Physics Careers in Government Agencies

by
David G. Seiler
Chief, Semiconductor Electronics Division, National Institute of Standards and Technology, Department of Commerce

Presented at the March
American Physical Society Meeting
March 14, 2010

Agenda

- Who Am I?
- Where Do I Work?
  - Department of Commerce
  - NIST
- What Does NIST do?
- What Is a Physicist?
  - Education
  - Characteristics of Physicists
- Physicists in the Federal Government
  - Finding a Job
- Career Advancement at NIST
- How Did I Get Here?
- Reflections from a Government Physicist
- Summary and Conclusion

Why Should You Listen to Me?

- Worked for the same Federal Agency (NIST) for the past 22 years and spent 1 year at the National Science Foundation
- Currently holds leadership role (Division Chief) at the National Institute of Standards and Technology
- Made a mid-career transition from University work to Government work – unique perspective on both career paths

Department of Commerce

Gary F. Locke
Secretary of Commerce

Dennis F. Hightower
Deputy Secretary of Commerce

Gary F. Locke confirmed as US Commerce Secretary on March 24, 2009

Dennis F. Hightower confirmed as Deputy Secretary of Commerce on August 7, 2009

- National Oceanic and Atmospheric Administration
- International Trade Administration
- US Patent and Trademark Office
- **National Institute of Standards & Technology**
- Economics and Statistics Administration
- other agencies...

The historic mission of the Department is "to foster, promote, and develop the foreign and domestic commerce" of the United States. This has evolved, as a result of legislative and administrative additions, to encompass broadly the responsibility to foster, serve, and promote the Nation's economic development and technological advancement.

Patrick D. Gallagher
Director

President Obama's nominated Dr. Gallagher to be the 14th Director of NIST on September 10, 2009. Confirmed by the Senate on November 5, 2009.

President's Science and Innovation Plan

President Barack Obama gives a speech at the National Academy of Sciences on April 27, 2009.

Commerce Secretary Gary Locke and Harvey V. Fineberg President of the Institute of Medicine., NAS.

- The President's budget recognizes that NIST is a capable partner that is strategically positioned to help the Nation improve its innovation performance and respond effectively and efficiently to national priorities.
  - Double NIST laboratory/construction budget
  - Growth of Hollings MEP Program
  - Growth of Technology Innovation Program
- NIST programs align well with Presidential priorities:
  - Smart Grid
  - Health IT
  - Cyber-security
  - Manufacturing
  - Innovation and competiveness

Photos by Patricia Pooladi courtesy National Academy of Sciences.

President's Innovation Strategy:

Driving Towards Sustainable Growth and Quality Jobs

Innovation for Sustainable Growth and Quality Jobs

August 5, 2009

Catalyze Breakthroughs for National Priorities

- Unleash a clean energy revolution
- Support advanced vehicle technology
- Drive breakthroughs in health IT
- Address the "grand challenges" of the 21st century

Promote Competitive Markets that Spur Productive Entrepreneurship

- Promote American exports
- Support open capital markets that allocate resources to the most promising ideas
- Encourage high-growth and innovation-based entrepreneurship
- Improve public sector innovation and support community innovation

Invest in the Building Blocks of American Innovation

- Restore American leadership in fundamental research
- Educate the next generation with 21st century knowledge and skills while creating a world-class workforce
- Build a leading physical infrastructure
- Develop an advanced information technology ecosystem

National Institute of Standards and Technology

NIST Mission

- To promote U.S. innovation and industrial competitiveness by advancing
  - measurement science,
  - standards, and
  - technology

  in ways that enhance economic security and improve our quality of life

NIST Assets Include:

- 2,900 employees
- 1,800 associates
- $843 million operating budget
- NIST Laboratories – National measurement standards
- Manufacturing Extension Partnership
- Baldrige National Quality Award
- Technology Innovation Program

"…NIST is the only Federal research agency with the express mission of working with industry to keep US technology at the leading edge…"

Science for the 21st Century, July 2004

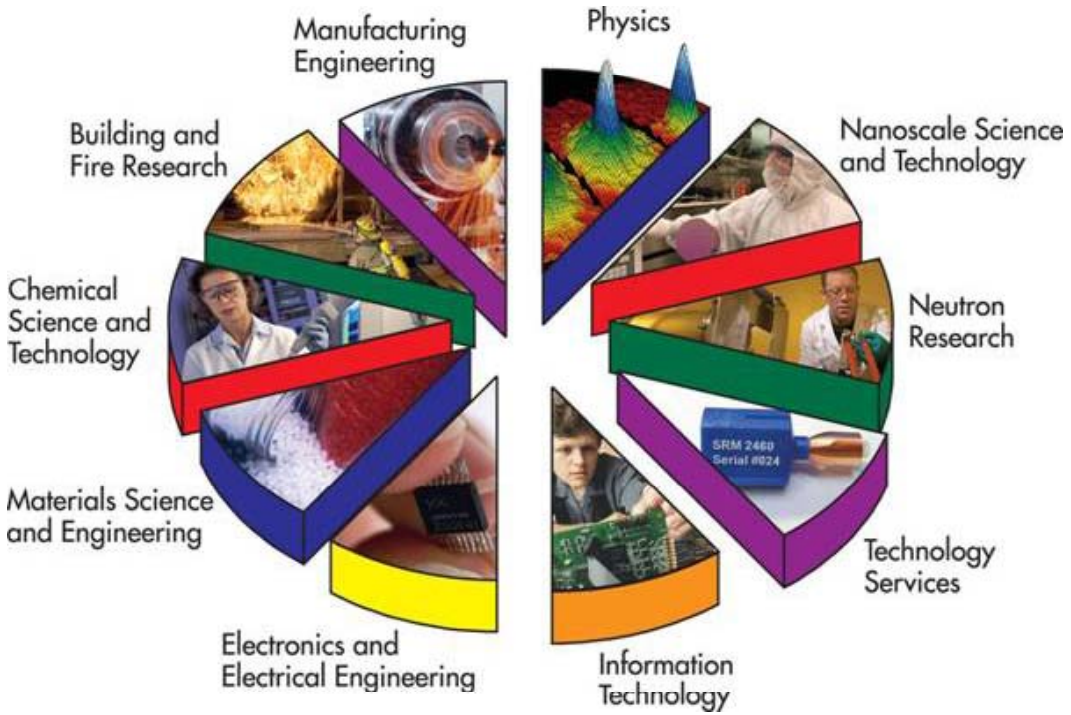
The NIST Laboratories

NIST's work enables

- Science
- Technology innovation
- Trade
- Public benefit

NIST works with

- Industry
- Academia
- Other agencies
- Government agencies
- Measurement laboratories
- Standards organizations



Electronics and Electrical Engineering Laboratory (EEEL) Organization

EEEL Laboratory Headquarters
Kent Rochford, Acting Director
James Olthoff, Deputy Director

Office of Law Enforcement Standards
Mark Stolorow

Office of Microelectronics Programs
J. V. Martinez de Pinillos

Optoelectronics Division

Perry Wilson (Acting Chief)

Semiconductor Electronics Division
David Seiler

Quantum Electrical Metrology Division
Michael Kelley (Acting Chief)

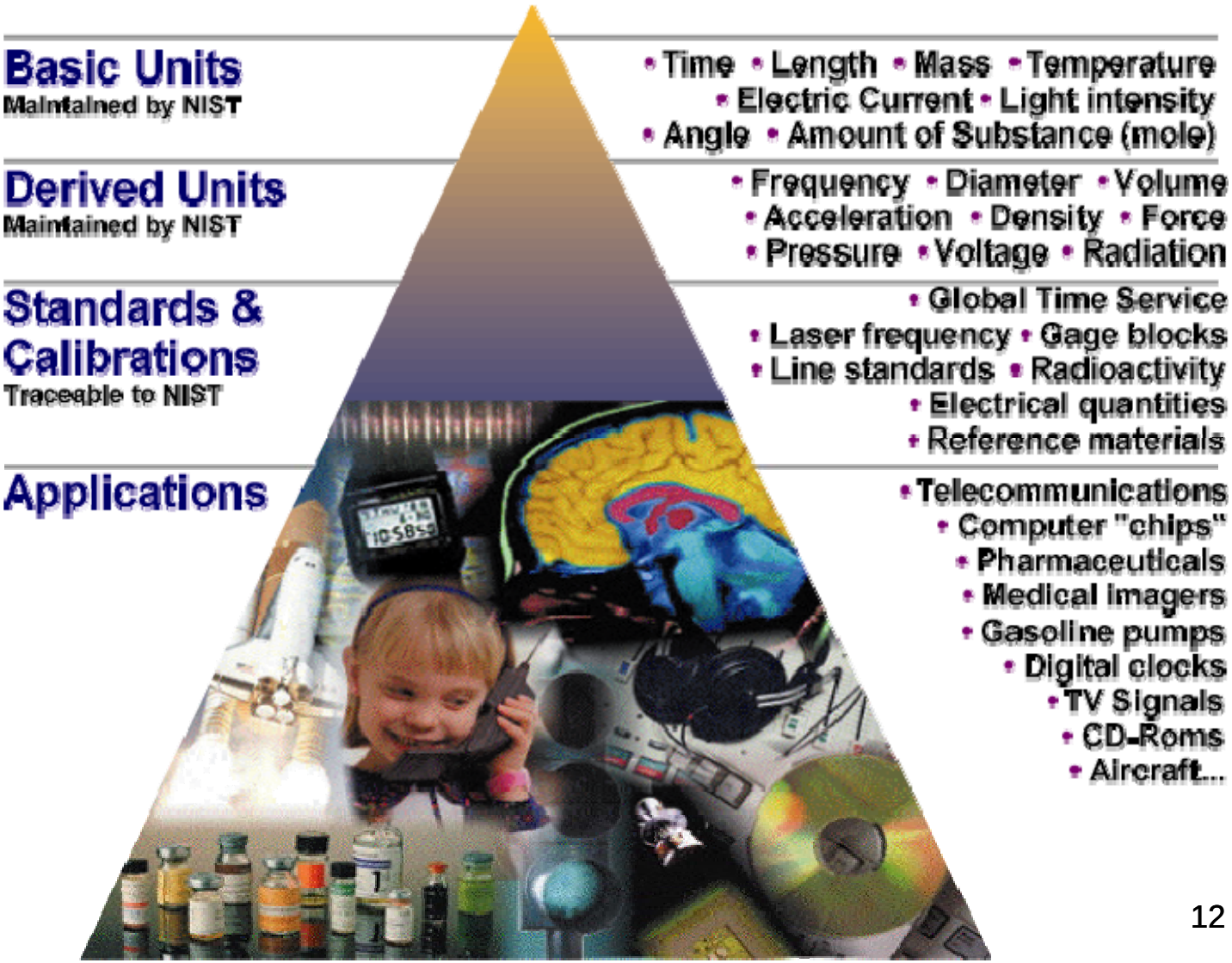
Electromagnetics Division
Robert Hickernell
(Acting Chief)

I Have the Privilege of Working with Great People

Division Program/Project Research Areas

- MicroNanoTechnology
  - MEMS (test methods and standards)
  - Microfluidics (cellular biometrology)
  - Bioelectronics (interface between electronics & biological systems)
  - Nanoparticles (self-assembly & characterization)
  - Center for MicroRobotics (metrology needs)
- Nanobiotechnology
  - Nanopore metrology (world-class)
  - Single molecules
    - Detection and mass spectrometry
    - Combined optical/electrical metrology
- Power Electronics
  - SiC device metrology
  - Leadership with DARPA
  - Fuel cell electrical metrology with DoE
- Extreme CMOS (Electrical & reliability characterization)
  - Advanced gate dielectrics
  - New material systems
  - Advanced structures (FINFETs, etc.)
- Beyond CMOS or Nanoelectronics (test structures & test methods)
  - Molecular electronics
  - Si Nanowires
- Organic/Macro Electronics
  - Facilities for fabricating state-of-the-art devices
  - Accurate dc measurements & modeling
  - Defect spectroscopy at critical interfaces
  - Reliability program (1st of kind)
- Center for Nanoelectronics Device Reliability
- Information Technology & Software
  - Electronic Date Exchange
  - Time stamping
  - Materials data exchange for PC boards
  - Sensor simulation test bed for on-board clocks

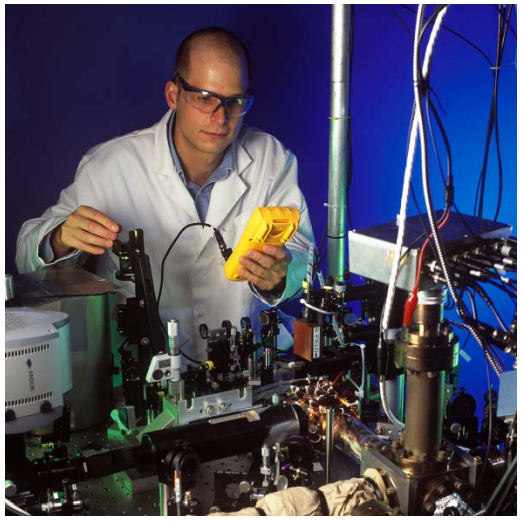
U.S. Economy Depends on NIST Measurements



Advanced Standards: The Electronic Kilogram

- Lowest uncertainty of 36 x 10-9 reported on value of Planck constant in 2005
- New values consistent with system rebuilt after 1998
- Apr 2005 Metrologia paper sparked CIPM decision to consider redefinition of kilogram
- Participating in annual discussions between the other metrology laboratories working on similar experiments

NIST Atomic Clock



Adjusting the quantum logic clock, which derives its “ticks” from the natural vibrations of an aluminum ion (electrically charged atom).

- NIST's atomic clock in Boulder, Colorado, serves as the ultimate standard for setting every wristwatch, every wall clock, every computer clock.
- The NIST F1 atomic clock which was developed, maintained, and improved by NIST, provides a time standard crucial for the leading edges of military and civilian technology and of science. It will neither gain nor lose one second in 60 million years.
- www.time.gov receives billions of hits daily.
- NIST is collecting data on two next-generation clocks: a mercury-based clock and an aluminum-based one (see left picture). Both clocks were built at NIST and both are at least 10 times more accurate than the current U.S. time standard, which is based on NIST’s F1 atomic clock.

NIST Center for Neutron Research (NCNR)

- **Neutron-based measurements are critical for 21st century innovation**
  - Determining the structure of materials and devices at the nanometer scale
  - Discover advanced new materials for technologies beyond semiconductors

- NCNR is the most reliable, most capable & most used facility for cold neutron research in the United States, serving over 2000 research participants per year
- Neutron Techniques
  - crystallography, reflectometry, small angle neutron scattering, spectroscopy, chemical analysis, and other methods (including interferometry, radiography, and fundamental physics)
- Center for High Resolution Neutron Scattering (CHRNS)
  - Is a joint NSF/NIST national user facility within NCNR for use by the general scientific community

www.nist.gov/ncnr/

The Graphene Collaboration

CNST: Joseph Stroscio, Nikolai Zhitenev, Mark Stiles, Gregory Rutter, Suyong Jung, Hongki Min, Shaffique Adam, Young Kuk (Seoul Nat. U.)
EEEL: David Newell, Nikolai Klimov, Curt Richter, Mark Keller PL: Angela Hight-Walker MSEL: Jan Obrzut, Eric Cockayne
GaTech (NRI INDEX): Philip First, Walter de Heer, Lee Miller, Kevin Kubitsa UTAustin (NRI SWAN): Allan MacDonald

Graphene Synthesis

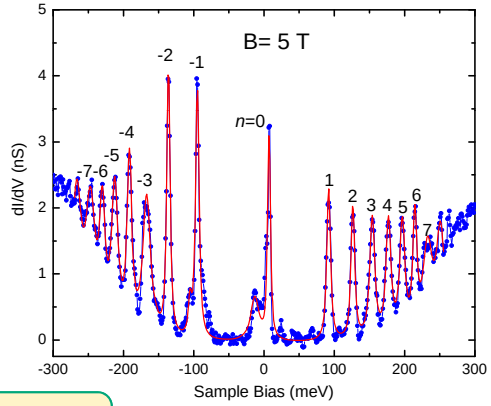
Three zone furnace (up to 1100 ˚C)

CMOS Thermal Oxidation and Diffusion Furnace

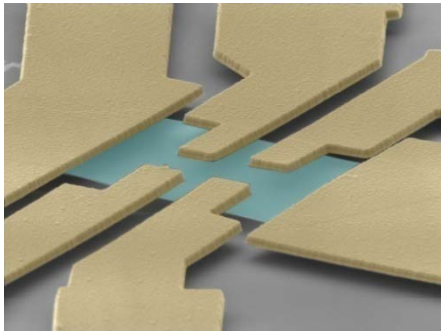
Graphene Metrology

ULT STM

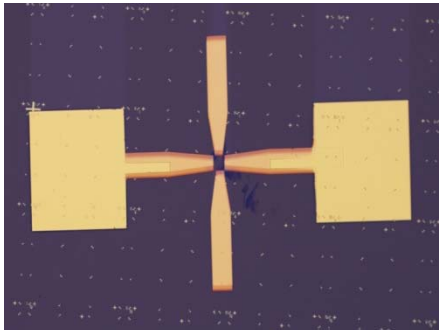
Landau Levels in Epitaxial Graphene



Device Fabrication



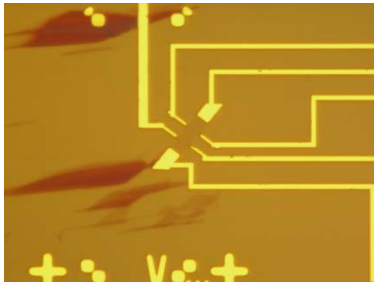
Suspended Graphene Transport Device

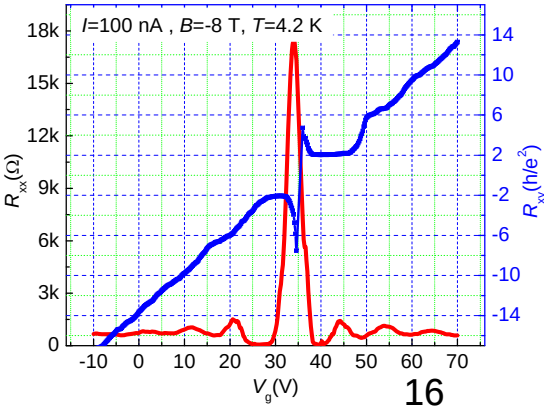


Device for STM Measurements

Device Characterization

Quantum Hall Effect in Single-Layer Graphene





www.nist.gov/cnst/

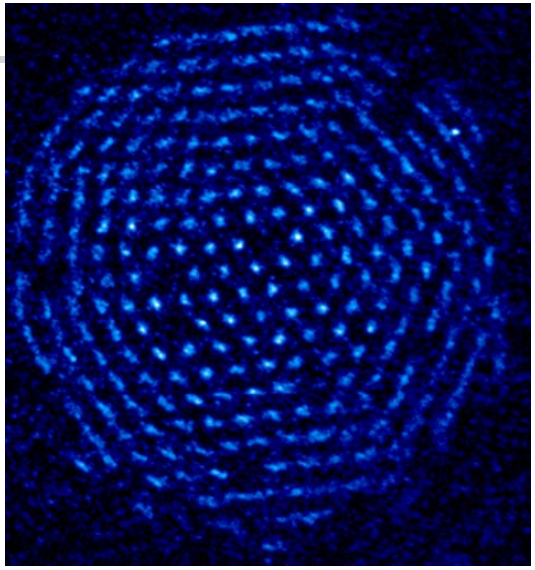
NIST Addressing Critical National Needs – Quantum Science and Cyber Security

Quantum-based Measurements – expands NIST's world-leading work in quantum science

- New tools to control, manipulate, and characterize quantum components to simulate more complex quantum systems
- Quantum tools to develop and disseminate standards, e.g., time
- Information Technology Security

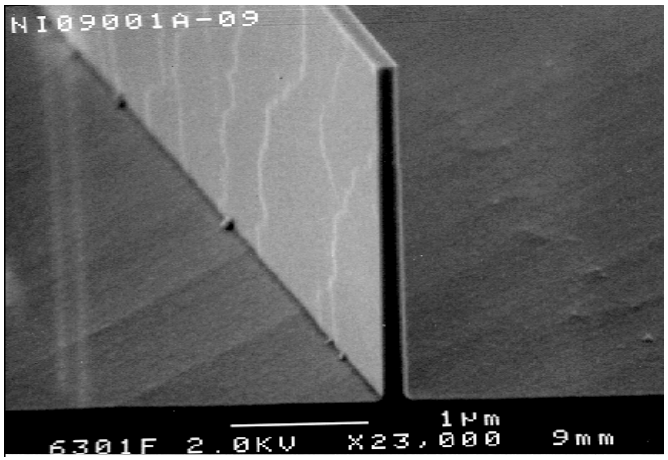
Cyber Security: Leap-Ahead Security Technologies for Interconnected Systems

- Improved cryptographic key management
- Improved understanding of security vulnerabilities of cloud and virtual networks
- Improved usability of security systems and technologies



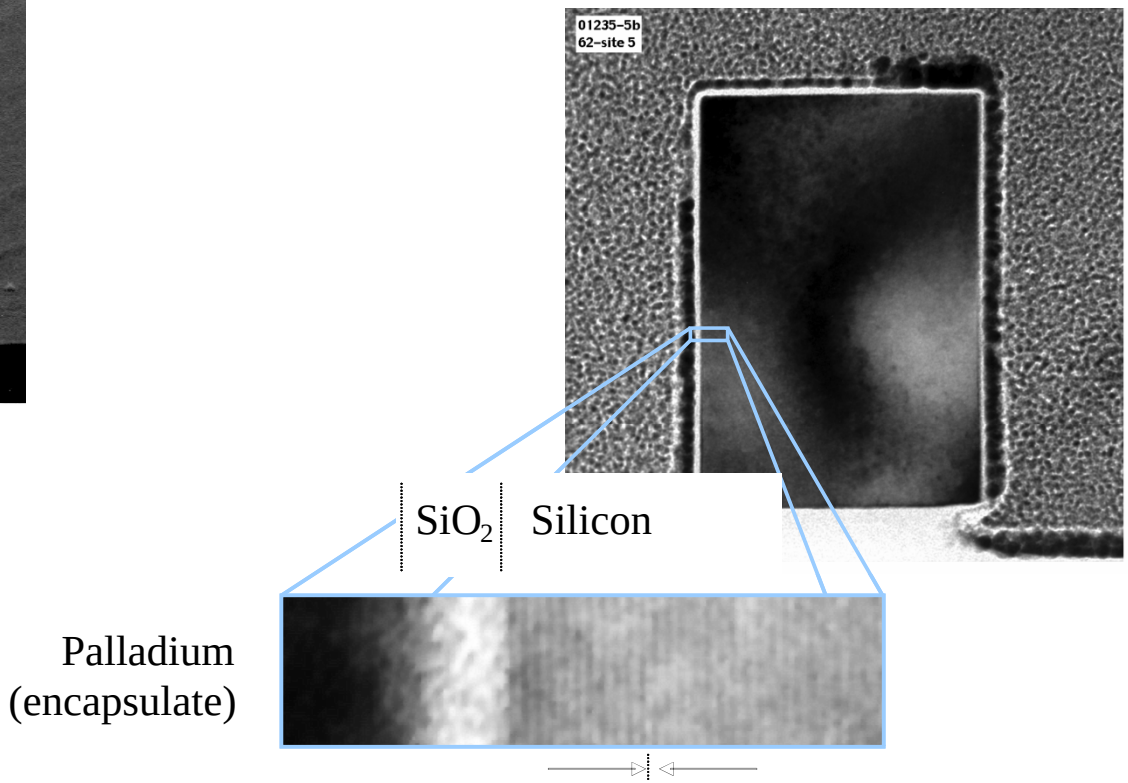
Credit: NIST

CD Reference Materials Uses Atomic Lattice for Calibration*



- Urgent need for critical dimension (CD) reference materials
- Uncertainty in a 100 nm CD line demonstrated to be about 1 nm
- Meets the need to compare CDs as measured on diverse metrology tools

HRTEM Image of 100 nm line



Fringe spacing = 0.313 560 137 nm

*Work supported in part by SEMATECH and VLSI Standards.

NIST Nobel Prizes for Physics

John L. (Jan) Hall, 2005

… for contributions to the development of laser-based precision spectroscopy, including the optical frequency comb technique

Eric A. Cornell, 2001

… for research leading to the landmark 1995 creation of the Bose-Einstein condensate and early studies of its properties

William D. Phillips, 1997

… for development of methods to cool and trap atoms with laser light

Physics – What Is It?

- Physics is the basis of science and technology. It deals with how and why matter and energy act as they do.
- Physics is a passport into a broad range of science, engineering, and education careers
- People then tend to specialize
  - Astrophysics, solid state, quantum, space, applied, medical, bio, nuclear, geo, health, laser, elementary particle, theory, nano, etc
- Physics is often driven by a strong curiosity combined with a process of ongoing learning – delve down into the underlying reasons why and how things work
- Many physicists are attracted by the fact that they have a chance to break new ground, a lot of what happens and a lot of what they work on has not been done before by anyone. It's often all new, frontier work.

What is a Physicist?

- **The physicist deals with all aspects of matter and energy.**
- **Categories for the study of physics :**
  - **Motion and properties of physical objects both large and small (classical and quantum mechanics, astrophysics),**
  - **Properties of waves (optics, acoustics, electromagnetics),**
  - **Properties of states of matter (solid state, plasma physics),**
  - **Fundamental properties of matter and energy (atomic, nuclear, and particle physics),**
  - **Specialization in theoretical and/or experimental work.**
- **Physics studies range from basic research of the fundamental laws of nature to the practical development of semiconductor devices & instruments, as well as the development of standards that enable commerce.**

Undergraduate Training

Broad Exposure in Physics

- **Mechanics**
- **Electrostatics**
- **Electricity and Magnetism**
- **Heat and Thermodynamics**
- **Optics**
- **Solid State Physics**
- **Nuclear Physics**
- **Principles of Quantum Mechanics**
- **Good background in Mathematics**
- **Life sciences and Engineering Basic Courses**

Graduate Training

Specialize

Develop discipline to formulate and carry out independent research

- **Study advanced courses**
- **Choose a thesis topic**
- **Develop a research plan**
- **Set up the equipment (Experiment)**
- **Run the experiment**
- **Collect data**
- **Analyze the data**
- **Make empirical deductions**
- **Develop theory & model**

Physicists Are Diversified

Because of their broad scientific background, physicists in government branch out into engineering fields and other scientific fields, working with engineers and other scientists in overlapping areas. Physicists are known for their ability to work in many areas and have helped create many non-traditional fields.

See Summary Report 19-2012.00 for Physicists from O*NET OnLine (online.onetcenter.org/link/summary/19-2012.00)

Physicist Qualities or Abilities Deemed Valuable

- Planning, organizing, and conducting research
- Problem solving
- Intellectual and personal creativity/imagination/inventiveness
- Working with a complex body of knowledge
- Working with computers
- Using advanced mathematical formulas and concepts
- Communication of one's ideas in spoken and in writing essential
- Teamwork spirit and ability to work cooperatively with others
- Versatility
- Applying abstract theories to practical problems
- Understanding and applying the scientific method
- Doing detailed work accurately and consistently
- Developing new technologies
- Honesty in dealing with data, theory, and colleagues

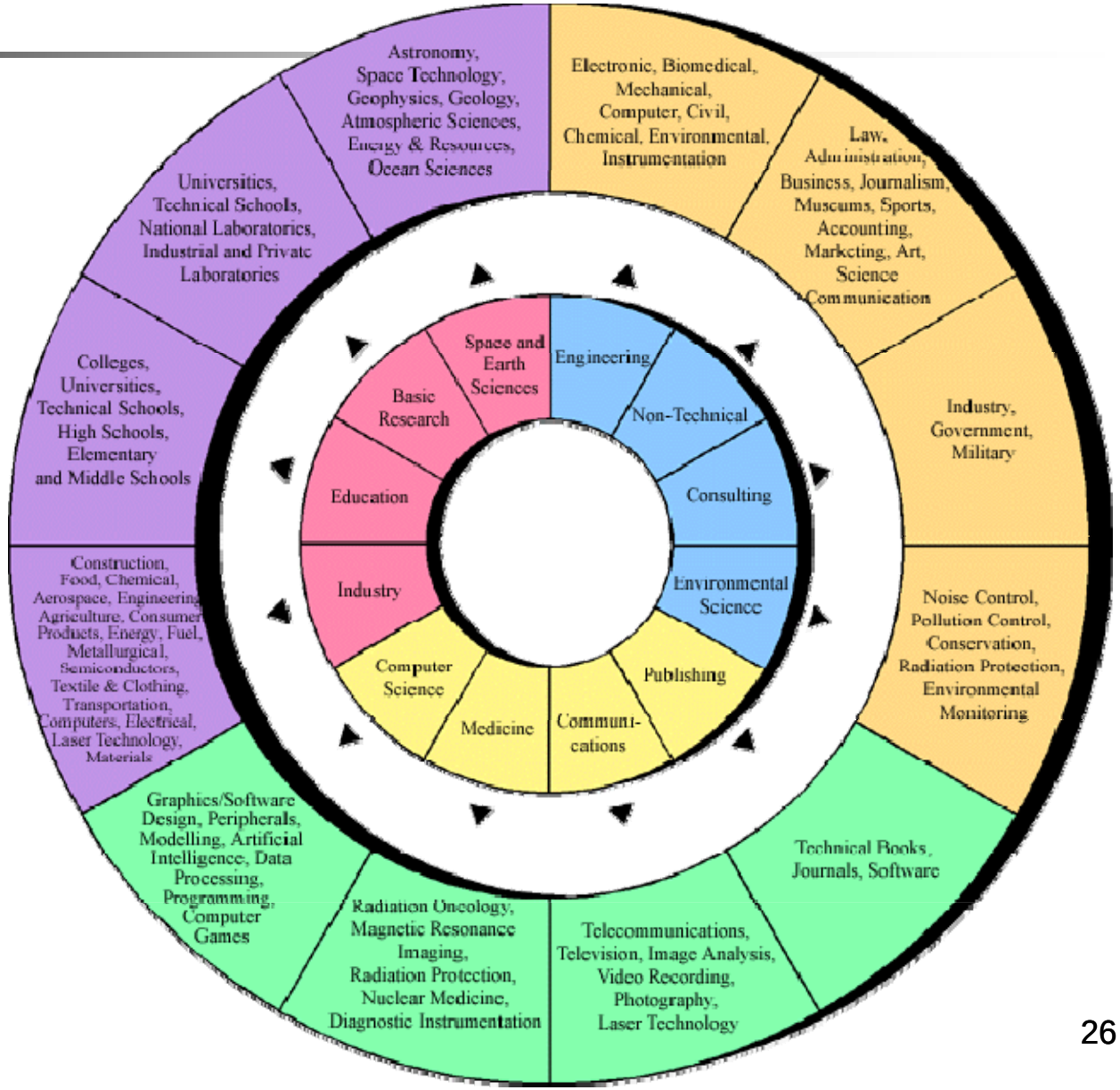
Physicists tend to be curious, creative, and dedicated.

Careers in Physics

Physics offers challenging, exciting, and productive careers. As a career, physics covers many specialized fields -- from acoustics, astronomy, and astrophysics to medical physics, geophysics, and vacuum sciences.

Physics offers a variety of work activities-lab supervisor, researcher, technician, teacher, manager. Physics opens doors to employment opportunities throughout the world in government, industry, schools, and private organizations.

from www.aip.org/careersvc/pify/indigo.html



Most Important Aspects of Physics Education in Shaping Careers of Government Employees

- **Analytical skills** – ability to identify the problem and provide solutions, disciplined way of thinking, logical thinking, taught me to question everything and to look at facts in making decisions
- **Physics knowledge** – a broad based understanding of the physical world, established me as a technical generalist, prepared me to look at systems and processes outside the field of physics, breadth of subjects covered
- **Technical knowledge** – learned very marketable and useful skills, e.g., laboratory experience, computing experience
- **Personal traits** – mental discipline and perseverance skills gained from applying myself, dedication in working with others, gained confidence to take on things I don't completely understand
- **Role model and personal contacts** – advice, counseling, and giving perspective from advisor, professors that knew their subjects thoroughly, loved their work, and made it interesting and challenging, contacts and acquaintances made in college

Government Positions for US Physicists

- Employ about 25–30% of all US Physicists
- National Aeronautics and Space Administration (NASA)
- National Science Foundation
- Nuclear Regulatory Commission
- Department of Commerce
  - NOAA, NIST
- Department of Health and Human Services
  - NIH
- Department of Energy
  - Office of Basic Energy Sciences, National Labs (Sandia, Brookhaven, Oak Ridge, National Renewable Energy Lab, Lawrence Berkeley, Los Alamos, Livermore, Argonne, etc)
- Department of Defense
  - Naval Research Lab, Army Research Lab, Wright-Patterson Air Force Base, etc.

Government Positions for Physicists

- Ph.D. Level: basic research and development
- Master's Level: Qualify for many jobs in applied research and development
- Bachelor's Level: Often qualify as technicians, research assistants, or other types of jobs
- Many physicists branch out beyond R&D work into management/leadership positions; e.g.,
  - David Seiler, NIST, Chief of Semiconductor Electronics Division
  - Patrick Gallagher, NIST, Director
  - Steven Chu, Secretary of Energy, DOE
  - William Brinkman, Director of Office of Science, DOE

Finding a Job in Government

Track Science & Technology Advances

- Subscribe to Technical and Professional Journals
- Read science & technology sections of NY Times & Wash. Post
- Websites of Professional Societies (AIP, APS, IEEE etc.)

Align Your Expectations With Reality

- Check government job websites to find out who is hiring
  - www.usajobs.gov
- Read budget projections to see who might have money to hire (align your expectations with reality)
  - NIST 2011 Budget Request: http://www.nist.gov/public_affairs/releases/budget_2011.html

Network, Network, Network

- Attend meetings (talk with people, get to know <u>new</u> people)
- Place calls to known contacts (professors, peers, colleagues)
- Investigate Summer Undergraduate Research Fellowship (SURF) and National Research Council and the NIST Postdoctoral Research Associateships Program
  - SURF - www.surf.nist.gov/surf2.htm
  - Postdoctoral Program - http://sites.nationalacademies.org/pga/rap/
  - NIST-specific Postdoctoral Program - www.nist.gov/oiaa/postdoc.htm

Resume

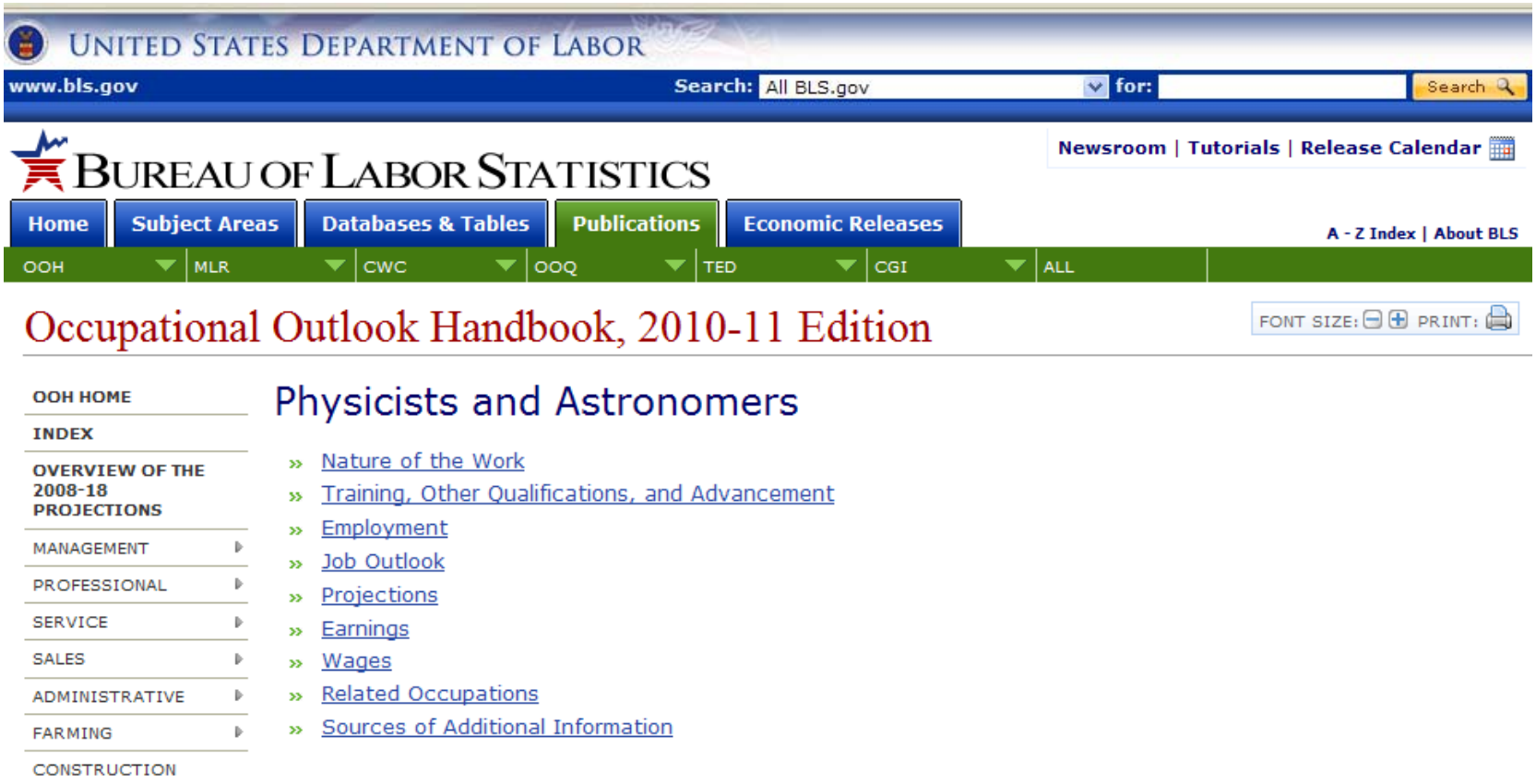
- Emphasize coursework & lab skills
- Emphasize breadth of knowledge
- Emphasize your skills

Career Advancement at NIST

- National research Council Post Doc
- Scientific Staff
- Project Leader (2 – 6 staff)
- Group Leader (8 – 20 staff)
- Division Chief (20 -70 staff)
- Laboratory Director (80 – 300 staff)
- NIST Director (appointed by president)

Occupational Outlook Handbook, 2010-11 Ed.

- For a general view, see the section on Physicists (www.bls.gov/oco/ocos052.htm):



Scientific Staff

- Technical excellence (analytical ability, expertise, publications, impact, etc)
- Communication skills
- Adaptability
- Teamwork
- Customer focused
- Creativity & imagination

Project Leader

- Leadership and vision for project
- Effective use of resources including staff and funds
- Promote visibility
- Mentor staff
- Manage conflict productively
- Ensure project safety

Group Leader

- Technical & financial leadership
- Achieve high impact for projects
- Strategic planning for multiple Groups
- Serve on Division management team
- Supervisory responsibilities
  - Develop performance plans and conduct employee appraisals
  - Promote learning and professional/career development of staff
  - Ensure timely submission of reports

Division Chief

- Provide overall leadership to Division
- Develop and implement strategic plans
- Set and drive vision & goals
- Oversee evaluation & promotion of staff
- Develop future leaders
- Ensure smooth administrative operations
- Monitor and control Division financial performance

Evolution of a Career

(LIFELONG LEARNING – STAGE ONE)

Started in K – 12

Interest in science (rock collecting) and math (doing extra homework)

Undergraduate Studies - Case Western Reserve University

- Tuition Scholarship Awarded
- 1st year excellent physics professor in a recitation section
- 2nd year – chose physics major
- Loved experimental lab work throughout
- 4th year – developed interest in solid state physics
- 1st paper published on Thin Films

Graduate Studies – Department of Physics, Purdue University

- Teaching & Research Assistant
- Loved problem solving in coursework
- Thesis Research – allowed me the freedom to develop discipline and character traits to do fundamental research. Identify thesis topic and necessary ingredients to complete thesis and publish papers

Evolution of a Career

(LIFELONG LEARNING – STAGE TWO)

- Assistant Professor, Department of Physics, University of North Texas (UNT), Denton, TX
  - Teach solid state physics and an advanced senior undergraduate laboratory course
  - Do research and supervise students in semiconductor physics
- National Bureau of Standards, Boulder, Colorado
  - InSb spin flip Raman laser
  - Learned to build and operate CO and CO2 infrared lasers
- Associate Professor, Department of Physics, University of North Texas (UNT), Denton, TX
  - Build IR lasers and use to study semiconductors
  - Start quantum electronics programs, teach laser courses, hire new professors
  - Laser induced hot electrons
  - Begin two photon absorption studies
- Research Scientist, Massachusetts Institute of Technology National Magnet Lab, Cambridge, MA
  - Dye and YAG lasers used to study two photon effects in semiconductors
- Professor, Department of Physics, University of North Texas (UNT), Denton, TX
  - Two photon spectroscopy, impurity and deep level spectroscopy
- Program Director
  Solid State Physics Program, Materials Research Division, The National Science Foundation (NSF), Washington, D.C.

Evolution of a Career

(LIFELONG LEARNING – STAGE THREE)

Started a new career in government

National Institute of Standards and Technology (Since 1988)

- Materials Technology Group Leader
  Semiconductor Electronics Division, National Institute of Standards and Technology (NIST)
- Program Analyst
  Program Office for the Director of NIST, National Institute of Standards and Technology (NIST)
- Division Chief, Semiconductor Electronics Division
  National Institute of Standards and Technology (NIST)

Reflections on My Management Philosophy

- Set realistic goals for yourself to achieve
- Never stop learning about yourself, your job, and the people you work with
- Motivating and empowering people are the most important facets of managing
- Expect excellence and quality from your staff
- Be a role model for what you “preach”
- Provide the proper environment that nourishes and stimulates creativity
- Listen well and communicate effectively

Reflections from a Government Physicist

- Challenges exist ‘tis true – bureaucracy, people management, ...

BUT STILL MANY OPPORTUNITIES EXIST:

- To do excellent research
- To be creative and innovate
- To demonstrate leadership
- Great opportunity to achieve high impact on problems of national importance
- Unique opportunities to collaborate both with industry and academia
- Enhances the technical expertise and reputation of the government and, in turn, the country
- Wide variety of mentorship opportunities
- Wide flexibility in career options

In summary, I have found my work in the government to be both challenging and satisfying

In an Age of Information

- Knowledge, innovation, and speed are necessary for technological leadership.
- Well-educated people possess a foundation of knowledge and know how to learn more.
- Creative people innovate.
- Motivated people accomplish more and faster
- Research universities graduate such people
  - learn from people who are on cutting edge.
  - learn how to formulate and attack problems not previously solved.

Thomas Everhart, President, Caltech
From a NIST talk, Nov. 19, 1996
"U.S. Research Universities: Key Advantages for Commercial Success in the Global Economy of the 21st Century"

Conclusion

- You have to continue to learn if you want to keep innovating.
- Imagination and Creativity will Enable Us to Extend CMOS Measurements to the Nanoscale.

"This is an amazing time to be a technologist. Just think of all the tools and components we have at our disposal--technology so powerful that our leverage is limited only by our imagination and creativity."

- Arno Penzias, vice president and chief scientist, Lucent Technologies, Bell Labs Innovations, 1999