NISTIR 4520

Center for Electronics and
Electrical Engineering

Technical Publication Announcements

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards
and Technology
Center for Electronics and
Electrical Engineering
Semiconductor Electronics Division
Gaithersburg, MD 20899

Covering Center Programs,
April to June 1990,
with 1991 CEEE Events Calendar

[redacted]

25

U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary
NATIONAL INSTITUTE OF STANDARDS
AND TECHNOLOGY
John W. Lyons, Director

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INTRODUCTION TO THE CEEE TECHNICAL PUBLICATION ANNOUNCEMENTS

This is the twenty-fifth issue of a quarterly publication providing information on the technical work of the National Institute of Standards and Technology (formerly the National Bureau of Standards) Center for Electronics and Electrical Engineering. This issue of the CEEE Technical Publication Announcement covers the second quarter of calendar year 1990.

Organization of Bulletin: This issue contains citations and abstracts for Center publications published in the quarter. Entries are arranged by technical topic as identified in the table of contents and alphabetically by first author within each topic. Following each abstract is the name and telephone number of the individual to contact for more information on the topic (usually the first author). This issue also includes a calendar of Center conferences and workshops planned for calendar year 1991 and a list of sponsors of the work.

Center for Electronics and Electrical Engineering: Center programs provide national reference standards, measurement methods, supporting theory and data, and traceability to national standards.

The metrological products of these programs aid economic growth by promoting equity and efficiency in the marketplace, by removing metrological barriers to improved productivity and innovation, by increasing U.S. competitiveness in international markets through facilitation of compliance with international agreements, and by providing technical bases for the development of voluntary standards for domestic and international trade. These metrological products also aid in the development of rational regulatory policy and promote efficient functioning of technical programs of the Government.

The work of the Center is divided into two major programs: the Semiconductor Technology Program, carried out by the Semiconductor Electronics Division in Gaithersburg, MD, and the Signals and Systems Metrology Program, carried out by the Electricity Division in Gaithersburg and the Electromagnetic Fields and Electromagnetic Technology Divisions in Boulder, CO. Key contacts in the Center are given on the back cover; readers are encouraged to contact any of these individuals for further information.

Center sponsors: The Center Programs are sponsored by the National Institute of Standards and Technology and a number of other organizations, in both the Federal and private sectors; these are identified on page 23.

Note on Publication Lists: Guides to earlier as well as recent work are the publication lists covering the work of each division. These lists are revised and reissued on an approximately annual basis and are available from the originating division. The current set is identified in the Additional Information section, page 16.

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SEMICONDUCTOR TECHNOLOGY PROGRAM

Compound Semiconductor Materials

Littler, C.L., Seiler, D.G., and Loloee, M.R., **Magneto-Optical Investigation of Impurity and Defect Levels in HgCdTe Alloys**, J. Vac. Sci. Technol. A, Vol. 8, No. 2, pp. 1133-1138 (Mar/Apr 1990).

We have observed and described magneto-optical transitions between impurity/defect levels and conduction band Landau levels for a variety of n-type HgCdTe samples with $0.2 < x < 0.3$. The activation energies of these levels fall into two categories: (1) 10 to 12 meV above the valence band edge, independent of E_g and (2) two closely spaced levels at ~0.5 E_g. In addition, the spectra of several narrow-gap ($E_g \leq 100$ meV) samples exhibit shallower and deeper acceptor-like levels.
[Contact: David G. Seiler, (301) 975-2074]

Dimensional Metrology

Postek, M.T., Keery, W.J., and Frederick, N.V., **Low-Profile High-Efficiency Microchannel-Plate Detector System for Scanning Electron Microscopy Applications**, Rev. Sci. Instrum., Vol. 61, No. 6, pp. 1648-1657 (June 1990).

A new design high-efficiency microchannel-plate detector and amplification system is described for use in the scanning electron microscope. This complete detector system consists of four basic units: (1) the microchannel-plate detector, (2) the video amplifier, (3) the high-voltage power supply, and (4) the control unit. The microchannel-plate detector system is efficient at both high and low accelerating voltages, and is capable of both secondary electron and backscattered electron detection modes. The size of the actual detector is approximately 3.5 mm in thickness and 25.4 mm in diameter. Thus, use of this detector system permits using almost all the sample chamber to accommodate large specimens with only the loss of 3.5 mm of working distance. Another feature is that this system also employs a unique video amplifier where there are no active elements at high voltage. The microchannel-plate detector system enables the investigation of secondary-electron-induced contrast mechanisms and backscattered electron detection at extremely low accelerating voltages, even those below 1.0 keV.
[Contact: Beverly Wright, (301) 975-2166]

Potzick, J., **Practical Photomask Linewidth Measurements**, Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, WA 98227), Vol. 1261, Integrated Circuit Metrology, Inspection, and Process Control IV, pp. 114-122 (1990).

The measurement cycle for practical accurate photomask linewidth measurements is analyzed as a differential measurement--the linewidth to be measured is compared to a known linewidth on a standard photomask. The linewidth-measuring instrument is thus a comparator. The conditions necessary for a valid measurement are discussed with regard to both the instrument and the comparison process. The principles discussed here apply to many other types of measurement as well.
[Contact: Beverly Wright, (301) 975-2166]

Power Devices

Hefner, Jr., A.R., **An Investigation of the Drive Circuit Requirements for the Power Insulated Gate Bipolar Transistor (IGBT)**, Conference Record, 21st Annual Power Electronics Specialists Conference (PESC '90), San Antonio, Texas, June 10-15, 1990, pp. 126-137 (June 1990).

The drive circuit requirements of the IGBT are explained with the aid of an analytical model. It is shown that non-quasi-static effects limit the influence of the drive circuit on the time rate-of-change of anode voltage. Model

Power Devices (cont'd.)

results are compared with measured turn-on and turn-off waveforms for different drive circuits, load circuits, and different IGBT base lifetimes.
[Contact: Allen R. Hefner, Jr., (301) 975-2071]

Photodetectors

Geist, J., and Schaefer, A.R., **Planar Silicon Photosensors: An Overview**, Proceedings of the Third International Forum on ASIC and Transducer Technology, Banff, Alberta, Canada, May 20-23, 1990, pp. 32-38 (May 1990).

Planar silicon photosensor technology, which is suitable for integrating photosensors and circuits, is advancing in four roughly orthogonal directions. These are: 1) the accuracy with which the photosensor output signal can be related to the incident radiation, 2) the level of integration as measured by the number of photosensors in a system, 3) the level of integration as measured by the complexity of the processing of the photosensor output signals before presentation to a human observer or another system, and 4) the complexity of the photosensor structure. A brief overview of each of these areas accompanied by illustrative results is presented.
[Contact: Jon Geist, (301) 975-2066]

Device Physics & Modeling

Seabaugh, A.C., Mathias, J.J., and Bell, M.I., **Semiconductor Measurement Technology: EPROP: An Interactive FORTRAN Program for Computing Selected Electronic Properties of Gallium Arsenide and Silicon**, NIST Special Publication 400-85 (May 1990).

A new computer program, EPROP (an acronym for Electronic PROPerties) is presented for use in interpreting measurements and experiments on gallium arsenide and silicon. EPROP computes a solution of the charge balance equation in thermodynamic equilibrium for up to six different impurities. The user supplies the density, energy level, and degeneracy for each impurity, and in response the program returns as many as 28 output parameters, such as the Fermi level, carrier density, and ionized impurity densities. These can be computed as functions of the temperature (or reciprocal temperature) or the density, energy, or degeneracy of any of the six possible impurities. Listings can also be obtained of various temperature-dependent parameters, such as the bandgap, densities of states, and effective masses. The interactive features of the program allow the user to send the output data to any combination of destinations: a terminal, a listing file, and/or up to four graphic output files, all at the user's direction. The user is also given freedom and ability to customize the data output to these destinations through menu-driven controls. The program is written in ANSI standard FORTRAN 77 and has been successfully compiled and run on both mainframe and microcomputers. Documentation is provided to assist the interested user in customizing the program for special applications, extracting portions for use elsewhere, or modifying the code to treat semiconductors other than silicon and gallium arsenide.
[Contact: David G. Seiler, (301) 975-2044]

Insulators and Interfaces

Marchiando, J.F., **Semiconductor Measurement Technology: A Software Program for Aiding the Analysis of Ellipsometric Measurements, Simple Spectroscopic Models**, NIST Special Publication 400-84 (April 1990).

MAIN2 is a software program for the analysis of spectroscopic ellipsometric measurements. MAIN2 consists mainly of subroutines written in FORTRAN that are used to invert the standard reflection ellipsometry equations for simple systems. Here, a system is said to be simple if the solid material sample is characterized by models which assume at

Insulators and Interfaces (cont'd.)

least the following: (1) materials are nonmagnetic; (2) samples exhibit depth-dependent optical properties, such as one with layered or laminar structure atop a substrate that behaves like a semi-infinite half-space; (3) layers are flat and of uniform thickness; and (4) the optical medium within each ambient/layer/substrate is isotropic, homogeneous, local, and linear. The ambient region refers to that region of space which lies external to the layer/-substrate structure of the sample. Usually, the ambient region involves a medium of air or vacuum. Each layer is characterized by a thickness and a dielectric function. The dielectric function of a region, i.e., ambient, layer, or substrate, is represented by the Bruggeman effective medium approximation (EMA). Within the EMA, the effective medium of a region is characterized by an aggregate mixture of constituent media, and the dielectric function of each constituent medium is known a priori. The constituent dielectric functions are taken from the literature. The ellipsometric equations are formulated as a standard damped nonlinear least-squares problem and then solved by an iterative method when possible. The program is sufficiently modular to allow one to modify some of the models used in the calculations.
[Contact: Jay F. Marchiando, (301) 975-2088]

SIGNALS & SYSTEMS METROLOGY PROGRAM

FAST SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

Waveform Metrology

McKnight, R.H., Lagnese, J.E., and Zhang, Y., **Characterizing Transient Measurements by Use of the Step Response and the Convolution Integral**, IEEE Transactions on Instrumentation and Measurement, Vol. 39, No. 2, pp. 346-352 (April 1990).

The convolution integral is used with experimentally determined step responses and analytic waveforms which represent modifications to ideal waveforms expected in an experimental arrangement to determine the suitability of a given system for measuring waveforms of interest. Examples of the application of the method to specific measuring systems are presented.
[Contact: John E. Lagnese, (301) 975-2423]

DC & Low Frequency Metrology

Field, B.F., **The Calibration of dc Voltage Standards at NIST**, Journal of Research of the National Institute of Standards and Technology, Vol. 95, No. 3, pp. 237-253 (May-June 1990).

This document describes the procedures used at NIST to calibrate dc voltage standards in terms of the NIST volt. Three calibration services are offered by the Electricity Division: Regular calibration service of client standard cells at NIST; the Volt Transfer Program, a process to determine the difference between the NIST volt and the volt as maintained by a group of standard cells in a client laboratory; and the calibration of client solid-state dc voltage standards at NIST. The operational procedures used to compare these voltage standards to NIST voltage standards and to maintain the NIST volt via the ac Josephson effect are discussed.
[Contact: Bruce F. Field, (301) 975-4230]

Fundamental Electrical Measurements

Cage, M.E., Marullo Reedtz, G., Yu, D.Y., and Van Degrift, C.T., **Quantized Dissipative States at Breakdown of the Quantum Hall Effect**, Semiconductor Science Technology, Vol. 5, pp. 351-354 (1990).

We report the breakdown of the nearly dissipationless quantum Hall effect into a set of distinct, quantized dissipative states in a wide, high-quality

Fundamental Elec. Measurements (cont'd.)

GaAs/AlGaAs sample. We found 35 dissipative states accurately quantized in fractional units of volts/tesla to within our typical ±0.6% measurement uncertainty on the $i = 2$ plateau, and 9 are quantized on the $i = 4$ plateau. The phenomena show characteristics consistent with an extension of the quasi-elastic inter-Landau level scattering model of Eaves and Sheard.
[Contact: Marvin E. Cage, (301) 975-4248]

Williams, E.R., **High Accuracy Determination of the Fine Structure Constant via Measurement of the Proton Gyromagnetic Ratio**, Bulletin of the American Physical Society, Vol. 35, No. 4, p. 1069 (April 1990).

The latest experiment at the National Institute of Standards and Technology to measure the gyromagnetic ratio of the proton in H_2O, γ'_p, by the low-field method has an uncertainty of 0.11 ppm for γ'_p (low). Using this experimental result, a value for the fine structure constant $\alpha^{-1} = 137.0359840(51)$ (0.037 ppm) can be calculated. The uncertainty in α is limited by the uncertainty in the γ'_p experiment. The most difficult part of this experiment was constructing a 2.1-m long solenoid with a precision of a few μm, then measuring its critical dimensions to 0.05 μm. Instead of measuring the wire locations, we measured the location of the current placed in each winding turn using the magnetic field produced by the current in that turn. We accurately measured the solenoid current in terms of the Josephson volt and Quantum Hall resistance. The resultant magnetic field was uniform to 1 in 10^7 over 7-cm diameter sphere. The precession frequency was measured using NMR. When this value of α is compared with that obtained from the electron magnetic moment anomaly, a_e, using Dehmelt et al.'s results and Kinoshita's calculation, we have one of the most precise tests of QED theory. The difference between the values of α obtained from a_e and γ'_p is (0.054 ± 0.038 ppm).
[Contact: Edwin R. Williams, (301) 975-6555]

Williams, E.R., Sheng, Y., Olsen, P.T., Elmquist, R.E., Ruimin, L., and Jones, G.R., **Latest Results of the Proton Gyromagnetic Ratio in Water Plus Related Experiments**, Proceedings of the International Symposium on Electromagnetic Metrology, Beijing, China, August 19-22, 1989, pp. 165-169 (International Academic Publishers, Beijing, 1989).

The results of the latest measurement made at the National Institute of Standards and Technology of the proton gyromagnetic ratio, γ_p'(low), are presented, and the resultant value of the quantized Hall resistance, R_H, and the fine structure constant, α, are compared. A discussion of possible sources for the (-0.102 ± 0.043) ppm discrepancy between the absolute ohm and this measurement is included along with a new method to measure h/e^2 by counting electrons in a storage ring.
[Contact: Edwin Williams, (301) 975-6555]

Cryoelectronic Metrology

Sutton, E.C., Danchi, W.C., Jaminet, P.A., and Ono, R.H., **A Superconducting Tunnel Junction Receiver for** 345 GHz, International Journal of Infrared and Millimeter Waves, Vol. 11, No. 2, pp. 133-150 (1990).

In this paper we discuss the design, fabrication, and testing of a quasiparticle tunnel junction receiver for use at 345 GHz. The design employs small-area Nb/Nb-oxide/PbInAu edge junctions in order to keep the device capacitance small and maintain a modest value for $\omega R_N C$. For optimum noise performance and beam properties, the mixer is contained in a waveguide-mounting structure. Our best sensitivity was obtained at 312 GHz where we measured a double sideband (DSB) noise temperature of 275 K. Noise temperatures of 400 K (DSB) or better were obtained out to 350 GHz.

Cryoelectronic Metrology (cont'd.)

[Contact: Ronald H. Ono, (303) 497-3762]

Noise Metrology

Perera, S., **A Simple Noise Calibration Radiometer**, Digest of the 1990 Conference on Precision Electromagnetic Measurements, Ottawa, Canada, June 11-14, 1990, pp. 32-33 (1990).

A relatively inexpensive radiometer, intended to serve the needs of a calibration laboratory with a moderate workload, was designed at NIST. It utilizes heterodyning for broad frequency coverage, and a precision waveguide-below-cutoff attenuator to achieve a null-balancing mode of operation. The overall accuracy (with a primary cryogenic standard attached) is about 2%.
[Contact: Sunchana Perera, (303) 497-3546]

Wait, D.F., Counas, G.J., Kessel, W., and Buchholz, F.I., **PTB-NIST Bilateral Comparison of Microwave Noise Power in Coaxial Transmission Line**, Digest of the 1990 Conference on Precision Electromagnetic Measurements, Ottawa, Canada, June 11-14, 1990, pp. 34-35 (1990).

The Physikalisch-Technische Bundesanstalt and the National Institute of Standards and Technology have compared microwave noise power in coaxial transmission lines. Each laboratory measured two solid state noise sources at 2.0 GHz, 4.0 GHz, and 8.0 GHz relative to their primary thermal noise standards. The agreement between laboratories is better than 0.07 dB.
[Contact: David F. Wait, (303) 497-3610]

Microwave & Millimeter-Wave Metrology

Daywitt, W.D., **First-Order Principal Mode Fields and Distributed Line Parameters for a Slightly Lossy Coaxial Transmission Line**, Digest of the 1990 Conference on Precision Electromagnetic Measurements, Ottawa, Canada, June 11-14, 1990, pp. 404-405 (1990).

A complete set of first-order field equations valid between the outer and center conductors of a slightly lossy coaxial line does not exist even with the considerable history concerning coaxial transmission line calculations. None of the field expressions found in the literature from Russell in 1909 to Stratton in 1941 to Gardiol in 1987 displays a set of fields that will satisfy Maxwell's equations to first order in the skin depth or surface impedance. The purpose of this summary is to present a complete set of principal mode field equations from which the distributed line parameters can be calculated to greater accuracy than previously. However, only the distributed line resistance will be found to be significantly different from the more traditional estimates.
[Contact: William C. Daywitt, (303) 497-3720]

Holt, D.R., **Determination of Scattering Parameters with Respect to the Characteristic Impedance of Precision Coaxial Air-Line Standards**, Digest of the 1990 Conference on Precision Electromagnetic Measurements, Ottawa, Canada, June 11-14, 1990, pp. 282-283 (1990).

Scattering parameter expressions with respect to the characteristic impedances in correspondence to the principal mode are developed for the coaxial air line standard. Dimensional variations of the inner and outer conductors and skin effect loss are included in the model. The local characteristic impedance, which is found from the stored energy principle, is derived from the forward and backward voltage and current waves of the principal mode. Four sources of error for $|S_{11}|$ are discussed.
[Contact: Donald R. Holt, (303) 497-3574]

Reeve, G.R., Marks, R.B., and Blackburn, D.L., **MMIC Related Metrology at the**

Microwave & Millimeter-Wave (cont'd.)

National Institute of Standards and Technology, Conference Record, IEEE Instrumentation and Measurement Technology Conference, San Jose, California, February 13-15, 1990, pp. 196-199.

Last year, a program was instituted at the National Institute of Standards and Technology specifically directed at developing improved metrology methods and standards to support microwave monolithic integrated circuit (MMIC) technology. This paper describes how the program was developed, the modes of interaction with the industrial community and the DARPA MIMIC initiative, and the particular projects being undertaken which will result in a more consistent measurement base for those engaged in the design and manufacture of MMIC devices.
[Contact: Gerome R. Reeve, (303) 497-3557]

Weil, C.M., Marler, F.E., Major, J.R., Weidman, M.P., and Russell, D.H., **Dual Six-Port Reflectometer Systems Using Waveguide in the Frequency Range 18-50 GHz** [original title: Development of Waveguide Dual Six-Port Systems for Measurements in the Range 18 - 50 GHz], 33rd ARFTG Conference Digest, Long Beach, California, June 15-16, 1989, pp. 76-87 (September 1989).

The development and evaluation of three waveguide dual six-port reflectometer systems, covering the frequency range 18 to 50 GHz, are discussed. These are capable of automated or semi-automated operation and will provide complex scattering parameter data for customer waveguide components, as well as effective efficiency data for power sensors. Some representative measurement data are presented which demonstrate that these systems yield results that do not differ significantly from those obtained using older measurement systems. Some discussion of measurement uncertainties is also included.
[Contact: Claude M. Weil, (303) 497-5305]

Optical Fiber Metrology

Franzen, D.L., **Measurement Standards to Support Photonics Technology**, Conference Record, IEEE Instrumentation and Measurement Technology Conference, San Jose, California, February 13-15, 1990, pp. 326-328 (1990).

Standards to support the emerging photonics/lightwave technology industry can be classified into two groups: physical primary standards maintained by national standards laboratories and standard measurement procedures agreed upon by domestic and international voluntary standards bodies. The measurement of absolute optical power leads the prioritized list of primary standards needs. The progress at the National Institute of Standards and Technology (NIST) toward the development and distribution of optical power and other primary standards is reviewed. Standard measurement procedures to characterize fiber, cables, sources, detectors, and lightwave systems have been the focus of domestic and international standards bodies for the past decade. The interaction between NIST and these standards groups to evaluate the precision and accuracy of several test methods is reported. In some cases, the evaluations resulted in technical changes to commonly accepted practices.
[Contact: Douglas L. Franzen, (303) 497-3346]

Electro-Optic Metrology

Day, G.W., Veeser, L.R., Chandler, G.I., and Cernosek, R.W., **Progress in the Design of Optical Fiber Sensors for the Measurement of Pulsed Electric Currents**, Proceedings of the Workshop on Measurement of Electrical Quantities in Pulse Power Systems, Gaithersburg, Maryland, March 5-7, 1986, pp. 58-63 (1988).

The state of the art in the design of fiber sensors for pulsed electric currents is reviewed. Some of the more useful configurations are described and

Electro-Optic Metrology (cont'd.)

compared. Transfer functions are computed and used to illustrate the effect of linear birefringence and twisting on the characteristics of the sensors. The technique of annealing bend-induced birefringence is described and its present capabilities indicated. An analysis of the ultimate limits to noise equivalent current is given, suggesting that several orders of magnitude improvement should be obtainable.
[Contact: Gordon W. Day, (303) 497-5204]

Franzen, D.L., **Measurement Standards to Support Photonics Technology**, Conference Record, IEEE Instrumentation and Measurement Technology Conference, San Jose, California, February 13-15, 1990, pp. 326-328 (1990).

Standards to support the emerging photonics/lightwave technology industry can be classified into two groups: physical primary standards maintained by national standards laboratories and standard measurement procedures agreed upon by domestic and international voluntary standards bodies. The measurement of absolute optical power leads the prioritized list of primary standards needs. The progress at the National Institute of Standards and Technology (NIST) toward the development and distribution of optical power and other primary standards is reviewed. Standard measurement procedures to characterize fiber, cables, sources, detectors, and lightwave systems have been the focus of domestic and international standards bodies for the past decade. The interaction between NIST and these standards groups to evaluate the precision and accuracy of several test methods is reported. In some cases, the evaluations resulted in technical changes to commonly accepted practices.
[Contact: Douglas L. Franzen, (303) 497-3346]

Ghatak, A.K., Goyal, I.C., and Gallawa, R.L., **Mean Lifetime Calculations of Quantum Well Structures: A Rigorous Analysis**, IEEE Journal of Quantum Electronics, Vol. 26, No. 2, pp. 305-310 (February 1990).

A matrix method is described which will be applicable to an arbitrary potential variation represented by a set of linear functions, e.g., multiple-quantum-well structures in the presence of a static electric field. An analytical expression for the mean lifetime of the quasi-bound state of a single quantum well in the presence of a static electric field has been obtained.
[Contact: Robert L. Gallawa, (303) 497-3761]

Goyal, I.C., Gallawa, R.L., and Ghatak, A.K., **Bent Planar Waveguides and Whispering Gallery Modes: A New Method of Analysis** [original title: A New Method of Analyzing Bent Planar Waveguides Including the Effect of Whispering Gallery Modes], Journal of Lightwave Technology, Vol. 8, No. 5, pp. 768-774 (May 1990).

A new matrix method is used to analyze bent planar optical waveguides. The method is a modification of the numerical analysis matrix method for planar waveguides developed by Ghatak and colleagues at the Indian Institute of Technology, New Delhi (IIT), and may be used with absorbing or leaky structures. The new method is a refinement in that a nonuniform refractive index is approximated by a series of linear profiles rather than by a series of uniform profiles. The method is used to analyze a bent planar waveguide, yielding bend loss directly. The effect of "whispering-gallery" modes has also been studied. The new results suggest that the whispering-gallery explanation advanced previously by the IIT team may not be adequate.
[Contact: Robert L. Gallawa, (303) 497-3761]

Obarski, G.E., **Wavelength Measurement System for Optical Fiber Communications** [original title: A Wavelength Standard

Electro-Optic Metrology (cont'd.)

for Optical Communications], NIST Technical Note 1336 (February 1990).

A wavelength standard in the form of a lambdameter is described for measurement of single-mode sources used in optical fiber communications. The sources of interest are mainly diode lasers emitting at 1.3 and 1.5 μm, but the system can be used in the near IR and red regions of the spectrum. Accuracy in wavelength measurement is verified to be <0.1 ppm at the 0.63-μm HeNe line by comparing separately each of two adjacent modes from a polarization-frequency-stabilized HeNe laser with a single mode from a second polarization-frequency-stabilized HeNe laser. Wavelength instability of a commercially packaged 1.52-μm distributed-feedback diode laser was measured to be in the range ±1 ppm.
[Contact: Gregory E. Obarski, (303) 497-5747]

Sanford, N.A., Hickernell, R.K., and Craig, R.M., **Photorefractive Instabilities in Proton-Exchanged Waveguides: Two-Wave Coupling and Chaos**, 1990 Technical Digest Series, Vol. 5, 1990 Topical Meeting on Integrated Photonics Research, Hilton Head, South Carolina, March 26-28, 1990, pp. 91-92 (1990).

Forward and self-seeded backward waves in proton-exchanged waveguides exhibit repetitive transient coupling with a threshold of tens of milliwatts at 1064 nm. A time series of the quasi-periodic coupling suggests intermittency as a route to chaos.
[Contact: Norman A. Sanford, (303) 497-5239]

Sanford, N.A., Malone, K.J., and Larson, D.R., **An Integrated-Optic Laser Fabricated by Field-Assisted Ion Exchange in Neodymium-Doped Soda-Lime-Silicate Glass**, Optics Letters, Vol. 15, No. 7, pp. 366-368 (April 1, 1990). [Also to be published in the Proceedings of the 1990 Integrated Photonics Research Conference, Hilton Head, South Carolina, March 26-28, 1990].

A continuous-wave channel waveguide laser operating at 1057 μm has been fabricated in neodymium-doped soda-lime silicate glass by field-assisted ion exchange. Threshold for pumping at 528 μm is 31 mW. Slope efficiency is 0.5%.
[Contact: Norman A. Sanford, (303) 497-5239]

Schlager, J.B., Yamabayashi, Y., and Franzen, D.L., **Recirculating Pulse Erbium-Fiber Ring Amplifier**, Technical Digest, Optical Fiber Communication Conference, San Francisco, California, January 22-26, 1990, p. 198 (1990).

Erbium-doped fiber amplifiers have produced up to a 34-dB optical gain at 1536 nm. Further increases in gain are accompanied by an increase in amplified spontaneous emission (ASE), which saturates the amplifier. This paper describes a gated erbium-fiber ring amplifier which avoids the problem of ASE buildup and unwanted feedback. Moreover, a large effective gain can be realized from a small single pass gain by recirculating the pulse through the amplifier.
[Contact: John B. Schlager, (303) 497-3346]

Tu, Y., Gary, J., Goyal, I.C., and Gallawa, R.L., **A Numerical Method for Wave Propagation in a Nonuniform Optical Waveguide**, National Radio Science Meeting Abstracts, sponsored by USNC/-URSI in cooperation with the Institute of Electrical and Electronics Engineers and the University of Colorado, Boulder, Colorado, January 3-5, 1990, p. 261 (1990).

We propose an efficient numerical method to solve for the electromagnetic fields propagating in an optical waveguide that is nonuniform in the direction of propagation (z-direction) as well as in the transverse direction. In this method, the electromagnetic field is first expanded in terms of the Hermite-Gaussian basis functions. The scalar Helmhotz equation is then converted into matrix

Electro-Optic Metrology (cont'd.)

equations using the orthogonal collocation method. The incident field is sampled at the collocation points as the initial condition. Axial propagation is then determined by solving the matrix equations numerically, using the Runga-Kutta method.
[Contact: Robert L. Gallawa, (303) 497-3761]

Tu, Y., Goyal, I.C., and Gallawa, R.L., **A Comparison of Two Numerical Techiques for Planar Optical Waveguides of Arbitrary Refractive Index**, National Radio Science Meeting Abstracts, sponsored by USNC/URSI in cooperation with the Institute of Electrical and Electronics Engineers and the University of Colorado, Boulder, Colorado, January 3-5, 1990, p. 260 (1990).

In this paper we determine the eigenfunctions and eigenvalues for optical waveguides having nonuniform refractive index profiles in the transverse direction using two recent techniques. In one technique, we solve the scalar wave equation by expanding the fields in a Fourier series. The expansion is then used to develop matrix equations that result when the waveguide is approximated by a series of rectangular elements of constant refractive index. Far from the core region, artificial boundaries are imposed to require that the fields vanish at those boundaries. The propagation constant and field distribution are then found by solving the eigenvalue and eigenfunction problems.
[Contact: Robert L. Gallawa, (303) 497-3761]

Electromagnetic Properties

Baker-Jarvis, J.R., Geyer, R.G., and Domich, P., **Improvements in Transmission Line Permittivity and Permeability Measurements**, Digest of the 1990 Conference on Precision Electromagnetic Measurements, Ottawa, Canada, June 11-14, 1990, pp. 232-233 (1990).

The transmission/reflection and short-circuit line methods for complex permittivity and permeability determination in transmission line sample holders are examined. New equations for permittivity are presented that eliminate the ill-behaved nature of the commonly used transmission/reflection methods at frequencies corresponding to integer multiplies of one-half wavelength in the sample. The equations are also independent of reference plane position. Measurement results and an error analysis are presented. In addition, the scattering equations are solved using an optimization algorithm. The advantages and disadvantages of an optimization approach are discussed.
[Contact: James R. Baker-Jarvis, (303) 497-5621]

Geyer, R.G., **Dielectric Characterization and Reference Materials**, NIST Technical Note 1338 (April 1990).

Dielectric reference materials are analyzed with respect to fundamental requirements of linearity, homogeneity, and isotropy. Generalized frequency- and temperature-dependent dispersion relations are presented which allow the prediction of broadband dielectric behavior from limited measurement data, determination of valid modal field structure in cavity or waveguide fixtures, and identification of discrepancies and errors in measurement data. An approach for examining the influence of deviations of sample homogeneity on a precisely specified electromagnetic field structure is outlined, and sufficient conditions for isotropic, uniaxial, or biaxial anisotropic dielectric behavior are reviewed in terms of a material's chemical lattice physics. These characteristics direct the choices of suitable reference materials useful for confirming or improving the accuracy of dielectric measurements.
[Contact: Richard G. Geyer, (303) 497-5852]

Geyer, R.G., Weil, C.M., and Kissick, W.A., **Precision Dielectric Measurements**

Electromagnetic Properties (cont'd.)

Using a Mode-Filtered Cylindrical Cavity Resonator, Digest of the 1990 Conference on Precision Electromagnetic Measurements, Ottawa, Canada, June 11-14, 1990, pp. 174-175 (1990).

A 60-mm diameter cylindrical cavity resonator used at NIST for high-accuracy ($|\Delta\epsilon_R'/\epsilon_R'|<5 \times 10^{-4}$) permittivity measurements on low-loss materials is described. The cavity operates at X-band in the TE_{01P} mode and is of the mode-filtered type with helically wound walls. Measurement data on representative dielectric materials are presented together with an uncertainty analysis.
[Contact: Richard G. Geyer, (303) 497-5852]

Mopsik, F.I., and Martzloff, F.D., **Time Domain Spectroscopy to Monitor the Condition of Cable**, Proceedings of the U.S. Nuclear Regulatory Commission' Sixteenth Water Reactor Safety Information Meeting, Volume 3, Gaithersburg, Maryland, October 24-27, 1988, pp. 21-40 (March 1989).

The use of Time Domain Spectroscopy, the measurement of dielectric constant and loss using time-domain response, for monitoring the aging of reactor cable insulation is examined. The method is presented, showing its sensitivity, accuracy, and wide frequency range. The method's ability to acquire a great deal of information in a short time and its superiority to conventional single frequency data are shown. Different cable samples are examined before and after exposure to radiation and changes with exposure are clearly seen to occur. Also, it is shown that a wide range of behavior can be found in different insulation systems. The requirements for performing valid measurements are presented. The need for controlled samples and correlation with other criteria for aging is discussed.
[Contact: Francois D. Martzloff, (301) 975-2409]

Other Fast Signal Topics

Young, M., **The Pinhole Camera** [original title: Imaging Without Lenses or Mirrors: The Pinhole Camera and Its Relatives], The Physics Teacher, pp. 648-655 (December 1989).

The pinhole camera is an interesting and useful device. The pinhole focuses as a result of diffraction, and the camera displays an optimum focal length equal to the square of the pinhole radius divided by the wavelength. This paper discusses the history and the physics of the pinhole camera and some of its relatives, the Fresnel zone plate, cascaded apertures, the pinspeck camera, and the pinhead mirror.
[Contact: Matt Young, (303) 497-3223]

Young, M., **The Scratch Standard is Only a Cosmetic Standard**, Proceedings of SPIE (The International Society for Optical Engineering, P.O. Box 10, Bellingham, Washington 98227-0010), Surface Characterization and Testing II, Vol. 1164, pp. 185-190 (1989).

In this paper, I present a history of the scratch-and-dig standard for optical surface quality and show that this standard has since its inception been recognized as a cosmetic standard and not as an objective or performance standard. In addition, I attempt to dispel the myth that the scratch standard was changed during the 1960s and show that scratch number cannot be related to scratch width. Finally, I describe a preliminary aging experiment that suggests that the scratch standards have not aged with time and are, in fact, extremely stable.
[Contact: Matt Young, (303) 497-3223]

ELECTRICAL SYSTEMS

Power Systems Metrology

Martzloff, F.D., **Protecting Computer Systems Against Power Transients**, [original title: Transient Suppression for Computer-Based Systems], IEEE Spectrum, Vol. 27, No. 4, pp. 37-40

Power Systems Metrology (cont'd.)

(April 1990).

Computers have emigrated from the sheltered life of computer rooms to the tougher environment of offices, factories, and homes where they encounter interfering or damaging transients. The article outlines general causes and remedies, and how to deal with surges and maintain the integrity of a small computer system. Small computer systems, especially the stand-alone type, can be protected in a do-it-yourself mode. More complex systems may need the help of a specialist. Two case histories illustrate the problems and solutions; steps required to determine protection needs are described, with generic guidance on selecting an appropriate protective device.
[Contact: Francois D. Martzloff, (301) 975-2409]

Mopsik, F.I., and Martzloff, F.D., **Time Domain Spectroscopy to Monitor the Condition of Cable**, Proceedings of the U.S. Nuclear Regulatory Commission Sixteenth Water Reactor Safety Information Meeting, Volume 3, Gaithersburg, Maryland, October 24-27, 1988, pp. 21-40 (March 1989).

The use of Time Domain Spectroscopy, the measurement of dielectric constant and loss using time-domain response, for monitoring the aging of reactor cable insulation is examined. The method is presented, showing its sensitivity, accuracy, and wide frequency range. The method's ability to acquire a great deal of information in a short time and its superiority to conventional single frequency data are shown. Different cable samples are examined before and after exposure to radiation and changes with exposure are clearly seen to occur. Also, it is shown that a wide range of behavior can be found in different insulation systems. The requirements for performing valid measurements are presented. The need for controlled samples and correlation with other criteria for aging is discussed.
[Contact: Francois D. Martzloff, (301) 975-2409]

Olthoff, J.K., Van Brunt, R.J., Herron, J.T., Sauers, I., and Harman, G., **Catalytic Decomposition of S_2F_{10} and Its Implications on Sampling and Detection from SF_6-Insulated Equipment**, Conference Record of the 1990 IEEE International Symposium on Electrical Insulation, Toronto, Canada, June 3-6, 1990, pp. 248-252 (June 1990).

Recent findings indicate that S_2F_{10} is unstable with respect to decomposition on a surface. This paper reports the first results of a study investigating the mechanisms and rates of surface decomposition of S_2F_{10} under various conditions. Initial results indicate that surface decomposition rates on stainless steel increase with increased water content, temperature, and surface-to-volume ration, and with decreased gas pressure. The implications of these results for the preparation and storage of S_2F_{10} samples are discussed. Additionally, the use of this surface decomposition mechanism to enhance the detection sensitivity of small concentrations of S_2F_{10} in SF_6 using a gas chromatograph/mass spectrometer is investigated. Detection sensitivities of 1 ppm_v of S_2F_{10} in SF_6 are routinely achievable using this new technique.
[Contact: James K. Olthoff, (301) 975-2431]

Steiner, J.P., and Martzloff, F.D., **Partial Discharges in Low-Voltage Cables**, Conference Record of the 1990 IEEE International Symposium on Electrical Insulation, Toronto, Canada, June 3-6, 1990, pp. 149-152 (June 1990).

Testing of high-voltage apparatus for partial discharges has long been recognized as an important part of quality control for these devices. Recently, interest has been focused on methods for testing low-voltage cables to determine their integrity under adverse operating conditions such as a loss-of-coolant

Power Systems Metrology (cont'd.)

accident. A new method, utilizing partial discharges, is presented which has the potential for locating breaches in the insulation of in-situ, low-voltage, multi-conductor cables.
[Contact: Francois D. Martzloff, (301) 975-2409]

Stricklett, K.L., Kelley, E.F., Yamashita, H., Kawai, H., and Fenimore, C., **Electrical Breakdown and Streamer Statistics in N-Hexane Under Uniform Field Conditions**, Conference Record of the 1990 IEEE International Symposium on Electrical Insulation, Toronto, Canada, June 3-6, 1990, pp. 61-64 (June 1990).

Under uniform field conditions, two modes of electrical breakdown are observed in liquid n-hexane: breakdown may be initiated by either cathode or anode streamers. This observation suggests that two unique sets of phenomena lead to electrical breakdown. In the work described, high-speed photography is employed to obtain a record of each breakdown event, thereby providing statistical information regarding the relative frequencies of anode and cathode processes. The degree to which the relative probability for either process is influenced by experimental conditions is discussed.
[Contact: Kenneth L. Stricklett, (301) 975-3955]

Van Brunt, R.J., **Research for Electric Energy Systems - An Annual Report**, NISTIR 4339 (June 1990).

This report documents the technical progress in four investigations which make up the project, "Support of Research Projects for Electrical Energy Systems," funded by the U.S. Department of Energy and performed by the Electricity Division of the National Institute of Standards and Technology (NIST). Specifically, these investigations include: 1) an evaluation and critique of techniques for measuring ambient magnetic fields in support of epidemiological and in-vitro studies of biological field effects; 2) development of techniques for detecting the toxic gas S_2F_{10} in SF_6 and measuring its production rate from corona discharges in SF_6; 3) optical and electrical measurements of prebreakdown partial-discharge phenomena in dielectric liquids; and 4) development of improved electro-optical methods for measurement and characterization of fast, transient high-voltage impulses. The work discussed in this report is part of an ongoing research activity at NIST.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Superconductors

Tan, Z., Filipkowski, M.E., Budnick, J.I., Heller, E.K., Brewe, D.L., Chamberland, B.L., Bouldin, C.E., and Woicik, J.C., **Strontium-Induced Oxygen Defect Structure and Hole Doping in $La_{2-x}Sr_xCuO_4$**, Physical Review Letters, Vol. 64, No. 22, pp. 2715-2718 (28 May 1990).

We have discovered that the apical oxygen with the shortest La-O bond length is removed when La is substituted by Sr in polycrystalline $La_{2-x}Sr_xCuO_4$ under normal preparation conditions. It is reasoned that this missing oxygen is relocated at a defect site in the vicinity of the Sr dopant. We present evidence that this defect oxygen is intrinsic to Sr doping independent of processing conditions. A range of physical properties of $La_{2x}Sr_xCuO_4$ can be understood in terms of this Sr-induced defect oxygen and the proposed role of hole doping through this defect oxygen.
[Contact: Charles E. Bouldin, (301) 975-2046]

ELECTROMAGNETIC INTERFERENCE

Radiated Electromagnetic Interference

Crawford, M.L., Ladbury, J.M., Riddle, B.F., and Larsen, E.B., **EMR Test Facilities: Evaluation of a Small Reverberating Chamber Located at RADC, Griffiss AFB, Rome, New York**, NISTIR 90-

Radiated EMI (cont'd.)

3939 (June 1990).

This report describes measurement procedures and results from evaluating a small reverberating chamber located at Rome Air Development Center (RADC), Rome, New York. The chamber was developed for measuring and analyzing the electromagnetic susceptibility/vulnerability of weapon systems and the radio frequency (rf) shielding effectiveness of enclosures and materials. A brief description of the facility is given, including instrumentation for its evaluation and calibration by the National Institute of Standards and Technology (NIST). Work was done earlier at NIST to evaluate the RADC large reverberating chamber. A follow-on project to construct and evaluate a small chamber is discussed in this report. Measurements include: 1) voltage standing wave ratio of the transmitting and receiving antennas; 2) coupling efficiency of the chamber; 3) effectiveness of the chamber tuner; 4) E-field uniformity in the test zone; 5) calibration of test E-fields based on receiving antenna power measurements and calibrated dipole probe voltage measurements; 6) responses of standard equipment under test to test fields in the RADC reverberating chamber and the NIST anechoic chamber; and 7) performance of the reverberating chamber excited by rf pulses at ten frequencies from 0.9 to 18 GHz, four pulse widths from 0.1 to 3 μs, and for two values of chamber Q. Conclusions are that the chamber can be used at frequencies down to 500 MHz for cw testing, and for pulsed rf immunity testing with pulse widths as short as 0.3 μs. Estimates of measurement uncertainties are given.
[Contact: Myron L. Crawford, (303) 497-5497]

Hill, D.A., **Magnetic Dipole Excitation of an Insulated Conductor of Finite Length**, IEEE Transactions on Geoscience and Remote Sensing, Vol. 28, No. 3, pp. 289-294 (May 1990).

Excitation of currents on an insulated conductor of finite length with arbitrary terminations is studied for a magnetic dipole source. For matched terminations, the results agree closely with previous results for an infinitely long conductor, but other terminations produce end reflections that cause standing waves. Specific calculations are presented for a vertical magnetic dipole source because this source produces the appropriate horizontal electric field and could be used in a borehole-to-borehole configuration. Numerical results for the induced current and secondary magnetic field indicate that long conductors produce a strong anomaly over a broad frequency range for any type of termination.
[Contact: David A. Hill, (303) 497-3472]

Hill, D.A., and Anderson, L.R., **Propagation Along a Two-Wire Line Located at the Air-Earth Interface**, IEEE Transactions on Geoscience and Remote Sensing, Vol. 28, No. 3, pp. 400-402 (May 1990).

A simple quasi-static expression has been derived for the propagation constant of a two-wire transmission line located at the air-earth interface. A numerical solution of the mode equation shows that the quasi-static approximation is valid when the wire separation is much less than a free-space wavelength. The quasi-static approximation can be used to determine the complex dielectric constant of the earth from measurements of either the propagation constant or the characteristic impedance of the transmission line.
[Contact: David A. Hill, (303) 497-3472]

Hill, D.A., Kanda, M., Larsen, E.B., Koepke, G.H., and Orr, R.D., **Generating Standard Reference Electromagnetic Fields in the NIST Anechoic Chamber, 0.2 to 40 GHz**, NIST Technical Note 1335 (March 1990).

The NIST anechoic chamber is used to generate standard (known) EM fields for

Radiated EMI (cont'd.)

frequencies from 200 MHz to 40 GHz. The transmitting antennas used are open-ended rectangular waveguides from 200 to 500 MHz and pyramidal horns from 450 MHz to 40 GHz. The uncertainty in the electric field is currently estimated to be ±1.0 dB. A number of changes and additions are planned to improve the accuracy, repeatability, and efficiency of the system.
[Contact: David A. Hill, (303) 497-3472]

Wittmann, R.C., **Spherical Near-Field Scanning: Determining the Incident Field Near a Rotatable Probe**, 1990 Antennas and Propagation Symposium Digest, Dallas, Texas, May 7-11, 1990, Vol. 1, pp. 224-227 (1990).

Many radar cross-section, electromagnetic interference/electromagnetic compatibility, and antenna measurements require a known incident field within a test volume. To evaluate systems designed to produce a specific incident field (compact ranges, for example), we must measure the actual illumination for comparison with design specifications. Beyond its diagnostic value, these incident field data can also be used for error estimation and for calculating first-order corrections.

In this paper, we develop a spherical near-field scanning algorithm for determining incident fields inside a probe's "minimum sphere." This differs from the well-known spherical near-field scanning formulation which determines fields outside the source's minimum sphere. The scanner size depends on the extent of the region of interest and not on the extent of the (possibly much larger) source. The data may be collected using a standard roll-over-azimuth positioner.
[Contact: Ronald C. Wittmann, (303) 497-2236]

Conducted Electromagnetic Interference

Martzloff, F.D., **Coupling, Propagation, and Side Effects of Surges in an Industrial Building Wiring System**, IEEE Transactions on Industry Applications, Vol. 26, No. 2, pp. 193-203 (March/April 1990).

Measurements were made in an industrial building to determine the propagation characteristics of surges in the ac power wiring of the facility. The surges, of the unidirectional type or the ring-wave type described in ANSI/IEEE Standard C62.41-1980, were injected at one point of the system and the resulting surges arriving at other points were measured. The results show how unidirectional surges couple through transformers and produce a ring wave component in the response of the system. An unexpected side effect of these surges, applied to the power lines only, was the apparent damage suffered by the data line input components of some computer-driven printers.
[Contact: Francois D. Martzloff, (301) 975-2409]

Martzloff, F.D., **Protecting Computer Systems Against Power Transients**, [original title: Transient Suppression for Computer-Based Systems], IEEE Spectrum, Vol. 27, No. 4, pp. 37-40 (April 1990).

Computers have emigrated from the sheltered life of computer rooms to the tougher environment of offices, factories, and homes where they encounter interfering or damaging transients. The article outlines general causes and remedies, and how to deal with surges and maintain the integrity of a small computer system. Small computer systems, especially the stand-alone type, can be protected in a do-it-yourself mode. More complex systems may need the help of a specialist. Two case histories illustrate the problems and solutions; steps required to determine protection needs are described, with generic guidance on selecting an appropriate protective device.
[Contact: Francois D. Martzloff, (301) 975-2409]

Conducted EMI (cont'd.)

Martzloff, F.D., and Gruzs, T.M., **Power Quality Site Surveys: Facts, Fiction, and Fallacies**, Proceedings of the First International Power Quality Conference, Long Beach, California, October 15-20, 1989, pp. 492-505 (October 1989), and "Selected Readings" of the Second National Conference on Power Quality for End-Use Applications, San Francisco, California, March 21-23, 1990, pp. 1005-1018 (March 1990).

The quality of the power supplied to sensitive electronic equipment is an important issue. Monitoring disturbances of the power supply has been the objective of various site surveys, but results often appear to be instrument-dependent or site-dependent, making comparisons difficult. After a review of the origins and types of disturbances, the types of monitoring instruments are described. A summary of nine published surveys reported in the last 20 years is presented, and a close examination of underlying assumptions allows meaningful comparisons which can reconcile some of the differences. Finally, the paper makes an appeal for improved definitions and applications in the use of monitoring instruments.
[Contact: Francois D. Martzloff, (301) 975-2409]

Martzloff, F.D., and Leedy, T.F., **Electrical Fast Transient Tests: Applications and Limitations**, IEEE Transactions on Industry Applications, Vol. 26, No. 1, pp. 151-159 (January/February 1990). [Also published in the Conference Record of the IEEE Industry Applications Society Annual Meeting, Part II, San Diego, California, October 1-5, 1989, pp. 1625-1632 (October 1989) and in the Proceedings of the IEEE Industrial Applications Society 35th Annual Petroleum & Chemical Industry Conference, Dallas, Texas, September 12, 1988, pp. 1-8 (1988)].

According to a new standard of the International Electrochemical Commission (IEC), a fast-transient test must be applied to the connecting cables of electronic equipment. The purpose of the test is to demonstrate equipment immunity to fast transients resulting from switching. Tests and simulations of the propagation and attenuation of these fast transients in typical connecting cables are described, placing the IEC requirements in perspective.
[Contact: Francois D. Martzloff, (301) 975-2409]

ADDITIONAL INFORMATION

Lists of Publications

Lyons, R.M., and Gibson, K.A., **A Bibliography of the NIST Electromagnetic Fields Division Publications**, NISTIR 89-3920 (September 1989).

This bibliography lists publications by the staff of the National Institute of Standards and Technology's Electromagnetic Fields Division for the period from January 1970 through August 1989. Selected earlier publications from the Division's predecessor organizations are included.
[Contact: Kathryn A. Gibson, (303) 497-3132]

DeWeese, M.E., **Metrology for Electromagnetic Technology: A Bibliography of NIST Publications**, NISTIR 89-3921 (August 1989).

This bibliography lists the publications of the personnel of the Electromagnetic Technology Division of NIST in the period from January 1970 through publication of this report. A few earlier references that are directly related to the present work of the Division are included.
[Contact: Sarabeth Moynihan, (303) 497-3678]

Palla, J.C., and Meiselman, B., **Electrical and Electronic Metrology: A Bibliography of NIST Electricity Division's Publications, NIST List of Publications 94** (January 1990).

Additional Information (cont'd.)

This bibliography covers publications of the Electricity Division, Center for Electronics and Electrical Engineering, NIST, and of its predecessor sections for the period January 1968 to December 1989. A brief description of the Division's technical program is given in the introduction.
[Contact: Jenny C. Palla, (301) 975-2220]

Walters, E.J., **Semiconductor Measurement Technology, NBS List of Publications 72** [a bibliography of NBS publications concerning semiconductor measurement technology for the years 1962-1989] (March 1990).

This bibliography contains reports of work performed at the National Institute of Standards and Technology in the field of Semiconductor Measurement Technology in the period from 1962 through December 1989. An index by topic area and a list of authors are provided.
[Contact: E. Jane Walters, (301) 975-2050]

NEW CALIBRATION SERVICES OFFERED

The explosive growth of optical fiber use in the communications industry has resulted in a demand for calibration services. NIST's Boulder, Colorado, laboratory now offers **measurements of optical laser power and energy at wavelengths and power levels of interest to fiber optic producers and users**. Measurements are based on a standard reference instrument called the C-series calorimeter. An electrically calibrated pyroelectric radiometer (ECPR) is calibrated against the calorimeter and is then used to calibrate optical power meters at wavelengths of 850, 1300, and 1550 nm. To improve calibration capabilities, NIST is preparing test measurement systems for detector linearity, detector uniformity, and detector spectral responsivity. These systems should be available in 6 months. For a paper outlining NIST's optical power measurement capabilities, contact Fred McGehan, Div. 360, NIST, 325 Broadway, Boulder, Colorado 80303. For more information on calibration services, contact Thomas R. Scott, Div. 724, same address, or phone (303) 497-3651.

NEW NIST RESEARCH MATERIAL

NIST has announced the availability of **Research Material 8458**, a well-characterized artificial flaw used as an **artifact standard in eddy current nondestructive evaluation (NDE)**. The new Research Material (RM) is the outcome of work carried out by the Division to address the need for calibration standards for eddy-current NDE, for example as used to detect fatigue cracks in aircraft structures. The RM flaw is produced in an annealed aluminum alloy block by first indenting the block and then compressively deforming the resulting notch until it is tightly closed. The next operation is to restore a flat finish to the block face, after which the block is heat treated to the original temper. The controlled flaw has been named the "CDF notch," after its inventors (listed on patent application) Thomas E. Capobianco (Electromagnetic Technology Division), William P. Dube (Division 583), and Ken Fizer (Naval Aviation Depot, NAS Norfolk, Virginia).

In the past, the challenge has been to manufacture artificial flaws that closely simulate the mechanical properties of fatigue cracks. Currently used artifacts include electrical-discharge-machined and saw-cut notches, both of which are relatively poor representations of fatigue cracks as their widths are too great. The Division-developed method provides notches that can be made controllably in a variety of geometries, have known dimensions, with widths that are narrow enough to provide an acceptable representation of fatigue cracks.

An NIST Research Material is not certified by NIST, but meets the International Standards Organization definition of "a material or substance one or more

Additional Information (cont'd.)

properties of which are sufficiently well established to be used in the calibration of an apparatus, the assessment of a measurement method, or for assigning values to materials." The documentation issued with RM 8458 is a "Report of Investigation." Contact: technical information -- Fred Fickett, (303) 497-3785; order information -- Office of Standard Reference Materials, (301) 975-6776.

EMERGING TECHNOLOGIES IN ELECTRONICS...AND THEIR MEASUREMENT NEEDS, SECOND EDITION

This report assesses the principal measurement needs that must be met to improve U.S. competitiveness in emerging technologies within several fields of electronics: semiconductors, superconductors, magnetics, optical fiber communications, optical fiber sensors, lasers, microwaves, video, and electromagnetic compatibility. The report seeks feedback from industry and Government agencies on the assessment. The feedback will guide the development of NIST programs that provide U.S. industry with new documented measurement methods, new national reference standards to assure the accuracy of those measurement methods, and new reference data for electronic materials. Copies may be obtained by ordering Report No. PB90-188087/AS ($23.00 hard copy, $11.00 microfiche) from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161, (703) 487-4650.

JAN. 1, 1990 CHANGES IN THE U.S. ELECTRICAL UNITS

Effective January 1, 1990, the U.S. as-maintained (i.e., "practical") units of voltage and resistance were increased by 9.264 ppm and 1.69 ppm, respectively. The increases in the U.S. legal units of current and of electrical power will be about 7.57 ppm and 16.84 ppm, respectively. These changes result from efforts by the major national standardizing laboratories, including the National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards (NBS), to re-evaluate their as-maintained units in terms of the International System of Units (SI). The consequence of this activity has been the introduction of standards representing the SI units of voltage and resistance by the International Committee of Weights and Measures, an international body created by the Treaty of the Meter.[1] The use of these standards world-wide beginning January 1, 1990, will result in international consistency of electrical measurement as well as coherence among the practical units of length, mass, electricity, time, etc., inherent in the definitions of the SI.

Implementation of Changes at NIST

These changes have been instituted in the U.S. by NIST using the new, internationally-adopted constants K_{J-90} = 483 597.9 GHz/V exactly and R_{K-90} = 25 812.807 Ω exactly with the Josephson and quantum Hall effects to establish representations of the SI volt and ohm, respectively. The representation of the SI volt is attained by using K_{J-90} in the formula

$$U_J(n) = \frac{f}{K_J} \qquad n = 1,2,3,\ldots$$

to give the voltages $U_J(n)$ of the steps produced by the ac Josephson effect at a frequency f. The past value, K_{J-72}, was 483 593.42 GHz/V(NBS-72), thus leading to the 9.264 ppm change. Likewise, R_{K-90} is used in the following formula for the resistance of the i^{th} plateau of a quantum

[1]**Note that the SI Units have not been redefined; rather, they have been realized more accurately and a quantum physics representation of the ohm has been introduced, thus leading to the changes in magnitude of the practical or as-maintained units.**

Additional Information (cont'd.)

Hall effect device,

$$R_H(i) = \frac{R_K}{i} \qquad (R_K = R_H(1))$$

to realize a representation of the SI ohm. The most recent past national unit of resistance, $\Omega(\text{NBS-48})_t$, was based on a group of five Thomas one-ohm standards and had an uncompensated drift rate of approximately -0.053 ppm per year. Since the quantum Hall effect is used as the national standard, the U.S. representation of the ohm has no drift. (The past unit of voltage, V(NBS-72), was based on the Josephson effect since 1972, and accordingly had a zero drift rate.)

Reassignments to Non-adjustable Standards

Since the U.S. practical volt and ohm units increased on January 1, 1990, the changes must be implemented in non-adjustable standards calibrated in terms of V(NBS-72) and/or Ω(NBS-48) only by **reducing** the values assigned to them proportionally. The examples given below show how to do this for a standard cell and a standard resistor.

Sample Adjustments of Values of Standards

Standard cell:

"Old" emf 1.0180564 V(NBS-72)

Multiply "Old" emf by 0.999990736 to get emf in terms of the present volt representation 1.01804697 ≈ 1.0180470 V

Standard resistor:

"Old" resistance value
$9999.976\ \Omega(\text{NBS-48})_{01/01/90}$

Multiply "Old" resistance by 0.99999831 to get the resistance in terms of the present ohm representation
9999.9591 ≈ 9999.959 Ω

In the above, "Old" refers to the value of the standard which would have been in use on January 1, 1990, had the changes not been made; i.e., if a correction curve based on its past assigned values has been employed to obtain the currently-used value for a standard, the above represents a downward shift of the curve starting January 1, 1990. For resistance, the slope of the curve also changed (slightly) since Ω(NBS-48) has a drift rate and Ω(NIST-90) does not.

Do not send your standards to NIST for recalibration on January 1, 1990, unless they are normally due then. The changes are accurately known and corrections to existing standards may be applied.

Adjustment of Instrumentation

An assigned or calibrated value of a standard is merely a label giving the magnitude of the parameter embodied in the standard. The actual emf or resistance of a standard did not change on January 1, 1990; only what it is called should have changed. In the same sense, meter readings are labels giving the magnitudes of the parameters being measured. **Readings taken after January 1, 1990 using unadjusted meters will be too large in magnitude.** Adjustments to meters must have the effect of reducing the amplitudes of readings for fixed emf's or resistances.

Adjustable voltage and current sources or adjustable resistors for which nominal output is desired, on the other hand, must have their outputs **increased** proportionally by the above amounts. DVM calibrators are probably the largest class of this type of instrument.

Guidelines

The National Conference of Standards Laboratories (NCSL) and NIST have formed NCSL *ad hoc* Committee 91.4, Changes in the Volt and Ohm to assist industry and government laboratories in coming into compliance with the changes. A major responsibility of the committee is the

Additional Information (cont'd.)

generation and publication of a set of guidelines which describes unambiguous methods for adjusting standards and instruments, or their values, and delineates other types of problems which may arise, e.g., voltage values called out explicitly in maintenance procedures, values imbedded in software, and the like. These guidelines have been published as NIST Technical Note 1263, "Guidelines for Implementing the New Representations of the Volt and Ohm Effective January 1, 1990." This document is available at no charge through the NIST Electricity Division. To receive a copy, contact Sharon Fromm at 301-975-4222.

For further information, contact Norman B. Belecki (301-975-4223), Ronald F. Dziuba (301-975-4239), Bruce F. Field (301-975-4230), or Barry N. Taylor (301-975-4220).

U.S. REPRESENTATIONS OF ELECTRICAL POWER AND ENERGY

Watt, Var, Volt-Ampere
Joule, Watthour, Varhour
Volt-Ampere-hour, and Q-hour

Background

By international agreement, starting on January 1, 1990, the U.S. put into place new representations of the volt and ohm based, respectively, on the Josephson and Quantum Hall effects and which are highly consistent with the International Systems of Units (SI). Implementation of the new volt and ohm representations in the U.S. required that on January 1, 1990, the value of the present national volt representation maintained by the National Institute of Standards and Technology (NIST, formerly the National Bureau of Standards) be increased by 9.264 parts per million (ppm) and that the value of the national ohm representation be increased by 1.69 ppm (1 ppm = 0.0001%). The resulting increase in the national representation of the ampere is 7.57 ppm. The resulting increase in the national representations of the electrical quantities of power, namely the watt, var, and volt-ampere, and the quantities of energy, namely the joule, watthour, varhour, volt-ampere-hour, and Q-hour is 16.84 ppm.

The adjustment for electrical power and energy is generally very small compared to revenue metering measurement uncertainties (typically greater than ±0.1%) and therefore are not likely to have a significant effect. Adjustments do not need to be applied in the above instances. However, for the highest accuracy calibrations of power and energy standards having uncertainties less than ±0.020%, adjustments should be made. Accordingly, all Reports of Calibration and Reports of Test issued by NIST after January 1, 1990, reflect the appropriate changes.

For instruments calibrated prior to January 1, 1990, adjustments to the calibration values due to the change in the volt and ohm can be made without instrument recalibration. The adjustments are exact and, if properly applied, will not introduce any errors. Examples given below will illustrate proper procedures for applying the new adjustments.

Adjustments for Wattmeters, Varmeters, and Volt-Ampere Meters

Calibrations of wattmeters, varmeters, and volt-ampere meters at NIST provide customers with corrections and uncertainties given in units of watts, vars, or volt-amperes, as appropriate. Applying the appropriate adjustment due to the new representations of the volt and ohm for power measuring instruments (i.e., wattmeters for "real power" and varmeters for quadrature or imaginary power) requires minor calculations. First, it is necessary to assess the magnitude of the calibration uncertainty in percent and then decide if applying adjustments for the change in the volt and ohm are required. To determine the percentage

Additional Information (cont'd.)

uncertainty, simply divide the uncertainty in watts, vars, or volt-amperes by the product of the applied voltage and current times the power factor (the real power) and multiply that quantity by 100, as

$$U\% = [(U_w,\ U_v,\ \text{or}\ U_va)/(V_a \times I_a \times PF)] \times 100,$$

where

$U\%$ is the uncertainty in percent,
U_w is the calibration uncertainty in watts,
U_v is the calibration uncertainty in vars,
V_{va} is the calibration uncertainty in volt-amperes,
V_a is the applied voltage in volts,
I_a is the applied current in amperes, and
PF is the power factor (including its sign).

For example, if the uncertainty is stated on a Report of Calibration as ±0.060 watts for the calibration of a wattmeter at an applied voltage of 120 V and an applied current of 5 A at unity power factor, then

$$\text{Percent Uncertainty} = U\% = [(\pm 0.060\ \text{W})/(120\ \text{V} \times 5\ \text{A} \times 1)] \times 100 = \pm 0.010\%.$$

If the percentage uncertainty, as calculated above, is less than ±0.020%, (as it is in the above example), then it is recommended that an adjustment of 0.0017% (0.001684% rounded to four significant decimal places) due to the new representations of the volt and ohm be applied.

The second step is the calculation of how large the adjustment will be (in units of watts, vars, or volt-amperes, as appropriate), due to the reassignment of the volt and ohm. For the same example given above, if the calibration correction was given in a Report of Calibration as +0.052 watts, then the adjustment due to the change in the volt and ohm may be calculated by multiplying the product of the applied voltage and current times the power factor by 0.000017 (0.0017% expressed in proportional parts), as

$$\text{Adjustment} = (V_a \times I_a \times PF) \times 0.000017$$
$$\text{Adjustment} = (120\ \text{V} \times 5\ \text{A} \times 1\ ) \times 0.000017 = 0.010\ \text{watts}.$$

The resulting product should be rounded to the same number of significant decimal places as the old calibration correction was given. This result is then subtracted from the old calibration correction, as in the following example:

Old Calibration Correction
(prior to 1/1/90) = {+0.052 watts}
less 0.000017 x Applied
Volt-amperes x PF = -{+0.010 watts}
New Calibration Correction
(after 1/1/90) = {+0.042 watts}

If the old calibration correction (prior to 1/1/90) at test conditions of 120 V, 5 A, and at a power factor of 0.5 lag, happened to be a negative quantity, for example, -0.031 watts, then the old calibrations correction would be decreased (made more negative) by 0.0017% of the applied volt-ampere product times the power factor, as in the following example:

Old Calibration Correction
(prior to 1/1/90) = {-0.031 watts}
less 0.000017 x Applied
Volt-amperes x PF = -{+0.005 watts}
New Calibration Correction
(after 1/1/90) = {-0.036 watts}

The process of making the corresponding change for the varmeter corrections is identical to that show above. For volt-ampere meters, the adjustment is made independent of the power factor (i.e., a value of PF = 1 may be used). However, most varmeter and volt-ampere meter calibrations have stated uncertainties greater than ±0.020%, and hence, would not require an adjustment.

Additional Information (cont'd.)

Adjustments for Joule, Watt-, Var-, Volt-Ampere- and Q-Hour Meters

Applying adjustments to electric energy measuring instruments (i.e., joule, watthour, varhour, volt-ampere-hour, and Q-hour meters) for changes in the representation of the volt and ohm, is more straightforward because the common calibration constant for energy metering is expressed as a "percentage registration." The amount the registration is to be adjusted can be subtracted directly as a percentage, regardless of power factor.

For example, if a watthour meter has a registration of 100.015% before January 1, 1990, then after that date, the new assigned registration would be decreased by 0.0017% (rounded from 0.001684%) as

Old percentage registration (prior to 1/1/90)	-	100.015%
less amount due to change in volt and ohm	-	-0.0017%
New percentage registration (after 1/1/90)	-	100.0133%
Rounded to three significant decimal places	-	100.013%

The process of making the corresponding changes for the joule, varhour, volt-ampere-hour and Q-hour meters are identical to that shown above. If the associated uncertainty of the calibration is greater than ±0.020%, no adjustments are necessary, as stated in the instances for wattmeters, varmeters, and volt-ampere meters. The uncertainties for varhour, volt-ampere-hour, and Q-hour meters are seldom less than ±0.020%, and hence adjustments generally do not need to be made.

Reference

N. B. Belecki, R. F. Dziuba, B. F. Field, and B. N. Taylor, Guidelines for Implementing the New Representations of the Volt and Ohm Effective January 1, 1990, NIST Tech. Note 1263, June, 1989.

Copies of the above document are available at no cost from:

National Institute of Standards and Technology
Electricity Division, MET B146
Gaithersburg, MD 20899
Telephone: (301) 975-4222

For Further Information

For further information concerning the above information, contact either John D. Ramboz (301) 975-2434 or Thomas L. Nelson (310) 975-2427, or write:

National Institute of Standards and Technology
Electricity Division, MET B344
Gaithersburg, MD 20899

NEW BROCHURE FOR SEMICONDUCTOR SRMs

Standard Reference Materials for Semiconductor Manufacturing Technology lists a series of SRMs for use in characterizing semiconductor materials and processes. The SRMs include a series of silicon resistivity materials for calibrating four-probe and eddy-current test equipment [Technical Contact: James R. Ehrstein, (301) 975-2060]; sizing materials for calibrating optical microscopes [Technical Contact: Robert D. Larrabee, (301) 975-2298]; SRMs for optical measurements [Technical Contact: Jon Geist, (301) 975-2066]; and sizing materials for calibrating scanning electron microscopes, SRMs for mechanical testing, X-ray and photographic films, X-ray diffraction, and the chemical analysis of materials [General Contact: Office of Standard Reference Materials, Cindy Leonard, (301) 975-2023].

1991 CEEE CALENDAR

January 20-31, 1991 (New Orleans, LA)

SEMATECH/ASTM/SEMI/NIST Workshop on Silicon Materials for Mega-IC Applications. To foster the understanding of circuit requirements and silicon properties that affect circuit performance, 1991 CEEE Calendar (cont'd.)

SEMATECH, ASTM, SEMI, and NIST are sponsoring this Workshop on mega-IC applications. Working sessions will consider requirement and specification issues on the following topics: silicon substrate and epi wafers, epitaxial processes, silicon on insulator technologies, contamination issues, and diagnostics and metrology. As this Workshop is being held in conjunction with meetings of SEMI Standards Committees and ASTM Committee F-1 on Electronics, a parallel aim of the Workshop is to provide guidance to and increased participation in the silicon-related standards work of ASTM and SEMI. [Contact: Robert I. Scace, (301) 975-2220]

March 18-21, 1991 (Research Triangle Park, NC)

First International Workshop on the Measurement and Characterization of Ultra-Shallow Doping Profiles in Semiconductors. Sponsored by Microelectronics Center of North Carolina (MCNC) in cooperation with the Semiconductor Research Corporation, the National Institute of Standards and Technology, and Northern Telecom Electronics, this workshop will provide a forum for a thorough discussion and evaluation of the different one- and two-dimensional techniques available for the measurement of ultra-shallow doping profiles in semiconductors. To be presented are invited papers by preeminent authors assessing the state of the art of different measurement techniques along with a prognosis for future extension of each technique. Topics to be covered by contributed papers include sputter depth profiling techniques, spreading resistance measurements, other electrical characterization techniques, and microscopy for junction profiling and interface characterization. Strategies for forming very shallow junctions will be featured in a plenary session.
[Contact: James R. Ehrstein, (301) 975-2060]

September 8-11, 1991 (Research Triangle Park, NC)

Third Workshop on Radiation-Induced and/or Process-Related Electrically Active Defects in Semiconductor-Insulator Systems. This workshop is sponsored by the Microelectronics Center of North Carolina (MCNC), North Carolina State University, and the University of North Carolina at Charlotte, in cooperation with the Semiconductor Research Corporation, the IEEE Electron Devices Society, and the National Institute of Standards and Technology. Some areas of interest are: relationships between processing and electrically active defect densities, measurement methods, theoretical modeling of electrically active defects, process control of the sensitivity of insulators to ionizing radiation, removal of radiation damage, controlled radiation standard sources, and memory effects.
[Contact: Jeremiah R. Lowney, (301) 975-2048]

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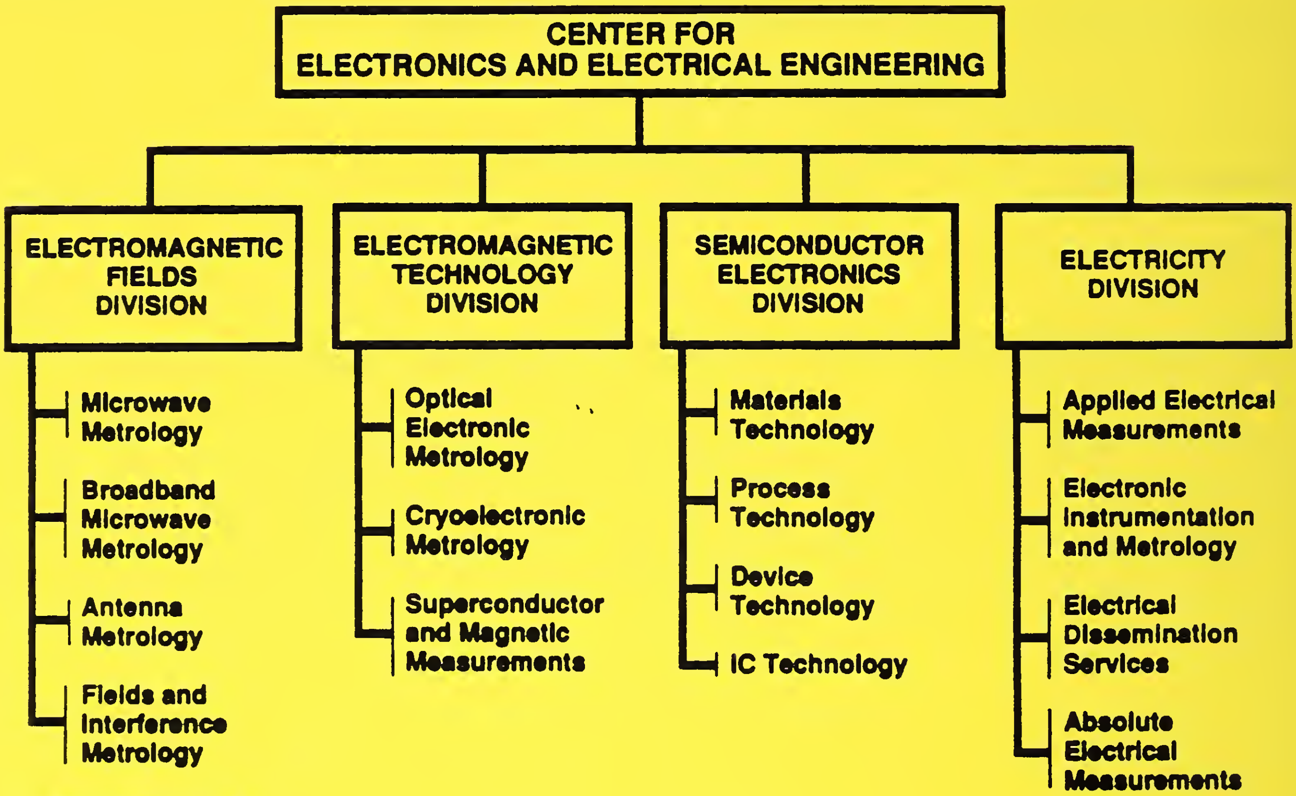

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KEY CONTACTS

Center Headquarters (720)	Director, Mr. Judson C. French (301) 975-2220
	Deputy Director, Mr. Robert I. Scace (301) 975-2220
Electromagnetic Fields Division (723)	Chief, Dr. Ramon C. Baird (303) 497-3131
Electromagnetic Technology Division (724)	Chief, Dr. Robert A. Kamper (303) 497-3535
Semiconductor Electronics Division (727)	Chief, Mr. Frank F. Oettinger (301) 975-2054
Electricity Division (728)	Chief, Dr. Oskars Petersons (301) 975-2400

INFORMATION:

For additional information on the Center for Electronics and Electrical Engineering, write or call:

Center for Electronics and Electrical Engineering
National Institute of Standards and Technology
Metrology Building, Room B-358
Gaithersburg, MD 20899
Telephone (301) 975-2220

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