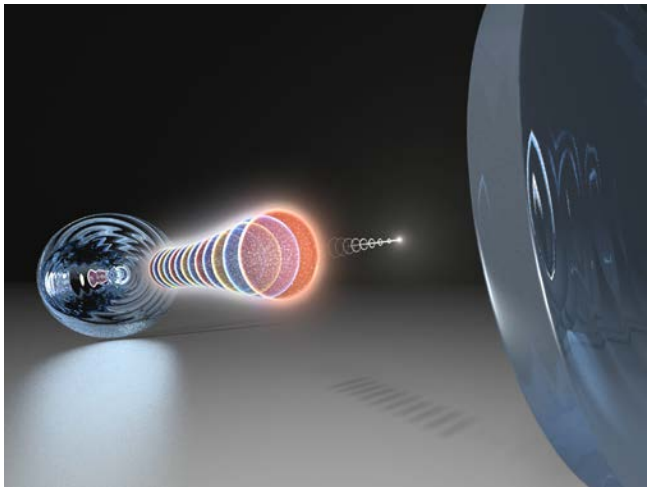
A Few Examples: Quantum Physics Division Accomplishments

Collective (Many-Body) Quantum Phenomena



Record spin-squeezing measurements
James Thompson

Reduced spin measurement back-action for a phase sensitivity ten times beyond the standard quantum limit
Nature Photonics J.G. Bohnet; K.C. Cox; M.A. Norcia; J.M. Weiner; Z. Chen; J.K. Thompson (2014)

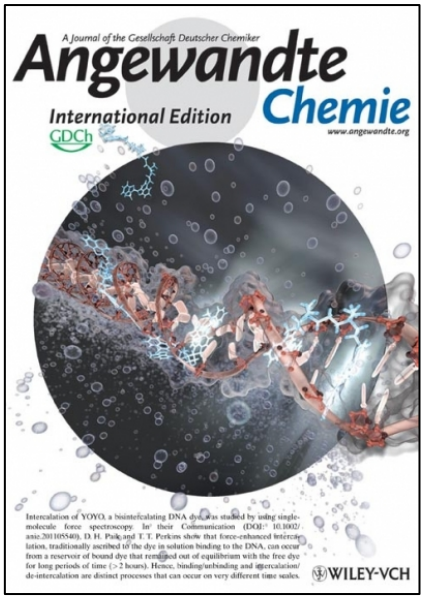


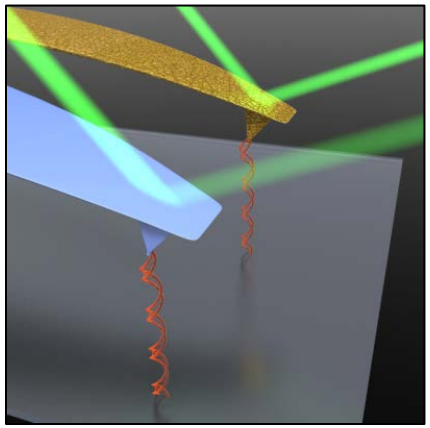
Super-radiant laser
James Thompson

A steady-state superradiant laser with less than one intracavity photon
Nature J.G. Bohnet; Z. Chen; J.M. Weiner; D. Meiser; M.J. Holland; J.K. Thompson (2012)

A Few Examples: Quantum Physics Division Accomplishments

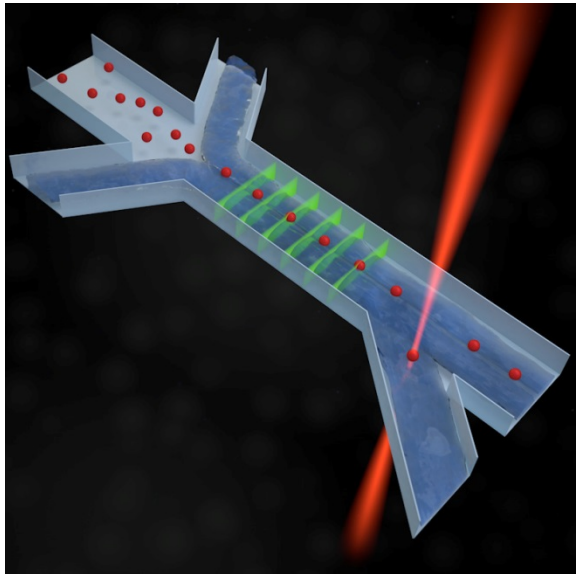
Biophysics (integrating JILA AMO expertise)





Precision DNA dynamics measurements with world's most stable AFM
Tom Perkins

H. D. Paik and Perkins, T. T. , "Dynamics and Multiple Stable Binding Modes of DNA Intercalators Revealed by Single-Molecule Force Spectroscopy", ***Angewandte Chemie*** *International Edition*, vol. 51, pp. 1731 – 1731 (2012)

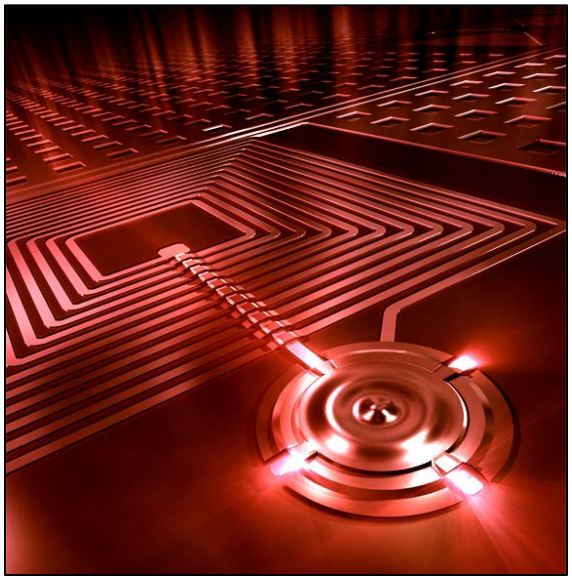


Orders of magnitude speed and accuracy increase in measurements of properties of individual living cells, and automated selection of desired cells
Ralph Jimenez

Microfluidic cytometer for high-throughput measurement of photosynthetic characteristics and lipid accumulation in individual algal cells R.A. Erickson and Jimenez, R., ***Lab On A Chip* 13** (2013)

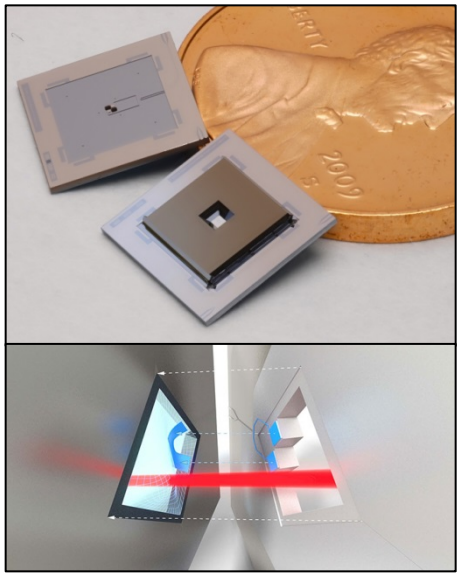
A Few Examples: Quantum Physics Division Accomplishments

Nanoscience



- *First cooling to quantum ground state of macroscopic object (microresonator)*
- *First entanglement of macroscopic object (microresonator) with photons (microwave field)*

Konrad Lehnert



First lossless coherent state transfer between optical and microwave fields; mediated by microresonator

Konrad Lehnert

Sideband cooling of micromechanical motion to the quantum ground state
J.D. Teufel, T. Donner, D. Li, J.W. Harlow, M.S. Allman, K. Cicak, A.J. Sirois, J.D. Whittaker, K.W. Lehnert, R.W. Simmonds, ***Nature*** 475, 359–363 (2011).

Entangling Mechanical Motion with Microwave Fields
T.A. Palomaki, J.D. Teufel, R.W. Simmonds, K.W. Lehnert, ***Science*** 342, 710-713 (2013).

Bidirectional and efficient conversion between microwave and optical light
R.W. Andrews, R.W. Peterson, T.P. Purdy, K. Cicak, R.W. Simmonds, C.A. Regal, K.W. Lehnert, ***Nature Physics*** 10, 321–326 (2014).

A Few Examples: Quantum Physics Division Accomplishments

- Selected examples of accomplishments 2010 – 2015 (through April 30, 2015):
  - 84 graduate students supported.
  - 59 postdocs supported.
  - ~30 Visiting Fellows supported.

Publications with Quantum Physics Division Authors

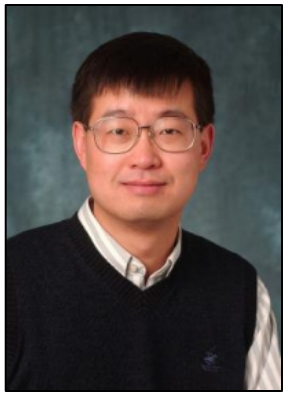
Calendar Year	Number of Publications
2010	85
2011	57
2012	83
2013	75
2014	58
2015 (through April 30, 2015)	17
Total	**375**

Journal	Number of Publications
Physical Review Letters	52
Nature group	29
Science	5
Optics Express	14
Optics Letters	7
Applied Physics Letters	2
Journal of Physical Chemistry Letters	3
Nano Letters	4
Biophysical Journal	22
Total	**131**

A Few Examples: Quantum Physics Division Accomplishments

- Awards to Quantum Physics Division scientists and trainees directly supported by NIST Cooperative Agreement.

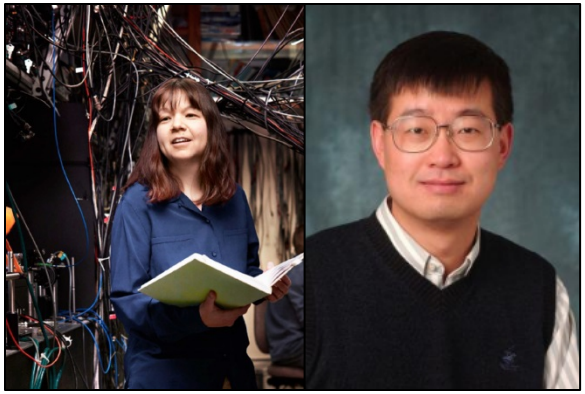
Recognition for Quantum Physics Division Scientists and Supported Trainees



Jun Ye
Election to National Academy of Sciences

Konrad Lehnert
APS Fellow

Ana Maria Rey
MacArthur Fellowship ("Genius Award")



Debbie Jin & Jun Ye
Dept. of Commerce Gold Medal

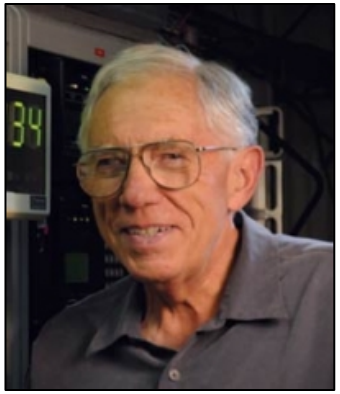
Eric Cornell
Marci Medal for Molecular Spectroscopy

Debbie Jin
L'Oreal/UNESCO Women in Science

Recognition for Quantum Physics Division Scientists and Supported Trainees

Ana Maria Rey
APS Maria Goeppert Mayer Award

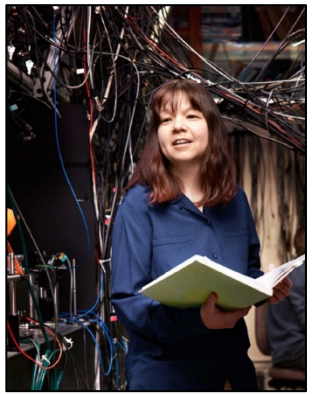
Steve Cundiff
OSA Meggars Award



Judah Levine
US Presidential Rank Award

David Nesbitt
Election to American Academy of Arts & Sciences

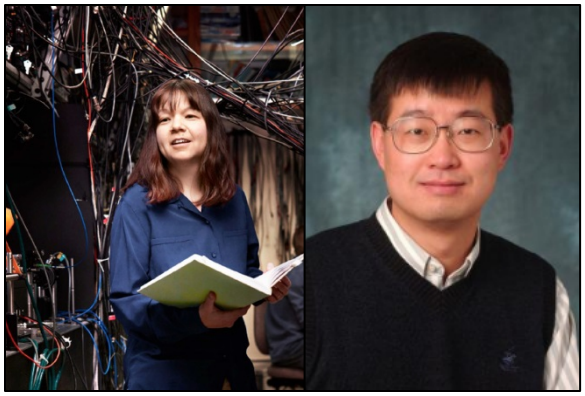
James Thompson
Dept. of Commerce Bronze Medal



Debbie Jin
UK IOP Isaac Newton Medal

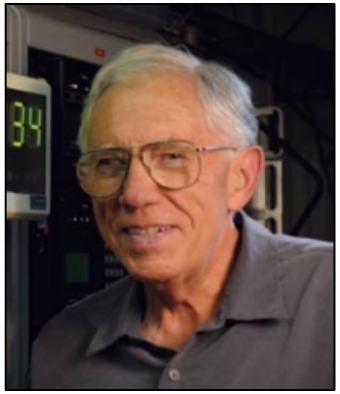
Recognition for Quantum Physics Division Scientists and Supported Trainees

Tom Perkins Flemming Award for Outstanding Federal Service



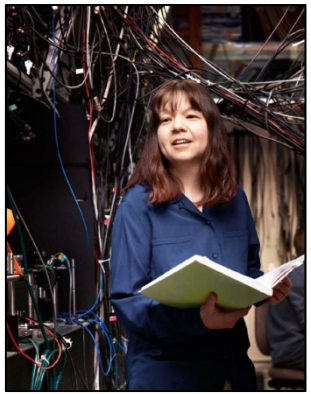
Debbie Jin & Jun Ye World's Most Influential Minds (Among top 144 most-cited physicists)

Ana Maria Rey Great Minds in STEM Most Promising Scientist



Judah Levine IEEE Rabi Award

Steve Cundiff IEEE Fellow



Debbie Jin NAS Comstock Prize in Physics

Recognition for Quantum Physics Division Scientists and Supported Trainees

Ana Maria Rey
Presidential
Early Career
Award
(PECASE)

Steve Cundiff
Dept. of
Commerce
Silver Medal

Michael Foss-Feig
(Rey grad student)
APS DAMOP Best
Thesis Award

Travis Nicholson
(Ye grad student)
IEEE Best Paper
Award

JILA
APS Physics
Historic Site

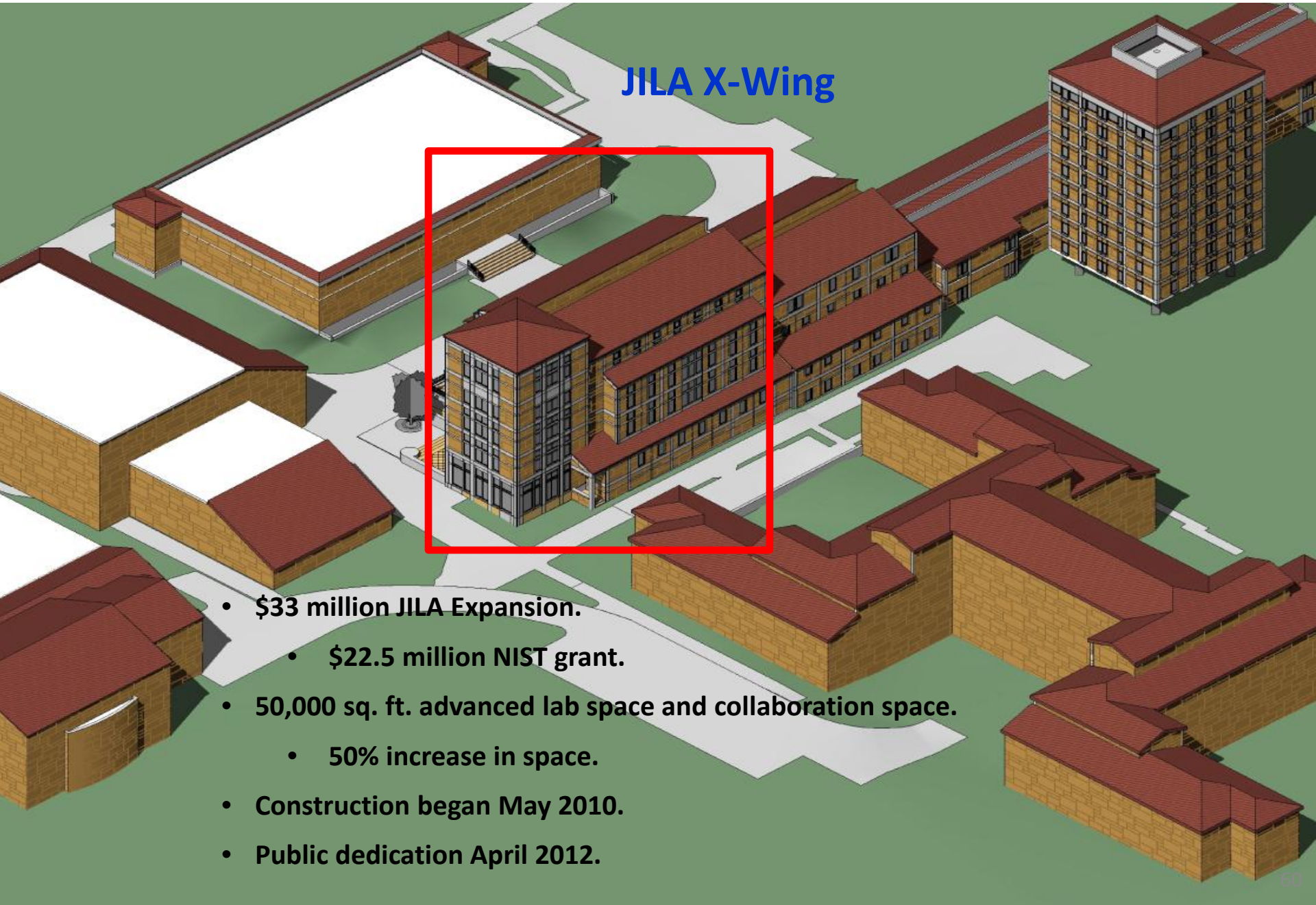
Quantum Physics Division Collaborations with other NIST Divisions

- A few selected examples, many more available:
  - Direct atomic clocks comparisons between JILA and NIST using BRAN fiber.
  - JILA theory support for NIST trapped ion array quantum simulation.
  - JILA/NIST “Molecular Movies” project: Ultrahigh speed x-ray spectroscopy.
  - JILA/NIST frequency comb development and applications.
  - JILA/NIST collaborations on quantum state engineering of micromechanical systems.
  - JILA/NIST joint studies of large biomolecules.
  - Training: More than half the scientists in Time and Frequency Division were trained at JILA (students, postdocs, etc.).

A Few Examples: Quantum Physics Division Accomplishments

- Continual evolution into new scientific areas.
    - Cold atoms $\rightarrow$ Cold molecules.
    - Individual quantum objects $\rightarrow$ Collective quantum phenomena.
    - Extend frequency comb research and applications into XUV and far IR.
    - Expansion beyond "traditional" JILA AMO programs:
        - Growing strength in biophysics.
        - Growing strength in nanoscience.
        - Both well integrated into "traditional" JILA AMO programs.

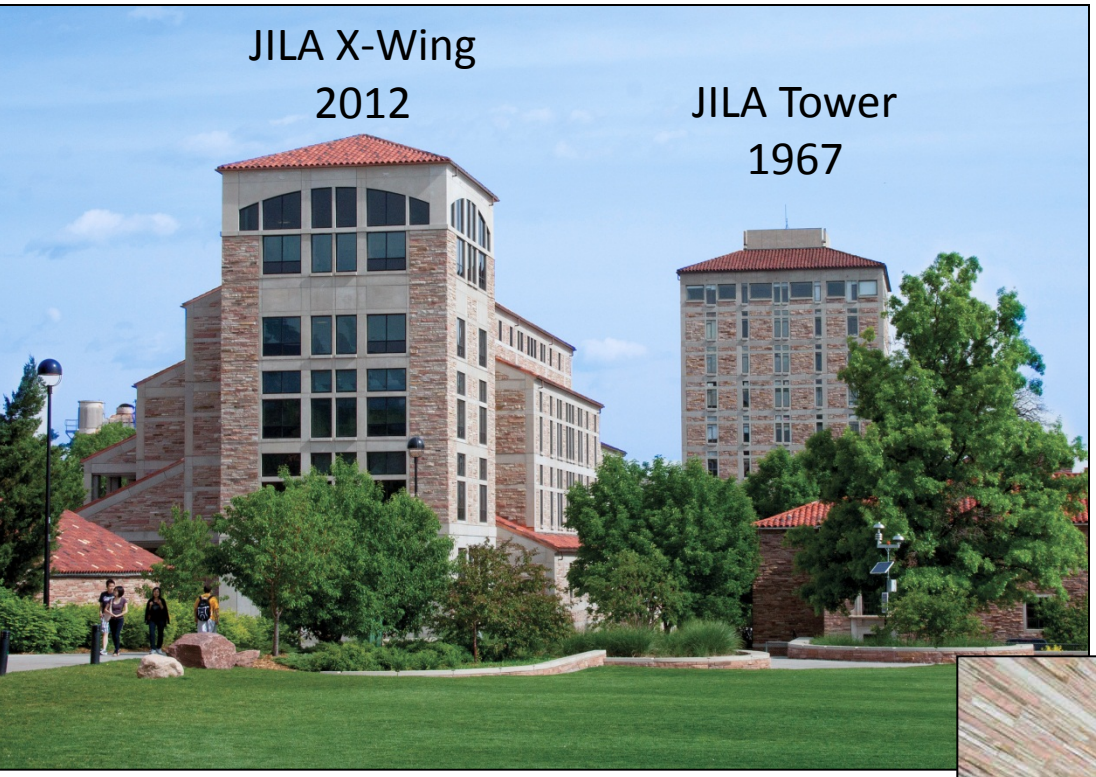
A Few Examples: Quantum Physics Division Accomplishments



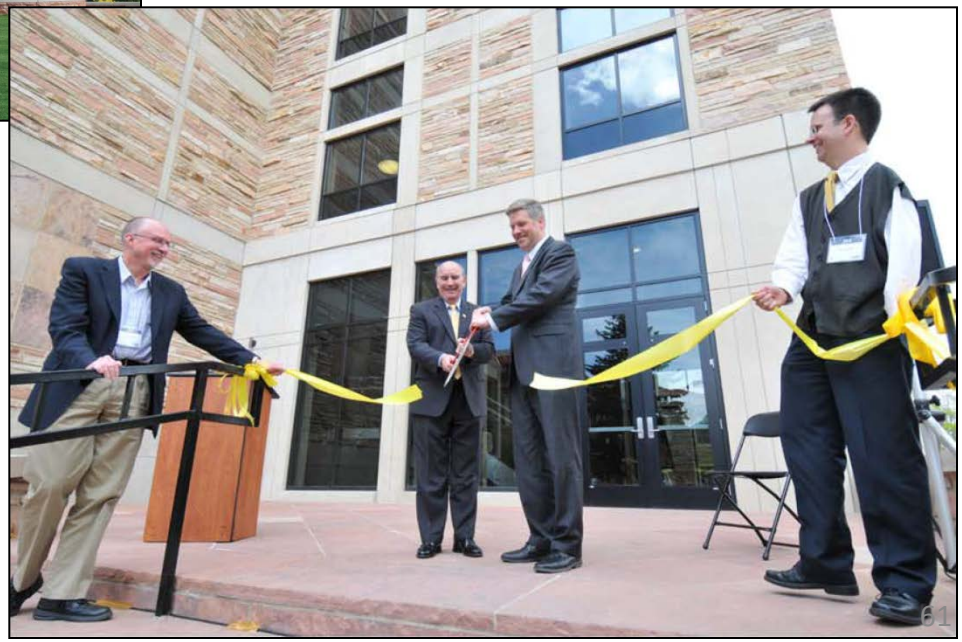
JILA X-Wing

- $33 million JILA Expansion.
  - $22.5 million NIST grant.
- 50,000 sq. ft. advanced lab space and collaboration space.
  - 50% increase in space.
- Construction began May 2010.
- Public dedication April 2012.

A Few Examples: Quantum Physics Division Accomplishments



JILA X-Wing Dedication
April 13, 2012



A Few Examples: Quantum Physics Division Accomplishments

- Retention:
  - Successfully retained top young NIST JILAns against very strong external recruitment offers.

Ana Maria Rey
AMO Theory

Konrad Lehnert
Nanoscience

  - Lost one senior NIST JILAn to very strong external offer.

Steve Cundiff
Ultrafast AMO

Future of Quantum Physics Division

- New research areas:
  - Advance cold molecule programs.
  - Advance generation and control of light into new spectral areas (XUV, far IR, etc.).
  - New focus on collective quantum phenomena.
    - Strengthen both experimental and theoretical programs.
    - New Center for Theory of Quantum Matter.
      - JILA, CU Physics, NIST.
  - Recruit top young new NIST JILA Fellow.

Assessment of the NIST Quantum Physics Division

Charge to the NRC Board on Assessment of NIST Programs from the NIST Director through contract with NRC (*paraphrased*):

1. Technical programs.
   - Quality of research compared to rest of world.
   - Are technical programs adequate to achieve stated mission?

2. Scientific expertise.
   - Quality of technical staff compared to rest of world.
   - Is technical staff expertise adequate to achieve stated mission?

3. Infrastructure.
   - Are quality of facilities, equipment, human resources adequate to achieve stated mission?

4. Dissemination of outputs.
   - How effectively does the organization disseminate/transfer its outputs?

Assessment of the NIST Quantum Physics Division

1. Technical programs.
   - Quality of research compared to rest of world.
   - Are technical programs adequate to achieve stated mission?

Long list of best in the world / first in the world programs and accomplishments in:

- Cold atoms.
- Quantum degenerate gas mixtures.
- Cold molecules and chemistry.
- Atomic clocks.
- Frequency comb development and applications.
- Ultrafast spectroscopy of solids.
- Precision measurements.
- Force spectroscopy of biomolecules.
- Biophotonics.
- Quantum states of micromechanical objects.
- Quantum electro-opto-mechanical transduction.
- Innovative laser development.
- More…

- Outputs/outcomes from 12 Quantum Physics Division PIs…

Assessment of the NIST Quantum Physics Division

2. Scientific expertise.
   - Quality of technical staff compared to rest of world.
   - Is technical staff expertise adequate to achieve stated mission?

- List of innovations and accomplishments in very challenging areas confirms quality of scientific staff.

- Multiple international awards and recognition for Quantum Physics Division scientists and trainees.

- On-going intensive recruitment efforts on Quantum Physics Division scientists demonstrates stature.

Assessment of the NIST Quantum Physics Division

3. Infrastructure.

- Are quality of facilities, equipment, human resources adequate to achieve stated mission?

- Facilities.
  - Original labs (constructed 1967 and 1988) not sufficient to support the most demanding research and measurements.
  - X-Wing commissioned in 2012.
    - State of the art lab performance.
      - Temperature control.
      - Vibration isolation.
      - Air quality.
    - Increases lab and collaboration space by 50%.
    - Designed to encourage “productive collisions.”

Assessment of the NIST Quantum Physics Division

3. Infrastructure.

- Are quality of facilities, equipment, human resources adequate to achieve stated mission?

- Equipment.
  - Generally sufficient funding to acquire any needed equipment and supplies.
  - NIST 50% overhead on equipment is barrier to large capital equipment purchases.
- Budget.
  - JILA Fellows (Quantum Physics Division and CU) forced to spend more time applying for grants, lower success rate, increasing restrictions on how grants can be spent, etc.
  - Overall, sufficient funding through combination of NIST, CU and external grants.

Assessment of the NIST Quantum Physics Division

3. Infrastructure.

- Are quality of facilities, equipment, human resources adequate to achieve stated mission?

- Technical support.
  - Unique, highly-productive JILA instrument shops.
  - Highly productive JILA electronics shop.
  - Highly effective JILA IT shop.
  - JILA Clean Room.
  - JILA Keck Lab (imaging and analytical capabilities).

Assessment of the NIST Quantum Physics Division

3. Infrastructure.

- Are quality of facilities, equipment, human resources adequate to achieve stated mission?

- Administrative support.
  - Significantly stronger investment in administrative support (proportionally) than in “regular” NIST Divisions.
  - Attempt to minimize the administrative workload on scientific staff.
  - Reduces total funding available for research, but seems to be net productivity gain.

Assessment of the NIST Quantum Physics Division

4. Dissemination of outputs.

- How effectively does the organization disseminate/transfer its outputs?

- Very strong record of high impact publications.

- Patents.

- Significant new technology development, innovation.

- Extremely strong record of training next generation of scientists, metrologists, innovators, entrepreneurs.
  - 400 JILA-trained employees and associates at NIST.
  - Many at industry labs.
  - Many start new high-tech companies.
  - Many have university faculty positions.

- Strong Visiting Fellow program refreshes and disseminates JILA knowledge.

- Exchange of skilled people is most effective form of tech/knowledge transfer.

Assessment of the NIST Quantum Physics Division

Charge to the NRC Board on Assessment of NIST Programs from the NIST Director through contract with NRC (*paraphrased*):

1. Technical programs.
   - Quality of research compared to rest of world.
   - Are technical programs adequate to achieve stated mission?

2. Scientific expertise.
   - Quality of technical staff compared to rest of world.
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3. Infrastructure.
   - Are quality of facilities, equipment, human resources adequate to achieve stated mission?

4. Dissemination of outputs.
   - How effectively does the organization disseminate/transfer its outputs?

JILA "Secret Sauce" – A Highly Personal View

What has made JILA successful?

- JILA is obviously not the only model for successful university/government partnerships. But consider some of the factors that have contributed to JILA's success.

- At its 1962 founding, JILA was not a predestined success.
  - An attempt by NIST (then NBS) scientists to break free from the organization and establish a new research direction (laboratory astrophysics).
  - University of Colorado not a top tier physical sciences research university at that time.
  - Original scientific vision has dramatically evolved. "Laboratory astrophysics" as envisioned by the JILA founders is essentially non-existent today at NIST or JILA.

JILA "Secret Sauce" – A Highly Personal View

What has made JILA successful?

- Some factors in JILA's success (a personal view):
  - Intentional creation and maintenance of a strong JILA-centric culture.
    - Demand collaboration and cooperation among Fellows.
    - High expectations for research, training, support services.
  - Fund for success.
    - Limited number of well-supported JILA Fellows.
    - Strong investment in JILA infrastructure.
      - World-class Instrument shop, Electronics shop, IT support.
      - High performance administrative support.
  - Encourage and embrace continual evolution.
    - Essentially zero laboratory astrophysics conducted at JILA now.
    - Leverage AMO strengths into new areas of biophysics and nanotechnology.
    - Favor new JILA Fellows who are likely to pioneer new research directions, while embracing the JILA culture.
  - Limit size to ensure the above.

JILA "Secret Sauce" – A Highly Personal View

What has made JILA successful?

- Some factors in JILA's success (a personal view):
    - Internal shared governance.
        - Key strategic and operational decisions made by JILAns.
        - Substantial independence from parent organizations (NIST and CU) in scientific decision-making.
        - JILA internal decisions consistent with broad goals of parent organizations.

JILA "Secret Sauce:" Culture and Investment

- JILA shared governance by JILA Fellows.
  - Adhere to broad NIST and CU goals, but substantial independence from parent organizations in scientific decision-making and in internal operations.

- Encourage/demand collaboration and cooperation.
  - Among JILA Fellows.
  - Active visitor/external collaborator programs.

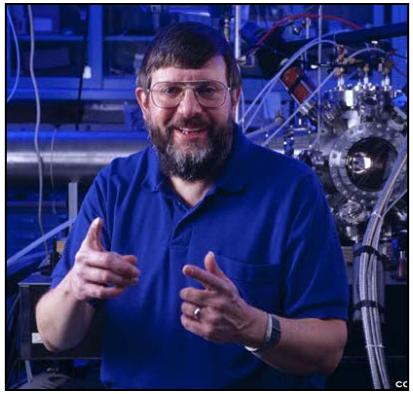
- Strong investment in limited number of the best people.

- Strong investment in research infrastructure.
  - Instrument shop with highly skilled instrument makers.
  - Electronics shop with highly skilled designers/technicians.
  - IT.
  - Administrative support.

- Long-term stable NIST and CU investment.
  - About 1/3 of total Institute funding from NIST.
  - Leverage NIST, CU, Federal-funding agency investments.

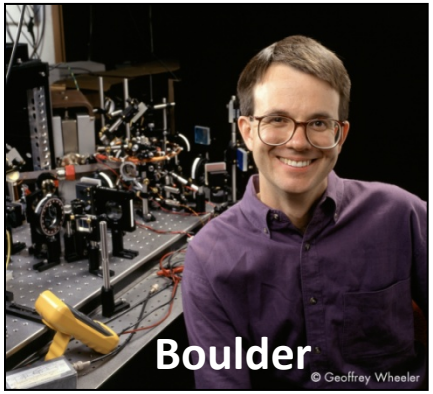
- Invest in high quality public outreach.
  - Celebrate success, tell the stories to different audiences.

NIST Nobel Research: World-leading Science with Direct Mission Impact



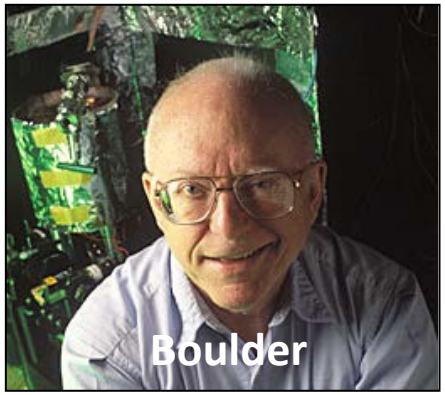
Bill Phillips, 1997
Laser cooling of neutral atoms. Used every day for NIST-F1/F2 primary frequency standards, source of all NIST time and frequency measurements. Crucial to many other precision measurements.

NIST and JQI



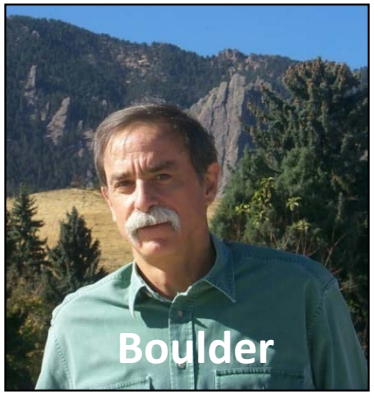
Eric Cornell, 2001
BEC (new quantum states of matter). New laboratory for understanding superconductivity, magnetic data storage, etc. Many future impacts in precision measurements.

NIST and JILA



Jan Hall, 2005
Laser frequency comb. Biggest revolution in precision measurements since laser (1960). Used in atomic clocks, medical diagnostics, remote chemical analysis, communications, identifying exoplanets, much more…

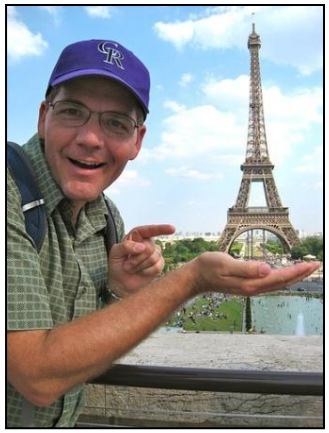
NIST and JILA

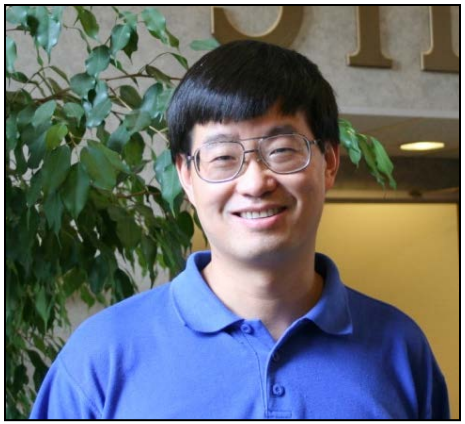


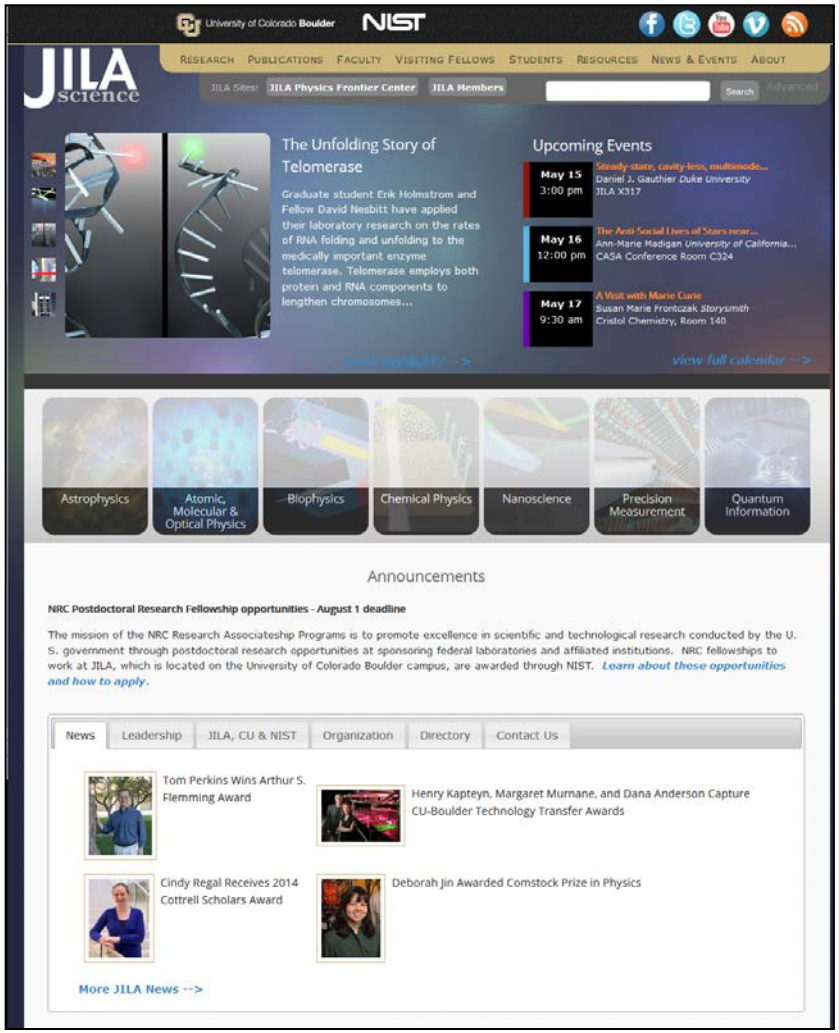
Dave Wineland, 2012
Quantum state measurement and manipulation. Used in world's most accurate atomic clocks, quantum computing, quantum simulation, 10^{-22} newton force measurements, future precision metrology.

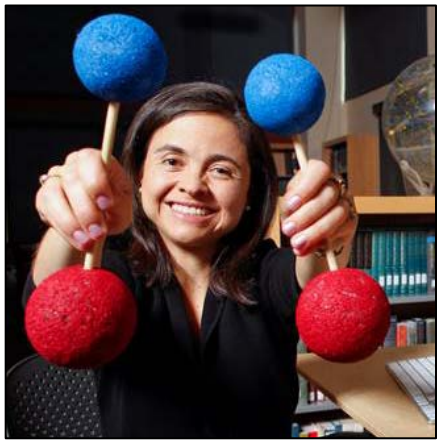
NIST and CU

jila.colorado.edu









Assessment of the NIST Quantum Physics Division

Questions?

Comments?

Discussion?