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News Briefs

General Developments

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NIST REPORTS MEASURABLE SUCCESS OF ADVANCED ENCRYPTION STANDARD

An independent study confirms industrys early adoption and implementation of NIST's Federal Information Processing Standard (FIPS) 197, Advanced Encryption Standard (AES).

The number of products worldwide that implemented the NIST Data Encryption Standard (DES), including Triple DES, grew rapidly from 1999 through June 2001, but leveled off by December 2001. The slowdown in the announcement of new DES products apparently was due to the impending adoption of FIPS 197, AES, which was approved by the Secretary of Commerce on Dec. 6, 2001. In December 2001, a private survey found a total of 74 products had already implemented the AES, indicating very rapid acceptance and adoption of the AES algorithm, with companies already offering products in anticipation of final approval of the standard.

The early adoption of AES is perhaps more remarkable because, prior to the approval of FIPS 197, AES algorithm testing was not available through NIST's Cryptographic Module Validation Program (CMVP), a program for assurance testing of cryptographic modules jointly operated by NIST and the Canadian Government Communications Security Establishment. NIST has now released an updated algorithm test tool to the CMVP laboratories that includes AES algorithm testing and expects to see many more AES implementations now that validation testing is available.

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NIST DATA UNDERPINS NEW REFERENCE WORK

A group of 17 scientists at Kobe University, Japan, have published an extensive set of data entitled *Doppler-Free High Resolution Spectral Atlas of Iodine Molecule, 15000 to 19000 cm^{-1}*. The set consists of four volumes, each having more than 1000 pages. The spectral plots and numerical data in these volumes are to be used as a source of precision reference wavelengths for researchers working with very-narrow-band tunable lasers in the green and red regions of the spectrum. The work was carried out under the auspices of the Japanese Research Promotion Committee of Photoscience.

Calibration of the absolute wavelength scale for this work was based on precision measurements of wavelengths for the iodine molecule by a NIST scientist published in the *Journal of the Optical Society of America* in 1997. In recognition of this contribution, the project leader at Kobe University has presented NIST with a set of these volumes together with a laudatory letter about the value the NIST measurements to their large project.

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NIST'S IMPROVED INVERSE SOLUTION METHOD PRESSES DOPANT PROFILING TOWARDS INDUSTRY GOALS

NIST has demonstrated a higher accuracy and higher spatial resolution inverse solution method for determining dopant profiles from scanning capacitance microscope (SCM) images of silicon transistors. Dopant profiles are a major factor controlling the functional operation of deep sub-micrometer transistors. High accuracy measurements of dopant profiles are needed to improve the predictive quality of transistor models and design. The breakthrough is embodied in computer code that makes a large step towards meeting the aggressive spatial resolution goals set out in the International Technology Roadmap for Semiconductors (ITRS).

In the mid-1990s, SED launched a systematic effort to address the so-called shallow-junction-profiling problem and has since developed the SCM as a practical tool for imaging the two-dimensional dopant concentration distribution in transistor junctions near their gates. An essential element for quantifying the measurement is a detailed model of how the microscope interacts with the junction during imaging. Up to this point, models treated each data point of an SCM image independently. A forward solution (calculation of SCM signal from a dopant profile) was used to calculate a calibration curve, which could then be used to deduce dopant profiles with spatial resolution of about 20 nm. The spatial resolution of this model was still far short of the current goal of 4 nm (increasing to 1 nm by 2016) defined by ITRS.

Recent breakthroughs in the NIST modeling approach now allow for a better inverse solution of the dopant profile, in which the dopant concentration at each measurement point is calculated considering the effects of the neighboring points. The regression procedure makes use of both coarse and fine grid meshes, so that only a few iterations are needed to reach convergence. Preliminary demonstrations with one-dimensional model data indicate the resulting spatial resolution could meet current and future ITRS goals. The recent NIST National Research Council panel recognized that the inverse solution of SCM data could potentially overcome one of the key roadblocks expressed in the ITRS.

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NIST COLLABORATION TO INCREASE MACHINING PRODUCTIVITY FOR U.S. NAVY

NIST has been collaborating with the Naval Surface Warfare Center, Carderock, MD, and the Naval Foundry and Propeller Center, Philadelphia, PA, since 1999.

This collaboration resulted in significant advancements in the understanding of process dynamics during high speed machining and the optimization of machining process parameters for cutting the nickel-aluminum-bronze material of interest to the Navy. Submarine propellers are roughly 6 meters in diameter and 2 meters deep. Currently, production costs for a single propeller are about $1.6 million and the production takes about 12 months. The goal of the joint effort is to decrease the production time for a propeller down to 4 months.

NIST results to date have achieved a 10 fold increase in material removal rate during the machining operations of the propeller—a significant improvement in machining productivity for the U.S. Navy. NIST results also form much of the technical basis for the procurement and expected operation of the new Navy system. In addition, a NIST scientist completed dynamic measurements of a representative high-speed spindle to be used with a NIST-developed algorithm, called receptance coupling substructure analysis, to select the appropriate tooling and machining parameters prior to delivery of the machine. This result will reduce the development time typically required when manufacturing a new part on a newly installed machine.

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INITIAL TESTS SHOW HIGH PERFORMANCE OF NIST RM 8240 STANDARD BULLETS

The fabrication of 20 standard bullets (Reference Material 8240) was completed on Jan. 7, 2002, by a team composed of NIST researchers. Based on comments received from bullet examiners on prototype standard bullets developed at NIST in 1998, these reference material bullets were designed with six signatures from six master bullets of the ATF and FBI national laboratories, and with material, color, and shape similar to real bullets. In February, NIST researchers visited a private company in Canada, the principal manufacturer of optical instruments used to link suspect weapons to bullets and casings recovered from crime scenes. The purpose of the visit was to test the reproducibility of the NIST bullets and to discuss procedures for their use and opportunities for dissemination.

The instrument manufactured by the private company is the Integrated Ballistics Identification System (IBIS). Six NIST bullets were tested there using one of their IBIS systems. The initial test results showed that the reproducibility of the manufactured bullet signatures on the different bullets is close to the measurement reproducibility of the IBIS system itself. That suggests that when these bullets are distributed nationwide for IBIS calibrations, they can virtually play the same function as a single standard bullet.

Scientists and engineers at the company also agreed to investigate the use of a NIST developed parameter based on autocorrelation functions, combined with the use of NIST standard bullets, for establishment of traceability and quality control for ballistics measurements. A NIST workshop is planned for bullet examiners before the delivery of these bullets to government and law enforcement agencies. The NIST RM 8240/8250 standard bullets and casings project will support the ATF and FBI, as well as homeland security.

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W3C AND NIST RELEASE DOM CONFORMANCE TEST SUITE

The World Wide Web Consortium (W3C), in partnership with NIST, released the first version of the Document Object Model (DOM) Conformance Test Suite, Level 1 Core. The DOM Test Suite aims to help implementers test their implementations conformance with the W3C DOM Level 1 specification. This work, launched by W3C and NIST, is a publicly developed and open framework to test the DOM Level 1 Core implementations.

The DOM is a platform- and language-neutral interface that allows programs and scripts to dynamically access and update the content, structure, and style of documents. The DOM test suite consists of over 600 tests for the DOM Java and ECMA Script bindings. An additional set of more than 1000 tests for the HTML module and HTML-compatible core will be released soon. The test suite was developed using XML technology and automated test generation techniques. The tests are represented in an XML grammar (i.e., in XML schema and in DTD form) that was automatically generated from the DOM specification using an XSLT transform. These tests, which are language-neutral, are used together with XSLT style sheets to generate the Java and ECMA Script bindings of the tests. This method of generating tests ensures traceability to the specification as well as a consistent set of executable tests across language bindings.

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SEVENTH NIAP COMMON CRITERIA TESTING LABORATORY APPROVED FOR IT SECURITY TESTING

The National Information Assurance Partnership (NIAP), a U.S. Government collaboration between NIST and the National Security Agency, announced approval of the seventh information technology security testing laboratory under the Common Criteria Evaluation and Validation Scheme (CCEVS). The new Common Criteria Testing Laboratory (CCTL), a private company in Linthicum, MD, successfully completed the rigorous National Voluntary Laboratory Accreditation Program process and has been accredited to conduct evaluations of commercial products against the Common Criteria for Information Technology Security Evaluation (ISO/IEC15408) standard. This process included an in-depth analysis of the laboratory's quality system and procedures, the administration of a comprehensive proficiency test covering the application of the Common Criteria and the Common Evaluation Methodology, and an on-site assessment of the laboratory facilities.

The Common Criteria evaluation technical reports produced by testing laboratories and validated by the NIAP CCEVS Validation Body are recognized by 14 other countries currently participating with the United States in the Arrangement on the Recognition of Common Criteria Certificates in the Field of Information Technology Security, signed during the First International Common Criteria Conference in May 2000. In order for the Validation Body to issue an internationally recognized common criteria certificate, the evaluation must have been conducted by an independent third party, laboratory in accordance with the requirements of the NIAP CCEVS.

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INDEPENDENT TESTING FOR CONFORMANCE TO BACnet® BEGINS

For many years, the building industry struggled with the problem of integrating control devices made by different manufacturers in order to optimize operations, improve safety, and reduce maintenance costs. NIST researchers worked with industry to develop a communication protocol standard for building automation and control systems known as BACnet® that was adopted in the mid-1990s.

A marketplace barrier to BACnet products has been the lack of an independent testing program to verify that products correctly implement the standard. Consequently, NIST created a BACnet Interoperability Testing Consortium with 22 private sector companies. NIST researchers and the consortium partners worked together to develop test procedures that are now incorporated in a draft American national standard. NIST also developed software tools that can be used to implement the BACnet tests. The results of these efforts have now resulted in the creation of the BACnet Manufacturers Association (BMA), a private sector BACnet Testing Laboratory (BTL), and the completion of the first set of tests on commercial products.

The BMA will issue a BTL mark and publish a list of products that have passed the tests. The goal is for the BTL mark and listing program to play a role in the building automation and control industry much like the more well know Underwriters Laboratory mark and listing program for product safety.

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PARCS ADVANCES THROUGH NASA REVIEWS

The NIST-led program entitled Primary Atomic Reference Clock in Space (PARCS) has successfully completed its second NASA review, the requirements definition review. This review, which included both a science panel and an engineering panel, considered both the scientific merits of the mission and the technical feasibility of the proposed experiments. This was the final review of the science. A series of additional reviews also address engineering issues of the flight systems.

In its report to NASA, the review panel recommended that "the PARCS project should proceed with all possible speed and deliberation toward the preliminary design review." The complete preliminary design of the system will be considered in the next review, which is scheduled for late summer.

This NASA-funded mission, which is a collaboration of NIST, the Jet Propulsion Laboratory, the University of Colorado, the Harvard-Smithsonian Center for Astrophysics, and the Politecnico di Torino, is currently scheduled to fly in 2005. The objectives are to test certain aspects of relativity theory, to improve upon the realization of the second, to study the performance of GPS clocks, and to study the dynamics of atoms in microgravity.

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QUENCHED NARROW-LINE COOLING OF CALCIUM

Since their invention, atomic clocks have operated in the microwave portion of the spectrum, where their output frequencies have been amenable to electronic systems. However, the precision of such standards has been limited by their spectral linewidths (relative to the reference frequencies themselves). Substantial progress in this field can be achieved by using very narrow optical transitions instead, in part because the reference frequencies are orders of magnitude higher.

NIST has achieved a technical milestone in its push to develop optical atomic frequency standards and clocks. The objective is to improve upon the accuracy and stability of the calcium optical standard, which is the only optical standard for which high-accuracy international comparisons have been made. The best comparison to date is between NIST and PTB where a difference of only 30 Hz was measured for the 456 THz (657 nm) transition. This was well within the uncertainties of the individual measurements.

The 26 Hz uncertainty in recent measurements at NIST arose from the limitations of the laser-cooling method that was then available. In calcium, normally only Doppler cooling is possible. However, the Doppler limit is large, of the order of 1 mK.

NIST has recently achieved sub-Doppler cooling of ^{40}Ca to near the recoil limit using a quenched narrow-line laser-cooling method. A laser operating just below 657 nm (on the clock reference transition) provides a cooling force while a second, co-linear laser (at 552 nm) provides both additional cooling and optical pumping required for the process to work. Using this method, calcium atoms were cooled in one dimension to < 2 μK and in three dimensions to below 10 μK. Further improvements will include further reduction in temperature and increased cooling efficiency.

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EXTREME ULTRAVIOLET REFLECTIVITY INTERCOMPARISON

In the microelectronics industry, the number of transistors on an integrated-circuit chip doubles about every 18 months (Moore's Law). This accomplishment has been made possible by utilizing shorter and shorter wavelengths of radiation for photolithography. Today, leading manufacturers are pushing deeper into the ultraviolet spectrum. However, the end is in sight for further incremental changes. Very different technology will be required for wavelengths shorter than 157 nm.

A number of leading chip companies have formed the EUV LLC research consortium to develop next-generation manufacturing technology. Extreme ultraviolet (EUV) radiation at 13.4 nm holds promise because of the fortuitous high reflectivity of Mo/Si multilayer mirrors at this wavelength.

The NIST/DARPA Reflectometry Facility at NIST's Synchrotron Ultraviolet Radiation Facility (SURF) was established in anticipation of these needs. It is the only facility in the world capable of making a complete measurement of reflectivity on the large mirrors being used by EUV LLC in their engineering test stand, an instrument intended to provide the foundation for the ultimate design of an EUV lithographic tool.

A just-completed international intercomparison confirmed NISTs capabilities. Seven test samples were studied by NIST, PTB, Lawrence Berkeley Laboratory, ASET (a Japanese consortium), and the Himejii Institute of Technology (Japan).

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ROTATING CONDENSATES PUT NEW SPIN ON SUPERFLUIDITY

Scientists at NIST have been studying the behavior of Bose-Einstein condensates subject to rotation of the trap, which is a key issue in the phenomenon of superfluidity. When the trap is subject to a low rate of rotation, the condensate does not exhibit any net circulation, unlike a classical fluid that will circulate with the trap. Nevertheless, the condensate does acquire some angular momentum, which results in an anisotropic density distribution.

NIST scientists had the simple theoretical insight that when a condensate is released from a rotating trap it flies apart under conditions in which angular momentum is conserved, preserving the anisotropy in the density distribution. This effect is simple to observe and possible to test with considerable quantitative accuracy. An experimental group at Oxford University, having received a preprint of the NIST paper, performed the experiment and confirmed the theoretical predictions. The theoretical and experimental papers were published simultaneously in the February 11, 2002, issue of *Physical Review Letters*.

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THERMAL-INFRARED TRANSFER RADIOMETER VALIDATES RADIANCE SCALES USED ON LAND, AT SEA, AND IN SPACE

The Thermal-Infrared Transfer Radiometer (TXR) was designed at NIST to permit NIST staff to perform field calibrations of critical instruments used for environmental remote sensing. As word spread through the remote-sensing calibration community about this unique and valuable measurement capability, the TXR was deployed on three critical missions during the summer of 2001.

In May, NIST in collaboration with NASAs Goddard Space Flight Center deployed the TXR at an infrared radiometry workshop at the University of Miami (Florida) Rosenstiel School of Marine and Atmospheric Science. The TXR checked the radiance scales of blackbody sources used by the sea-surface remote sensing community to calibrate ship-based radiometers that validate satellite measurements of sea-surface temperature.

In July, the TXR was deployed to the NOAA Geostationary Operational Environmental Satellites (GOES) Imager calibration chamber at a private company in Ft. Wayne, IN. NIST staff, in collaboration with this company, performed measurements of the radiance of two calibration targets used for GOES Imagers during pre-flight calibration. These data will enable radiometric calibration models used by the GOES program to be checked against the NIST infrared radiance scale.

Finally, in August, the TXR was deployed to Los Alamos National Laboratory (LANL). NIST and LANL collaborated to measure in a cryogenic vacuum chamber, the radiance of blackbody sources which were used previously to calibrate a DOE satellite-based infrared sensor. These data will enable a comparison between the scale used for calibration of the DOE sensor and the NIST infrared radiance scale.

Presently, the TXR is back at NIST undergoing post-deployment recalibration and even more thorough characterization. Reports will soon be issued on the results of the 2001 measurement campaigns.

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PHOTOASSOCIATION IN A BOSE-EINSTEIN CONDENSATE

Two colliding atoms can absorb a photon and be photoassociated into an excited, diatomic molecule. NIST researchers investigated the fundamental rate at which this process can take place in a Bose-Einstein condensate (BEC) and demonstrated that simple classical saturation arguments do not work when applied to this situation.

While the photoassociation reaction has been well-studied in a thermal gas, one can argue that the same process will run into limitations under the conditions present in a BEC. A simple classical argument says that a pair of atoms has a narrow range of internuclear separations at which the photoassociation process can be driven to take place. Once atoms with this range of separations are depleted, the population must be replenished by the movement of atoms, and that this is limited by their thermal velocity (about 0.5 mm/s in this case). On the other hand, a quantum mechanical description of the BEC has a single wavefunction for all the atoms; each atom is extended across the entire region where the experiment is performed. The measured rate coefficient for the reaction is in good agreement with results from a quantum mechanical two-body scattering theory for all the intensities that were achievable experimentally, and can exceed the classical limit by more than four orders of magnitude.

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BROADBAND FERROMAGNETIC RESONANCE SPECTROMETER

NIST researchers have constructed a broadband spectrometer for measurements of ferromagnetic resonance (FMR) in magnetic thin films from 1 GHz to 26 GHz. Like electron paramagnetic resonance and nuclear magnetic resonance, FMR involves precession of the magnetization around an equilibrium direction, but motion of the magnetization is heavily influenced by the large magnetization that is characteristic of ferromagnets. Measurements of the resonance condition as a function of applied field direction are valuable for determining magnetic anisotropy energies and coupling between magnetic layers in multilayer structures such as the spin valves that are used as the active elements of read heads in modern disk drives.

The resonance line width includes the effects of both inhomogeneities and intrinsic damping. The extrinsic line width is an important indicator of film quality, and the intrinsic damping, which governs the magnetic relaxation rate, is projected to become increasingly important for the development of fast magnetic memory (MRAM) and GHz-rate disk drives. In disk drives, the relaxation rate is important for high data rate operation of the read head and for writing, both in the writer and in the media. In addition, the damping mechanisms that couple the magnetism to the thermal bath also drive the magnetic fluctuations that characterize the superparamagnetic limit of storage density.

The broad frequency range and the angular control provided by this new spectrometer allows thorough testing of line width and damping models that are needed to separate the inhomogeneous and intrinsic contributions to the measured resonance line width. Initial measurements using the new spectrometer have been made on films with intentionally created defects and nominally uniform films.

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BRILLOUIN LIGHT SCATTERING

NIST scientists have recently implemented a Brillouin light scattering facility for characterizing acoustic and magnetic waves in thin-film and bulk materials. This system is capable of measurements in the 3 GHz to 300 GHz range with sampling volumes less than 50 μm in diameter and a few hundred nanometers in depth, thus enabling detailed measurements on micron-scale patterned thin-film structures.

Because it can selectively detect both acoustic and magnetic waves, Brillouin light scattering can provide unique information on the coupling between magnetic states and thermal phonons. The initial research using this system is focused on measurements of ferromagnetic thin films with the goal of providing information on damping mechanisms that limit the switching times of magnetic memory elements, a project partly funded under the NIST Nanotechnology Initiative.

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NEW METHOD TO MEASURE MASS DISTRIBUTION OF POLYOLEFINS

A new technique for measuring the molecular mass distribution of polyolefins has been developed by researchers at NIST. The new method is based on mass spectrometry, a long-standing technique for characterizing low mass substances, but one that is difficult to use on high mass polymers owing to the requirement of producing intact charged molecules in the vapor state. In the past decade a variation of mass spectrometry, termed matrix assisted laser desorption/ionization (MALDI), has become a powerful tool to characterize biopolymers, such as proteins and nucleic acids. Most biopolymers and some types of synthetic polymers are readily charged. However, polyolefins lack the chemical composition for charging by the usual methods. NIST researchers have developed a method of chemically modifying polyethylene to a readily ionized molecule. The method has been demonstrated on polyethylene of masses to 15 ku, a mass limit that far exceeds what had been previously reported in the scientific literature. The first report of the NIST accomplishment appeared in the journal *Polymer*. A manuscript describing optimization of the method has been accepted by *Macromolecules*.

The method addresses a major need of polymer producers and users for rapid and reliable methods of measuring the molecular mass distribution of polymers. The need is especially urgent for polyolefins, examples are polyethylene and polypropylene that dominate the commercial market, where advances in catalysis have led to a plethora of new molecular variations. Owing to the way synthetic polymers are synthesized they possess a range of molecular masses. The distribution of the mass is critical to how the resins are processed into useful objects as well as the resultant properties. The methods currently used yield only averages of the mass distribution; chromatographic methods produce the mass distribution, if calibrated properly with polymer mass standards. All these methods require dissolution of the polymer in a solvent, for polyolefins this usually means using aggressive solvents at elevated temperature. This is one reason why few mass standards are available for polyolefins. The innovative mass spectro-

metric method provides a powerful direct approach for measuring mass distribution in polyethylene at a time of accelerated introduction of new molecular architectures.
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NIST PERFORMS ELECTROMAGNETIC SHIELDING EFFECTIVENESS TESTS ON A COMMERCIAL AIRCRAFT

NIST recently performed electromagnetic shielding effectiveness tests on a commercial aircraft using NIST designed broadband horn antennas and specialized time domain measurement methodology. The information gained in this effort is being used to develop low-cost and efficient measurement techniques for *in situ* testing of aircraft.

Shielding effectiveness measurements are performed to quantify the electromagnetic fields coupled into an aircraft from an external source, or conversely, internal to external coupling. It is best is to measure an aircraft at an open area test site. However, taking an aircraft out of the production chain is extremely costly for the aircraft industry. Continuous wave measurements made in a hanger or production facility suffer from unwanted reflections that make data interpretation difficult. Thus, the aircraft industry is interested in time domain methods that enable extraneous reflections due to hanger walls to be windowed out using gating techniques.

NIST engineers used time domain methodology developed at NIST to measure an aircraft in a paint hanger along the production line. In addition, NIST has developed a joint time-frequency analysis tool that will be used to extract critical cavity decay characteristics useful in aircraft shielding studies. The Naval Surface Weapons Center and a private company sponsor this effort.
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NIST OPENS NEW SPECIAL TEST MEASUREMENT SERVICE FOR 2.92 mm COAXIAL POWER DETECTORS

Staff at NIST recently opened a new Special Test Service for 2.92 mm coaxial power detectors. This new service measures the effective efficiency and calibration factor of thermistor, thin-film, and thermoelectric power detectors over a frequency range of 0.01 GHz to 40 GHz. Power measurements are basic to all measurements in the microwave and electronics industry.

In recent years, the instrument manufacturers have been moving to coaxial line sizes that operate at frequencies up to 40 GHz and beyond. A number of electronic instruments are now commercially available that have 2.92 mm coaxial connectors and that operate at frequencies up to 40 GHz. The new service will provide power measurement traceability for those devices. The power calibrations are made on the NIST direct comparison system. This system is calibrated using 2.4 mm thin-film detectors, and characterized 2.4/2.92 mm adapters. The new service was developed in cooperation with the Air Force, Army, and Navy Primary Standards Laboratories.
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NIST STUDY ACCELERATES UNDERSTANDING OF OXIDATION MECHANISMS IMPORTANT TO LASER MANUFACTURERS

Researchers at NIST have shown that the oxidation kinetics of AlGaAs are independent of semiconductor growth method and edge preparation conditions. Native semiconductor oxide layers are critical components of optoelectronic devices, such as vertical-cavity surface-emitting lasers (VCSEL) used in high-speed data communication, in which they provide optical and electrical confinement. VCSEL manufacturers have reported difficulties with the repeatability of their oxidation process.

NIST researchers conducted a study of oxidation rate as a function of relevant semiconductor growth and processing variables for initial AlGaAs layers having Al mole fractions from 0.9 to 1.0. They found that, contrary to the expectations of some device manufacturers, the oxidation rate did not depend on whether the initial layers were grown by molecular beam epitaxy or metalorganic chemical vapor deposition (MOCVD), the two methods most commonly used by the industry. The oxidation was independent of the V/III ratio of the growth, impurity level in the initial epilayer, and specimen edge preparation, whether wet etched, ion milled, chemically-assisted ion-beam etched, or cleaved. As expected, the oxidation reaction kinetics were a sensitive function of semiconductor composition, oxidation temperature, and time. The study did reveal, in one sample set grown by MOCVD by an outside laboratory, unintentional fluctuations in the epilayer composition during growth (as confirmed by SIMS analysis), which increased the oxidation rate.

The results of the NIST study are providing VCSEL manufacturers valuable insight into the tolerances of their native oxide fabrication process. They are also important input to a broader investigation of the impact of strain on device reliability. More details can be found in the paper "Comparison of AlGaAs Oxidation in MBE and MOCVD Grown Samples," by Y. Chen et al., Mat. Res. Soc. Symp. Proc. (2002) p. H6.11.1.
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NIST RESEARCHERS MEASURE WAVELENGTH-DEPENDENT GAIN OF RAMAN FIBER OPTICAL AMPLIFIERS

Staff at NIST recently completed measurements of the dependence of Raman gain in optical fiber on both the difference between the pump and signal wavelengths and the absolute pump wavelength. These measurements, made on four standard telecommunication fibers, represent the first direct measurements of the pump-wavelength dependence. The pump-wavelength dependence was measured using two complimentary techniques; a brute-force comparison of the Raman gain at different pump wavelengths and a simpler, more elegant comparison of the asymmetry in the Stokes and anti-Stokes Raman gain at a fixed pump wavelength.

Fiber Raman amplifiers are becoming increasingly important in optical fiber communication systems since they provide both lower noise performance and a wider wavelength coverage than conventional optical amplifiers. In fiber Raman amplifiers, a strong pump laser provides gain to signals at longer wavelengths through stimulated Raman scattering within the optical transmission fiber. The Raman gain will depend strongly on the wavelength difference between the pump and signal beams and weakly on the absolute pump wavelength. Previous measurements of the Raman gain have focused on its strong dependence on the wavelength difference between the pump and signal beams and have ignored the weaker pump-wavelength dependence. With the growing potential for widespread use of fiber Raman amplifiers in deployed systems, more complete measurements of the Raman gain are needed to provide input for system simulations.
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NIST DEVELOPS ACCURATE MODEL FOR ION BOMBARDMENT ENERGIES IN PLASMA ETCHERS

NIST scientists have recently developed and validated a model for predicting the kinetic energy of ions in plasma etching reactors used by the semiconductor industry. During plasma etching, substrates are bombarded by reactive chemical species and energetic ions generated in the plasma, resulting in selective removal of material from exposed areas of the substrate. The energy of ions striking the substrate surface plays an important role in determining the etching rate and the profile of etched features. To control ion energies, radio-frequency (rf) power is applied to the substrate electrode, but the effect of the rf power on ion energies is quite complicated. Models describing the relation between rf power and ion energy have been developed, but they often involve simplifying assumptions that have never been rigorously tested. Consequently, it is difficult to predict and to optimize ion energy distributions.

At NIST, a plasma model has recently been developed to predict ion energy distributions. This model includes a complete treatment of the time-dependent ion kinetics in the plasma sheath, the thin region between the plasma and the substrate surface. Unlike previous models, no simplifying assumptions are made regarding the time scale of ion motion or the frequency of the rf power applied to the substrate.

The new model has recently been validated by a comprehensive set of experiments performed in an inductively coupled plasma reactor. Measurements of ion energy distribution made by a mass spectrometer were combined with capacitive probe measurements of the time-dependent plasma potential and Faraday cup measurements of the total ion flux. Together, these measurements completely determine all the input parameters of the model, allowing a direct comparison of model results and measurements. Ion energy distributions predicted by the model were in good agreement with measured distributions over the entire range of frequencies investigated. The model was found to accurately predict the dependence of ion energy distributions on rf frequency, rf amplitude, total ion flux, and ion mass. The validated model can be adapted for use in commercial plasma simulations. It also enables new, model-based methods for in situ monitoring of ion energies during plasma etching.
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EXPORT ALERT! SERVICE HELPS INDUSTRY

The free Export Alert! web-based system operated by NIST automatically provides early warning of changes in trade-related technical regulations proposed by members of the World Trade Organization (WTO). The OSS National Center for Standards and Certification Information (NCSCI) is the U.S. inquiry point for the WTO and is responsible for distributing notifications to U.S. industry of proposed foreign technical regulations for review and comment as appropriate. The WTO requires its members to give notice of proposed regulations that might significantly affect trade. Using Export Alert! improves U.S. companies' awareness of proposals that might affect their business.

Subscribers can select specific industry sectors and/or countries in order to receive relevant e-mail messages. NCSCI can provide full-text copies of proposed regulations and will transmit comments to appropriate foreign ministries. When necessary, an extension of the comment period will be requested. Information on Export Alert! can be found at http://ts.nist.gov/ncsci.

Since its inception, over 1000 U.S. private and public organizations have registered for the service, and more than 1000 requests for copies of the full text of proposed regulations have been received by NCSCI staff. Many companies request two or more proposed regulations.
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PUBLIC RELEASE OF THE NIST FIRE DYNAMICS SIMULATOR 2.0

Official release versions of NISTs computer programs for modeling and visualizing fire and smoke flow, Fire Dynamics Simulator 2.0 and Smokeview 2.0, are now available for download at http://fire.nist.gov/fds/. The NIST Fire Dynamics Simulator predicts smoke and/or air flow movement caused by fire, wind, ventilation systems, etc. Smokeview visualizes the predictions generated by the Fire Dyanamics Simulator.

The Fire Dynamics Simulator is a computational fluid dynamics model which solves a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flows of smoke and hot gases generated in a fire. Version 2.0 of the Fire Dynamics Simulator includes improved combustion and radiation algorithms. Details of the numerical methods may be found in the Fire Dynamics Simulator Technical Reference Guide (NISTIR 6783). Smokeview visualizes the Fire Dynamics Simulator computed data by animating time dependent particle flow, two-dimensional slice contours and surface boundary contours. Details about Smokeview may be found in the Smokeview User's Guide (NISTIR 6761). Version 2.0 of Smokeview includes new visualization techniques such as animated isosurfaces and animated flow vectors. Instructions on how to use the Fire Dynamics Simulator and Smokeview can be found in the Fire Dynamics Simulator Users Guide (NISTIR 6784).
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PROTOTYPE OF FLEXIBLE BALL STEP GAUGE ARTIFACT

As part of the program to maintain quality control on coordinate measuring machines (CMMs) for the Air Force, NIST completed a prototype ball step gauge artifact. The gauge is the first of a series to be used throughout the Air Force as a new calibration procedure for CMMs. The use of a ball step gauge will allow CMMs to be calibrated quickly and easily according to an established protocol. The system is capable of positioning to eight azimuthal positions, at five different vertical incliniations. Each position is repeatable, so that CMM calibration can occur with a minimal of operator interaction. The data obtained from the calibrated gauge will be used to establish part-specific measurement uncertainty using the method of simulation by constraints developed at NIST.
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NIST RESEARCHERS DEVELOP REVOLUTIONARY DETECTOR FOR QUANTUM COMMUNICATION SYSTEM

NIST, in collaboration with Stanford University and Boston University, has demonstrated the first quantum-communications detector system that not only indicates when a photon arrives, but also determines how many photons arrive simultaneously. As a result, this new system can extract far more information from quantum-entangled photons than conventional detectors.

The new detectors are based on superconducting transition-edge sensor (TES) microcalorimeter technology, similar to that developed by EEEL for high-efficiency x-ray spectroscopy. The new TES photon counters have a very broad spectral response, from the near-infrared (3000 nm) through the visible and into the deep-ultraviolet (100 nm) with a quantum efficiency of about 50 %. Unlike traditional semiconductor-based photon counters, these TES photon counters do not suffer from dark counts, nor do they have a gap-limited infrared cut-off.

Even more exciting is the ability of the TES photon counter to provide the energy of the incoming photon. For broadband sources, this resolution capability allows spectral information to be determined from each photon. For monochromatic sources, such as quantum-entangled photon sources, the energy resolution capability allows the elimination of the multiphoton confusion problem of conventional detectors. A four-channel system designed around TES devices is under construction as a full Bell-state analyzer and may be very useful as a broadband detector calibration instrument based entirely on quantum standards. A demonstration of the four-channel instrument is underway using a correlated photon source at Boston University.

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HELPING THE POSTAL SERVICE ADD "ZAP" TO THE MAIL

As a member of the Mail Security Task Force of the White House Office of Science and Technology Policy (OSTP), NIST has been working on sanitizing letter mail contaminated or possibly cross-contaminated by the anthrax bioterror actions of last October. However, parcel packages present a different problem. The electron irradiation process that so effectively sanitizes letter mail is not penetrating enough to be used on the nearly 200 000 larger-volume packages that have been sitting in limbo at the Brentwood and Trenton postal facilities.

It has been decided that 5 MeV x-ray irradiation is the best tool for decontaminating parcel mail. NIST traceable dosimetry was used in phantom tests and spore-kill tests to provide quality assurance of the correct dose as required by the bacillus anthracis radiation-kill curves generated by the Armed Forces Radiobiology Research Institute (AFRRI).

On April 11, NIST and AFRRI researchers briefed White House staff and other federal agencies in the Indian Treaty Room of the Eisenhower Executive Office Building. The results of NIST-designed experiments were presented, including the survivability of biological spore indicators as a function of absorbed dose, an analysis of volatile organic compound emissions, and decontamination efforts using ethylene oxide. As a result, the Postal Service qualified a private company in Bridgeport, NJ, to begin irradiation of its backlog of suspect parcel mail. Anonymous mail with destination ZIP codes 202xx through 205xx (to Government offices) will be irradiated by electron or x-ray beams on an ongoing basis.

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NEWEST CRITICAL DIMENSION SCANNING ELECTRON MICROSCOPES USE NIST TECHNOLOGY

Scanning electron microscopes (SEM) are used extensively in the semiconductor production environment. NIST scientists are helping to improve SEM performance with an objective diagnostic procedure to ensure data fidelity by looking at the sharpness measurements.

The concept of continuous or periodic sharpness monitoring has been incorporated into a new commercial critical dimension (CD) SEM. This CD-SEM incorporates a "beam condition" monitor that provides numerical and graphical descriptions of the condition of the instrument and documents the instruments condition over time.

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SPUR-FREE, DISTORTION-FREE REFERENCE CLOCK

New generations of high-resolution Doppler radar rely on advanced digital-imaging and object-identification techniques. To test high data rate, high-fidelity digital signal processors in this application, the reference clock must have extremely low random noise and no spurious signals or half-period distortions.

NIST in Boulder has designed and built ultra-low-phase-noise reference clocks operating at 10 MHz and 100 MHz in which periodic and quasi-periodic spurious signals and half-period distortions are lower than any other reference source ever demonstrated. The performance of these clocks approaches the broadband phase-noise level set by thermal noise.

Jitter on a reference clock degrades conversion of radio signals to the digital-code domain. Small spurious signals and clock distortions cause spurious code responses and distortions in the conversion process, which can be far more problematic than random noise. We have recently shown how discrete lines due to external influences, such as electromagnetic interference, vibration, and power-supply ripple, translate to jitter. These low-frequency lines, rather than broadband phase noise, can be the dominant contributor to jitter, even for operations involving very high-rate (microwave-bandwidth) digital signals, where low-frequency modulation noise traditionally has been ignored as a concern.

We have demonstrated that jitter analyzers cannot sort out these lines, while phase-noise measurements can. Through a contract with industry, new filters were developed to reduce reference-frequency harmonic distortions, and these have been primarily responsible for the improved performance. However, further

improvement was achieved through powering the systems from separate isolated batteries, from a more compact design that reduces pickup of external signals, and from the addition of electromagnetic interference shields.
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Standard Reference Materials

NIST RELEASES TWO NEW CALIBRATION STANDARDS FOR OPTICAL FIBER COMMUNICATIONS

NIST is releasing two artifact calibration standards relating to polarization dependent measurements in optical fiber telecommunications applications.

NIST will provide traceable measurements for polarization dependent loss (PDL) in optical fiber and fiber components, using an artifact standard made available to customers through a Measurement Assurance Program (MAP). A NIST scientist developed the artifact and will conduct the MAP. When PDL is combined with polarization-mode dispersion in a communication channel, the bit error rate is degraded. Therefore accurate measurements are necessary to enable high data rate communication systems. The MAP artifact consists of a short section of polarizing fiber spliced to a single mode input fiber and a step-index multimode output, and its PDL is certified over the 1535 nm to 1560 nm wavelength range. The artifact is implemented as a MAP [rather than a Standard Reference Material (SRM)] to mitigate the degradation to uncertainty that is caused by exposure of the artifact to unpredictable temperatures. The MAP implementation includes a recording thermometer to indicate the temperature exposure of the device during transportation and the customer measurement process.

An additional SRM for polarization mode dispersion (PMD) will expand NIST traceability in this area. In an optical fiber communication system, propagation velocity depends on the polarization state of the light. The resulting PMD can broaden optical pulses and limit bit rate. The new SRM, developed by another NIST scientist, is SRM 2538, Polarization-Mode Dispersion, Non-Mode-Coupled. It is the second SRM for PMD. The first, SRM 2518, emulates the differential group delay in a long length of optical fiber. The new artifact, SRM 2538, is a fiber-pigtailed quartz plate, designed to emulate the PMD typically found in telecommunications components. This new SRM is certified for mean differential group delay over a wavelength range of approximately 1250 nm to 1650 nm. SRM 2538 is certified for measurement by all PMD techniques (subject to instructions in the documentation). Due to technical constraints, SRM 2518 is certified for only a particular class of PMD measurement techniques.
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