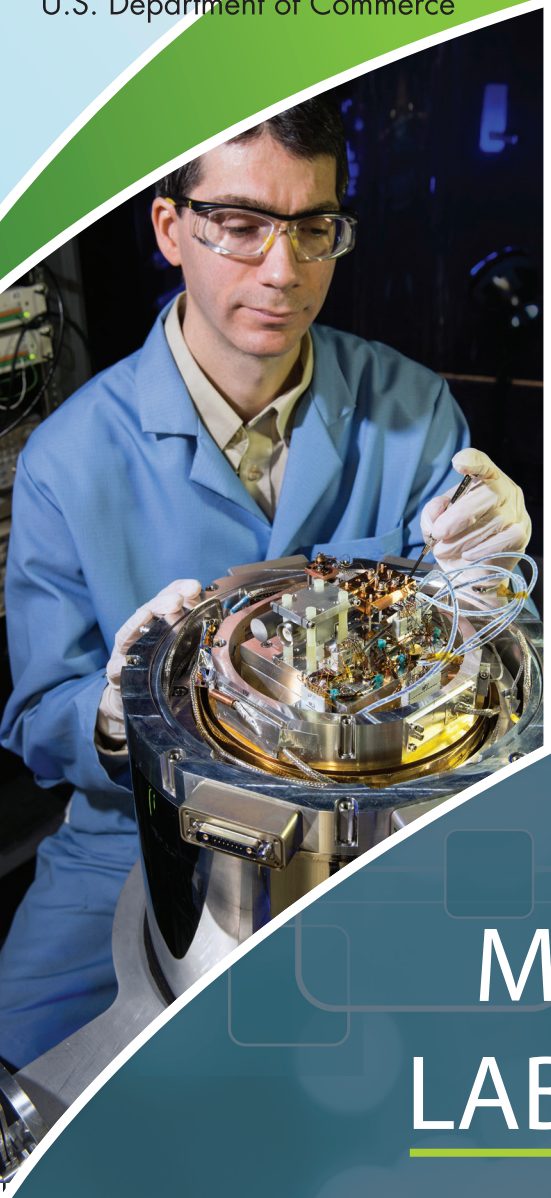
NIST
National Institute of Standards and Technology
U.S. Department of Commerce



NIST PHYSICAL MEASUREMENT LABORATORY

discovering and gauging nature on all scales . . .

PML

PML

PHYSICAL MEASUREMENT LABORATORY

PML, a major operating unit of the National Institute of Standards and Technology (NIST), sets the definitive U.S. standards for nearly every kind of measurement in modern life, sometimes across more than 20 orders of magnitude.

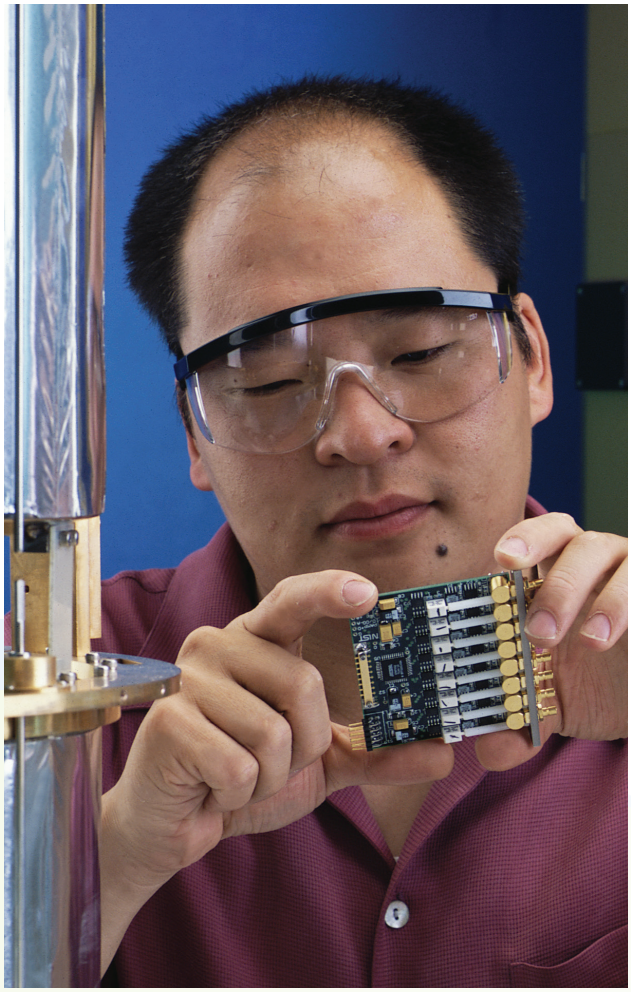
PML is a world leader in the science of physical measurement, devising procedures and tools that make continual progress possible.

Exact measurements are absolutely essential to industry, medicine, the research community, and government.

All of them depend on PML to develop, maintain, and disseminate the official standards for a wide range of quantities, including length, mass, force and shock, acceleration, time and frequency, electricity, temperature, humidity, pressure and vacuum, liquid and gas flow, and electromagnetic, optical, acoustic, and ionizing radiation.

PML collaborates directly with industry, universities, professional and standards-setting organizations, and other agencies of government to ensure accuracy and to solve problems.

It also supports research in many fields of urgent national importance, such as manufacturing, energy, health, law enforcement and homeland security, communications, military defense, electronics, the environment, lighting and display, radiation, remote sensing, space exploration, and transportation.



Laboratory Director
Dr. James K. Olthoff
james.olthoff@nist.gov

Deputy Laboratory Director
Dr. Carl J. Williams
carl.williams@nist.gov

Associate Director for Measurement Services
Gregory Strouse
gregory.strouse@nist.gov

Associate Director for Boulder Operations
Barbara Goldstein
barbara.goldstein@nist.gov

A Message from the Director

Progress in commerce, medicine, science, and technology depends critically on the ability to make increasingly precise and accurate measurements – often at unprecedented scale – of scores of properties and quantities.

Ensuring that America continues to lead the world in that endeavor is the central mission of NIST's Physical Measurement Laboratory (PML). We address our responsibility in two complementary ways: science and measurement services.

PML scientists and technicians are devoted to constant improvement and reduced uncertainties in a wide range of measurements crucial to today's needs. But they also work at the outermost frontiers of physics to identify and investigate the kinds of measurements that the future will demand, from nanoscale imaging and ultra-high-precision timekeeping to detection of subtle quantum effects, advanced photonics, spin electronics, the new quantum-based International System of Units (SI), artificial intelligence, and precision medicine.

At the same time, PML provides industry, government, and academia with state-of-the-art standards, calibrations, and methods for making their essential measurements, at NIST or at customer facilities, and helps solve problems they encounter. In addition, we provide many of the nation's authoritative science databases, operate active teaching and training programs, and play a leading role in the redefinition of the SI.

That work is accomplished by PML's more than 500 federal employees and nearly 800 associates working at NIST's Gaithersburg, MD, and Boulder, CO, campuses, and at two joint institutes: JILA, with the University of Colorado-Boulder, and the Joint Quantum Institute (JQI), with the University of Maryland at College Park.

Each of our many projects and programs, highlighted on the following pages, has a unique focus. But all share a common commitment to excellence in metrology for commerce, research, and government, and to America's ongoing global leadership in measurement science.

— James Olthoff

About the Laboratory

PML Provides

- nearly 700 calibration services
- numerous special testing services
- U.S. standard time dissemination
- over 100 standard reference materials
- Atomic Data Center
- Fundamental Constants Data Center
- Standard Reference Instruments

Our People Include

- 4 Nobel laureates
- 7 members of the National Academies
- more than 100 Fellows of APS, OSA, IEEE, SPIE, and AAAS
- more than 250 members of national and international standards organizations

For more information about the Physical Measurement Laboratory, including calibration services and postdoctoral opportunities, go to https://www.nist.gov/pml, send email to pmlinfo@nist.gov, or write to Physical Measurement Laboratory, National Institute of Standards and Technology, 100 Bureau Drive, Mail Stop 8400, Gaithersburg, MD 20899-8400.

Radiation Physics Division

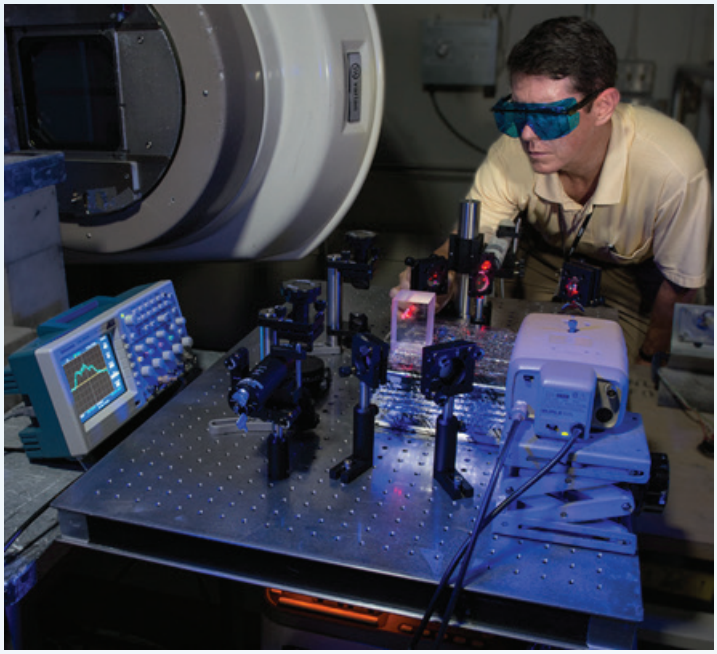
Accurate measurements of ionizing radiation and radioactivity are vital necessities for a host of life-saving medical procedures, as well as public safety and industrial processes, and must be based on authoritative standards.

This division develops, maintains, and disseminates those standards in the United States, and investigates and uses the fundamental physical interactions of ionizing radiation with biological systems, materials, environmental contaminants, and radiological, nuclear, chemical, and explosive devices.

That work supports:

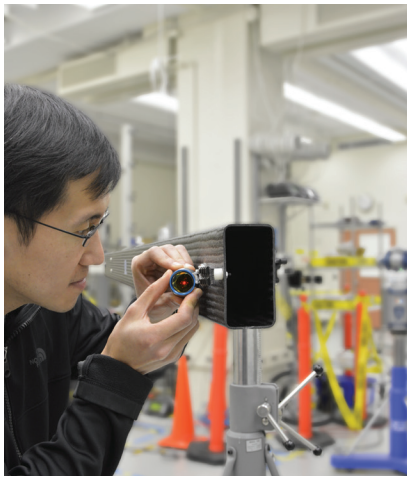
- radiation and nuclear applications in health care;
- worker protection and assurance for the nuclear energy and radiation industries;
- spectroscopic methods for biotechnology and medical applications;
- environmental protection and monitoring;
- homeland security and defense applications, detection, and countermeasures;
- manufacturing and industrial innovation; and
- fundamental research in radiation and neutron physics.

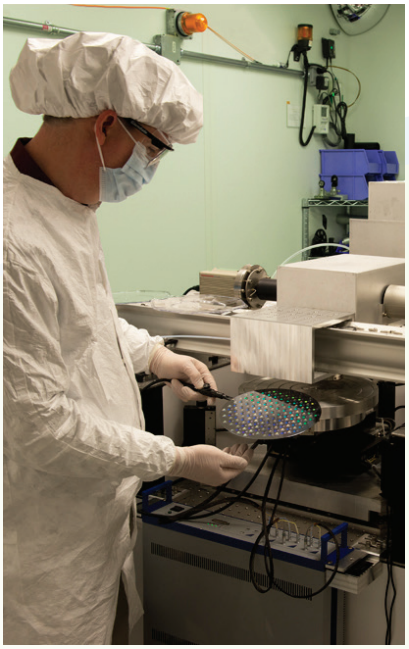
In addition to realizing the SI units for absorbed dose (the gray) and activity (the becquerel), the division conducts research in radiation and nuclear physics, radiation dosimetry, radionuclide metrology, and physical imaging technologies. This work has a far-reaching impact on medical research and clinical practice. For example, the accuracy of nearly 40 million mammograms and 40,000 radiation treatment plans for prostate cancer, every year, relies on measurements made here.

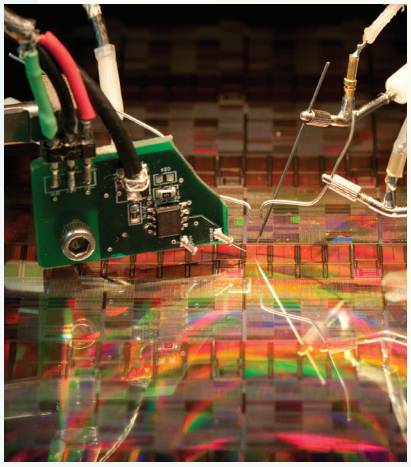


Dr. Michael Mitch, Acting Division Chief
(301) 975-5491 | michael.mitch@nist.gov
www.nist.gov/pml/radiation-physics

radioactivity and dosimetry of electrons, neutrons, x-rays, gamma rays







Engineering Physics Division

Working at the forefront of innovation in science and technology requires increasingly accurate, high-precision length and dimensional metrology, on scales ranging from kilometers to nanometers.

The Engineering Physics Division performs basic research in the physics that underlies length metrology and sensor technology, and provides traceability to the unit of length, as defined in the International System of Units (SI), through calibrations, reference materials, and standards.

Key research areas for the division are:

- Various kinds of interferometry for measuring motion displacement, surface figure, index of refraction, pressure, and other quantities that can be transduced into displacement, as well as measuring vibration and oscillatory motions up to gigahertz frequencies.

- The physics of probe/sample interactions involved in imaging and metrology to access new and more accurate knowledge, using probes such as light, electrons, and atomic-scale magnetic, electrical, and mechanical forces.

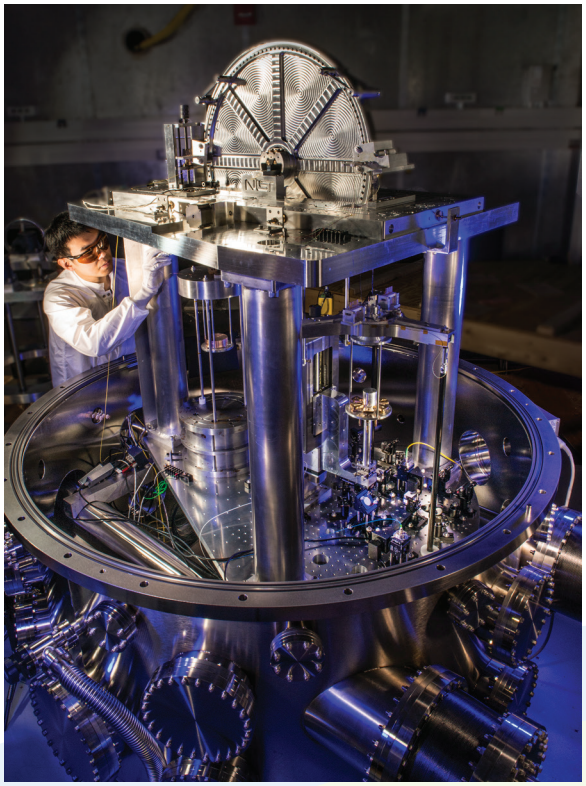
- Condensed matter physics and device characterization and reliability for next-generation electronics such as two-dimensional materials, molecular electronics, spintronics, memristors, and solid-state quantum systems.

- Light/matter mechanical interactions including the coupling of nanoscale mechanical oscillators with optical microcavities and optical trapping and levitation of particles, with applications in micro- and nano-electromechanical systems (MEMS/NEMS) sensors, molecular detection, accelerometers, and more.

This basic research is applied to areas of high impact and economic/societal value. Focus areas include: laser trackers and scanners for aerospace manufacturing and land surveying; microfeature metrology for forensics and law enforcement; acoustic metrology and hearing aid testing standards; vibration and shock calibration; Raman spectroscopy of nanomaterials; molecular transport through nanopores; high-definition electron spin resonance; nanoparticle properties; ultrafast, pulsed-laser spectroscopy; microfluidics; and electronic and optical biomolecule detection for precision medicine applications.

Dr. David Gundlach, Division Chief
(301) 975-2048 | david.gundlach@nist.gov
www.nist.gov/pml/engineering-physics-division

length, acceleration, acoustics, vibration



Quantum Measurement Division

In the 21st Century, world-class metrology demands measurements ranging from millions of pounds to below the atomic scale. This division performs basic electrical, mass, and force calibrations, and applies quantum physics research methods to achieve fundamental advances in measurement science.

The division has been heavily engaged with the international community in both proposing and contributing to the planned redefinition of the International System of Units (SI or metric system).

Part of that work is associated with the Fundamental Constants Data Center, which determines the best value of the fundamental constants and contributes directly to improving international standards through the Committee on Data for Science and Technology (CODATA) and other organizations. The division also provides metrology for the "Smart Grid" program to improve America's electric power distribution system.

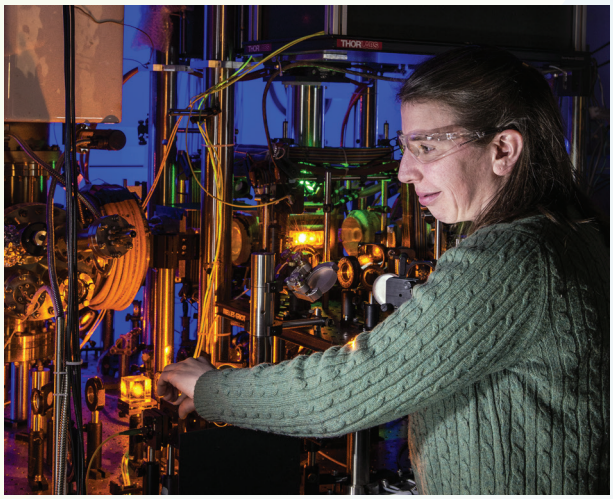
Division concentrations include:

- quantum processes and metrology including quantum optics, laser cooling and trapping, ultracold atoms and molecules, quantum simulations, modeling of quantum systems, single-photon sources and non-classical light, and precision measurements;
- both fundamental and applied electrical measurements; and
- mass and force.

Quantum measurements are essential to progress in defining the SI base units, including the second and the meter. Even the kilogram is the subject of PML measurement research, part of the worldwide effort to redefine the SI based on invariants of nature. The division and its focus on quantum measurements are pushing the frontiers in electrical, mass, and force metrology.

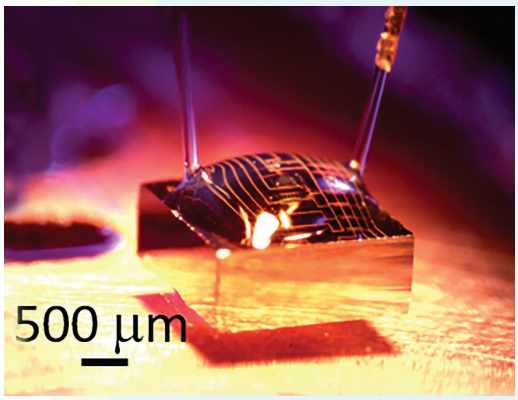
Significant portions of the basic research in quantum processes and metrology are also part of the Joint Quantum Institute (JQI), a joint research effort between NIST and the University of Maryland at College Park. The JQI develops fundamental measurements and technologies and helps to train future generations of scientists to pursue the outermost boundaries of measurement science.

Dr. Jon Pratt, Division Chief
(301) 975-5470 | jon.pratt@nist.gov
www.nist.gov/pml/quantum-measurement



voltage, resistance, capacitance, mass, force

Sensor Science Division

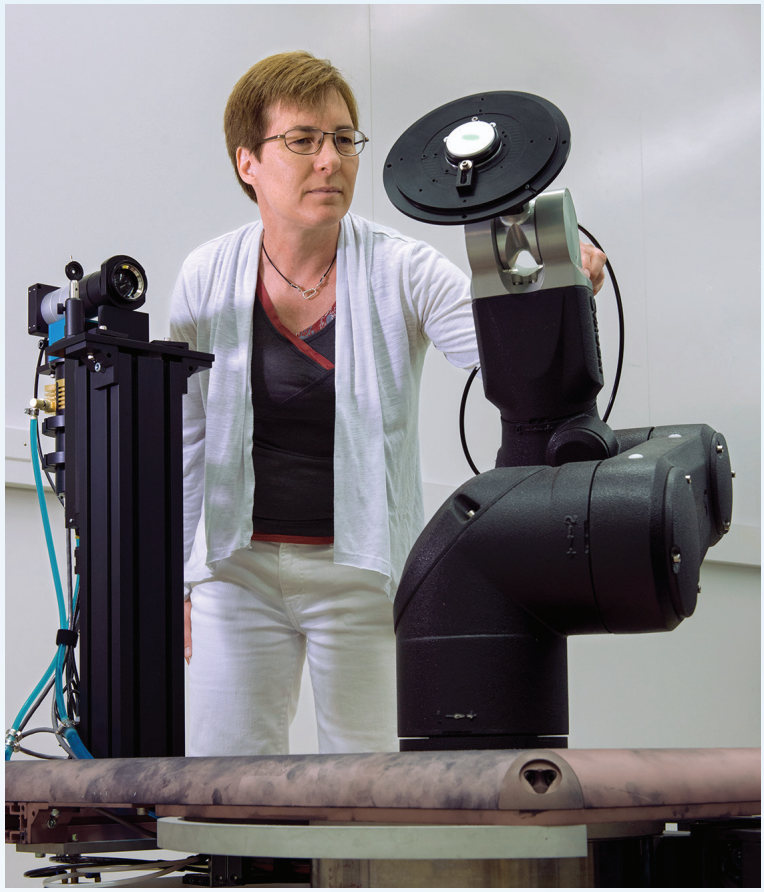


The explosion of highly sophisticated sensor and imaging technology in recent years has enabled dramatic improvements in personal safety, medical diagnosis and treatment, lighting efficiency, temperature measurement, precision manufacturing and monitoring, and Earth and planetary science, to cite a few examples.

This division maintains and advances the measurement science and standards for sensing optical and infrared radiation, temperature, humidity, pressure, vacuum, flow, and related phenomena to support U.S. industry and technology research.

In doing so, it provides:

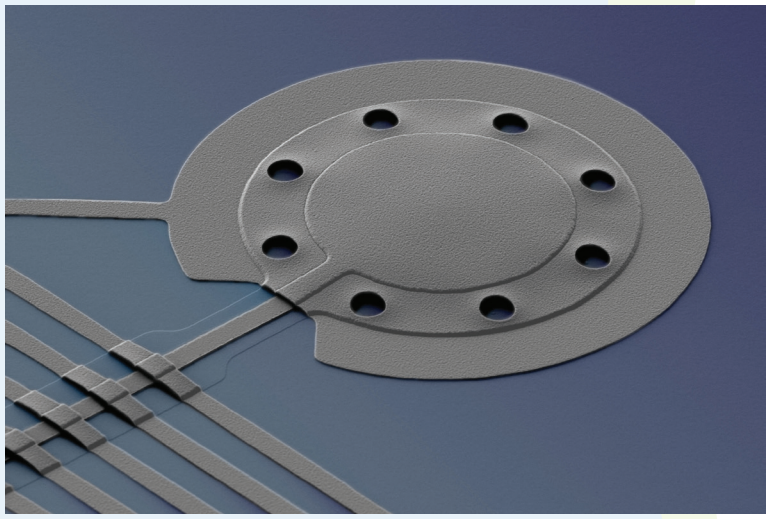
- the measurement foundation for multi-million-to-multi-billion-dollar space programs, including those supporting weather and space-weather monitoring and forecasting, land usage, and ballistic missile defense;
- metrology to enable the transition from incandescent and fluorescent to solid-state lighting;
- infrastructure for process plant operations and energy commerce through world-leading temperature, humidity, pressure, volume, and flow metrology;
- unique facilities for testing extreme ultraviolet optics and detectors, calibrating optical and infrared sensors and imagers, and characterizing color and lighting; and
- leading research in many fields, including photonic sensors and standards, photometry, optofluidics, optical scattering from surfaces, infrared technology, measurement of process variables in manufacturing, optical properties of materials and surfaces, medical imaging, and metrology of ultraviolet and extreme ultraviolet radiation.



Dr. Gerald T. Fraser, Division Chief
(301) 975-3797 | gerald.fraser@nist.gov
www.nist.gov/pml/sensor-science

optical & IR radiation, temperature, humidity, pressure, vacuum, flow

Applied Physics Division



Precise measurements of electromagnetic radiation underpin broad industrial sectors, impacting most aspects of everyday life. For example, manufacturing – from semiconductors to welding – requires precise measurements of many laser parameters, e.g., power and beam profile. Healthcare relies on standards for magnetic imaging and medical laser applications to ensure effective treatment and patient safety. To support those endeavors, the division concentrates on three primary areas:

- Sources and Detectors – establishing traceability for electronic components through advances in measurement science, measurement services, and device development. Sources include unique fiber frequency combs and single-photon sources, as well as multi-kilowatt lasers. Detectors include high-precision radiometers and single-photon technologies for quantum information science. Measurements of laser power and energy, as well as frequency/time transfer, are components of this focus area.

- Quantum properties of photonic and electronic systems – from complex superconducting circuits to state-of-the-art single-photon detectors and sources. The work is applied, for example, to the study of materials for new products, homeland defense, and support for quantum information science. Examples include hybrid electrical-mechanical-optical systems to aid progress in quantum information processing, communication, and metrology, and the generation of novel states of light to perform key tests of quantum mechanics.

- Metrology for imaging, sensing, and spectroscopy – applied to ultraprecise detection of greenhouse gases as well as the study of complex laser-matter interactions. Biomagnetic imaging research supports the development of standards, measurement methods, and new magnetic imaging modalities for biomedical and environmental applications. Terahertz imaging research enables detection of concealed contraband without the use of ionizing radiation.

Groundbreaking research in optical frequency combs has led to high-precision spectral, temporal, and spatial measurement tools for uses including gas monitoring and three-dimensional length metrology. Additional research topics include shape-shifting biomedical probes and standards development, optical/electrical nanoprobe development, and electron and ion microscopy of materials used in clean energy generation.

Dr. Nathan Newbury, Acting Division Chief
(303) 497-4227 | nathan.newbury@nist.gov
www.nist.gov/pml/applied-physics-division

metrology for photonics and magnetics, quantitative imaging

Quantum Electromagnetics Division

Harnessing the electromagnetic spectrum – from direct current through microwave, terahertz, and infrared radiation to x-rays and gamma rays – enables a wide range of applications, including electrical standards, photon sensing and imaging, information processing, and spectroscopy.

The division studies and exploits the unique quantum mechanical, electronic, magnetic, and photonic properties of materials to develop high-precision measurement devices, systems, standards, and methodologies for a broad customer base.

The division's unique innovations in metrology and nano-fabrication propel critical advances in high-performance superconducting electronics, digital logic, data storage, materials development, quantum computing, biophotonic imaging, climate science, nuclear forensics, and astronomical observations, as well as a deeper understanding of fundamental physics. For example, the division:

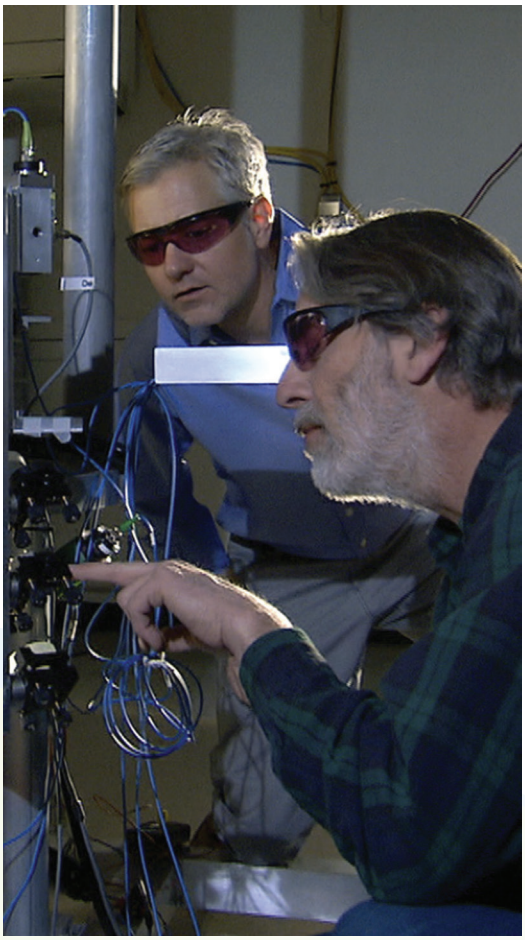
- develops and delivers the dc and ac quantum voltage standards that underpin electrical measurements throughout the world, and creates high-bandwidth electrical signal generation and instrumentation to characterize future communications systems;
- fabricates best-in-class, ultrasensitive superconducting detector arrays that are at the core of ultra-high-resolution spectrometers for advanced materials analysis (including defect identification in integrated circuits), x-ray fundamental line metrology, nuclear nonproliferation applications, and cosmological research;
- develops biophotonic imaging tools and standards for clinicians to more effectively diagnose cancers and other diseases;

- applies spin electronics and magnetodynamics research, particularly on nanoscale materials and devices, to the computing industry's need for higher-speed, lower-power electronics and information storage;
- conducts leading-edge applied research in areas including surface science for enhanced quantum computing, molecular spectroscopy for steel infrastructure monitoring, time-resolved x-ray probing of novel materials, greenhouse gas metrology, compact cryogenic systems, ultra-fast cryogenic computing, spin electronics, and superconducting circuits for quantum information science.

Dr. Robert Hickernell, Division Chief
(303) 497-3455 | robert.hickernell@nist.gov
www.nist.gov/pml/quantum-electromagnetics

electronics, nanomagnetics, photonics

Time and Frequency Division

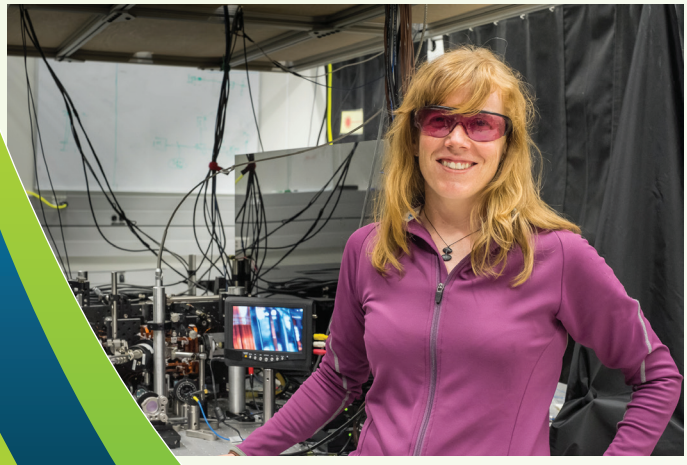


Much of the world's modern technology infrastructure relies on exquisitely precise timing and synchronization, from the Global Positioning System to telecommunications and data networks to electric power generation and distribution.

The division provides official U.S. standards for time and frequency measurements and related quantities. These measurements trace back to the laser-cooled NIST cesium fountain atomic clocks, two of the world's most accurate measuring devices of any kind.

The division provides official time to the United States and is the source of the nation's contribution to Coordinated Universal Time. In addition, the division distributes numerous time and related measurements customized for different customer needs. For example:

- The free Internet Time Service automatically synchronizes clocks in computers and network devices tens of billions of times every day, and is built into most computer operating systems.
- Special time code radio stations, including radio station WWVB, synchronize many millions of radio-controlled clocks and watches to official NIST time.
- Remote, automated calibration services provide the highest accuracy time and frequency information in the customer's lab, at any time.
- The division delivers unique measurements of timing jitter and spectral purity (phase noise).
- The division conducts research on future atomic clocks with accuracy equivalent to one second in billions of years, and develops applications of laser frequency combs for a wide variety of uses from remote sensing to secure communications to the search for exoplanets.



The division also performs research in quantum computing and develops ultraminiature (chip-scale) atomic devices for precision measurement of time, magnetic fields, acceleration, and a broad range of other applications.

Dr. Christopher Oates, Division Chief
(303) 497-7654 | chris.oates@nist.gov
www.nist.gov/pml/time-and-frequency-division

time, frequency, phase noise, chip-scale sensors

Quantum Physics Division

This division is the NIST part of JILA, the joint research institute between NIST and the University of Colorado-Boulder. JILA develops fundamental measurement-science tools and technologies and trains future generations of scientists and innovators.

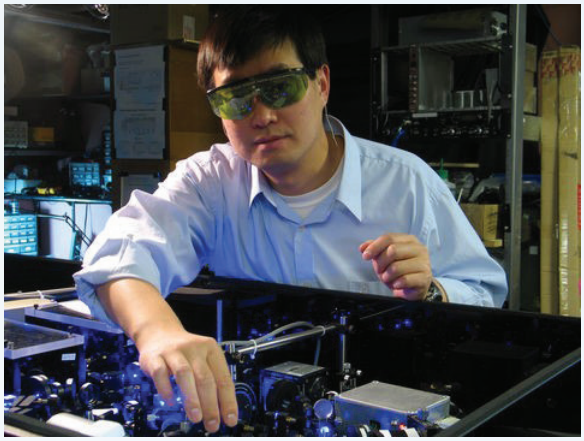
The division and JILA focus on the next generations of ultraprecision measurements and technologies based on the "new quantum revolution." In the 20th century, research successfully utilized the quantum properties of individual particles to make lasers, semiconductor devices, atomic clocks, etc. But that approach is subject to the Standard Quantum Limit (SQL), ultimately constraining measurement precision and technology capability. JILA is helping lead the 21st century quantum revolution by perfecting the creation and control of quantum matter, where unique quantum phenomena such as entanglement can enable measurements and technologies to break through the SQL.

Division research includes:

- Creation of new quantum matter from the ground up. Combined experiment and theory to make new quantum degenerate matter from atoms and molecules, just billionths of a degree above absolute zero. Fundamental studies of new types of quantum interactions among large systems to realize the promise of the new quantum revolution.

- New measurements and technologies from quantum matter. JILA scientists are already developing new types of atomic clocks that will be thousands of times more accurate than current research atomic clocks, sensitive enough to detect dark matter and gravity waves. Perfecting quantum control of human-made devices to enable future quantum networks with vastly greater bandwidth and security than today's telecom systems. Developing an entirely new type of laser based on quantum matter, with the potential for much greater stability than today's lasers, enabling a broad range of more precise measurements.

- Kinetics and dynamics of quantum systems. Frequency combs from soft x-rays to far infrared for completely resolved spectra of complex chemicals and studies of femtosecond transients in chemical reactions. Unique biomechanical measurements of individual protein and nucleic acid molecules for structure/function determination. Development of new quantum-based internal probes of living cell biochemistry.



JILA's advances lead to new commercial products, companies, and measurement tools, and JILA is a continuous source of trained measurement scientists and innovators through graduate and postdoctoral education. JILA alumni go on to found high-tech firms, direct industry and university research, and become leading NIST scientists.

Dr. Thomas O'Brian, Division Chief
(303) 492-6807 | thomas.obrian@nist.gov
https://jila.colorado.edu/

quantum matter, quantum technologies, advanced training

Office of Weights and Measures

PML's Office of Weights and Measures:

- ensures traceability of state weights and measures standards to the International System of Units (SI);
- develops procedures for legal metrology tests and inspections;
- provides technical guidance and online tools to facilitate the implementation and use of the SI; and
- conducts training for laboratory metrologists and weights and measures officials.

It also provides guidance on laws and regulations adopted by the National Conference on Weights and Measures (which promulgates uniform standards across states and other jurisdictions), and coordinates the development and publication of key NIST handbooks used by states for enforcement purposes.

The work has substantial impact: Sales of products or services affected by weights and measures laws represent about 50 percent of the U.S. Gross Domestic Product.

In addition, this office serves as the U.S. representative to the International Organization of Legal Metrology, which brings efficiency and cost savings to U.S. manufacturers and other stakeholders doing business overseas through the promotion of harmonized international standards and regulatory practices.

The office also analyzes training needs, obtains input from the community, designs and delivers training for laboratory metrologists and weights and measures officials, measures the impact and effectiveness of training to ensure ongoing continual improvement, and consults with the weights and measures community to ensure ongoing professional development.

The Weights and Measures training program is accredited by the International Association of Continuing Education and Training (IACET).

Dr. Douglas Olson, Chief
(301) 975-2956 | douglas.olson@nist.gov
www.nist.gov/pml/weights-and-measures

Measurement Services

NIST calibration services help the makers and users of precision instruments achieve the highest possible levels of measurement quality and productivity. Nearly all are conducted within or through PML. In FY 2016, NIST performed 13,264 calibrations in about 200 different categories, including:

DIMENSIONAL: Length; Diameter and Roundness; Complex/3D Dimensional Standards; Optical Reference Plane Standards; Angular Measures; Laser Measurements; Surface Texture; Nanoscale Structures

MECHANICAL: Hydrometers; Volume and Density; Flow; Air Speed Instruments; Mass Standards; Force; Vibration; Acoustics

ELECTROMAGNETIC: Resistance; Impedance; Voltage; Precision Ratio; Phase Meters and Standards and VOR; Power and Energy at Low Frequency; RF, Microwave and Millimeter Wave; EM Field Strength and Antennas; Field Strength Parameters; High-Speed Repetitive Wave Forms; Pulse Waveforms

OPTICAL RADIATION: Photometric; Optical Properties of Materials; Surface Color and Appearance; Spectroradiometric; Detector Calibrations in EUV; High-Frequency Optical Detectors; Lasers and Optoelectronic Components

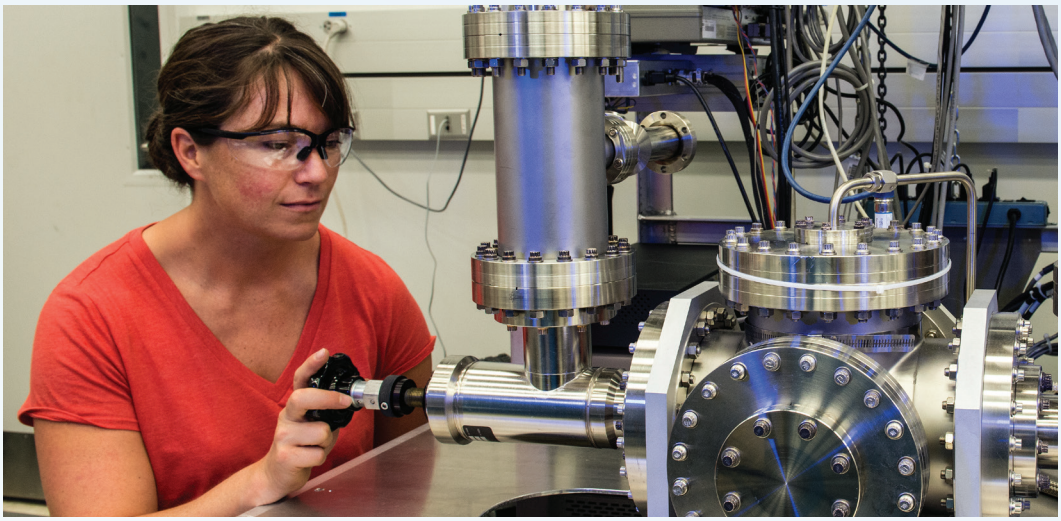
THERMODYNAMIC: Pressure, Vacuum, Temperature, Humidity, Thermal Resistance

ENVIRONMENTAL: Ozone, Mercury

IONIZING RADIATION: Radioactivity; Neutron Sources and Dosimetry; X-ray, Gamma-Ray, and Electron Dosimetry; Dosimetry for High-Dose Applications

TIME AND FREQUENCY: Broadcast and Measurement Services; Characterization of Oscillators; Phase Modulation and Amplitude Modulation Noise Measurement Systems

In addition, PML provides metrology training at NCSLI and MSC meetings, as well as at NIST facilities.



Gregory Strouse
PML Assoc. Dir. for
Measurement Services
(301) 975-4803

gregory.strouse@nist.gov
www.nist.gov/calibrations

calibrations, testing, metrology training

Joint Institutes for Research and Education

JILA
CU Boulder and NIST

JILA is supported and operated jointly by NIST/PML and the University of Colorado-Boulder.

Since 1962, JILA scientists have pioneered continually evolving research and innovations in such fields as ultra-stable lasers, ultracold matter (quantum degenerate gases, 2001 Nobel Prize), world-leading atomic clocks, femtosecond laser frequency combs (2005 Nobel Prize), chemical dynamics and kinetics, unique bio-mechanical measurements, and development and applications of quantum transduction. Most JILA research and technologies advance precision measurements.

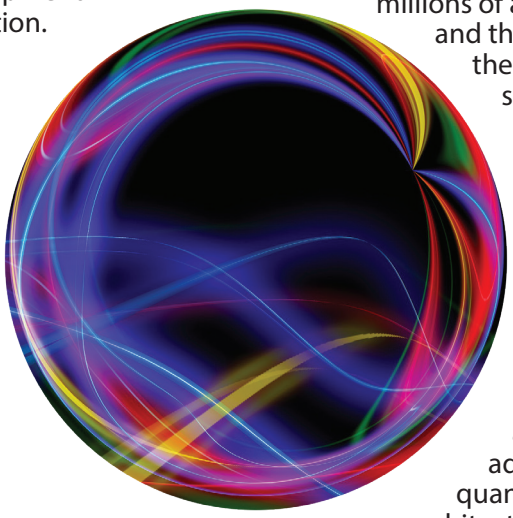
JILA's current major focus is on mastering the theory and experiment of quantum many-body physics to break through the measurement limits imposed by the standard quantum mechanics of individual particles. This focus includes building new forms of highly correlated quantum matter from basic constituents, leveraging quantum many-body physics and technologies for precision measurements previously not possible, and mastering the measurement and control of complex dynamic quantum systems including chemical and biological systems.

About 150 graduate students and post-doctoral fellows study precision measurements and quantum science at JILA at any time. JILA alumni become innovators in high-tech industry, leading measurement scientists at NIST, and mentors for future generations at leading universities. JILA hosts an NSF Physics Frontier Center promoting quantum many-body research, quantum technology development, training of JILA students and postdocs, and community STEM outreach.

JOINT QUANTUM INSTITUTE

The Joint Quantum Institute (JQI), founded in 2006, is a research partnership between PML/NIST and the University of Maryland (UMD), with support from the Laboratory for Physical Sciences (LPS).

JQI has over 150 scientists, including NIST scientists, UMD professors, postdoctoral fellows, and students. Together in a collaborative environment, these researchers study coherent quantum phenomena using both bottom-up and top-down approaches. They explore the quantum nature of individually controlled ion crystals, cryogenic quantum circuitry, single photons on silicon-based chips, and ultracold gases containing millions of atoms. They use experimental and theoretical tools to understand the complexities of these systems, such as many-body physics and entanglement.



These research areas connect directly to future applications. For example, finding ways to create and control quantum states on demand is a critical step towards developing practical quantum devices. The JQI is a world leader in the efforts to advance quantum computing and quantum information processing architectures.

JQI hosts an NSF Physics Frontier Center (PFC) devoted to leading-edge science at the interface of atomic physics and condensed matter. Also, through the PFC, JQI scientists actively engage the public of all ages in quantum science.

Scientists from another UMD-NIST initiative, called the Joint Center for Quantum Information and Computer Science (QuICS), work closely with JQI researchers in the frontier area of theoretical quantum computer science. As a primary element of their missions, JQI and QuICS train scientists for future opportunities in industry and academe, and provides U.S. commerce with a constant source of research results.

research and training at the frontiers of quantum science

STEM Education at PML

America's future in an innovation-driven world demands that we provide young people with a thorough grounding in science, technology, engineering, and math — subjects collectively known as STEM.

PML seeks to attract and inspire exceptional talent in a range of opportunities for STEM education at all levels, with programs including:

- NIST's Summer Undergraduate Research Fellowships (SURF), which provide 11 weeks of hands-on experience working with cutting-edge technology.
- The Summer High School Intern Program (SHIP) in which students participate for 8 weeks in research at PML, working closely with staff scientists and engineers.
- The Professional Research Experience Program (PREP), designed to provide valuable laboratory experience and financial assistance to undergraduate, graduate, and post-graduate students.
- 10-week summer intern positions for undergraduate physics students in cooperation with the Society of Physics Students.
- Summer fellowship opportunities in cooperation with the American Chemical Society's Project SEED, which provides fellowship funding for economically disadvantaged high-school students.
- NIST's NRC Postdoctoral Research Associateship Program, administered in cooperation with the National Academies/National Research Council. The program brings scientists and engineers of unusual promise and ability to perform advanced research, introduces the latest university research results and techniques to NIST, shares NIST's unique research facilities with the U.S. scientific and engineering communities, and encourages transfer of results from NIST to those communities.
- An internship program that provides students from high school to graduate level with opportunities to work in agencies to explore federal careers while still in school and while getting paid for the work performed.

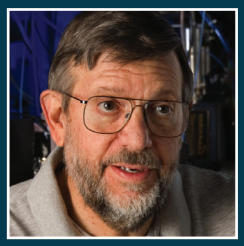
"The SURF program at PML provided me with a unique opportunity to put into practice the science I have been learning in school. I was able to operate state-of-the-art equipment and create software that provided NIST with a new Raman spectroscopy mapping capability. I am excited to have learned so much and to have actually made a difference at such an amazing place as NIST."

Rebecca Moore,
SURF Summer 2017
Associate

postdoctoral, grad/undergrad, high school

PML's Nobel Prize Winners

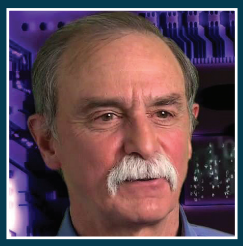
The Nobel Prize in Physics is awarded to scientists who revolutionize the way we understand and apply the fundamental laws of nature. Four PML scientists have received this award for advances that have enabled new types of measurements with direct impact on our national technology base, global competitiveness, economy, and quality of life.



BILL PHILLIPS (1997) for pioneering the use of lasers and magnetic fields to trap and cool a gas of atoms to within millionths of a degree above absolute zero. This breakthrough made possible much more accurate quantum measurements and provided a new kind of technology now used worldwide in many types of quantum research and in applications including ultra-precise timing.

JAN HALL (2005) for inventing an entirely new kind of laser — the laser frequency comb — that marked the most important revolution in precision measurement since the 1960 invention of the laser. The technology is now employed around the globe in many commercial devices and in ultra-precise optical atomic clocks 1,000 times more accurate than the current U.S. time standard.

ERIC CORNELL (2001) for extending Dr. Phillips' laser cooling techniques to create an utterly new state of ultracold matter: a Bose-Einstein condensate. At billionths of a degree above absolute zero, the atoms are all in exactly the same quantum state, constituting a "super atom" with exotic properties that make it an invaluable way to explore superconductivity, quantum magnetism, and more.



DAVE WINELAND (2012) for perfecting measurement and control of quantum states in individual ions, and generating unique quantum interactions among collections of ions. His work has made possible dramatic advances in new technologies including quantum computing and simulation, thanks to his mastery of key quantum phenomena: entanglement and superposition.

PML
PHYSICAL MEASUREMENT LABORATORY

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

www.nist.gov/pml

Image credit: Page 2 – © Geoffrey Wheeler