NISTIR 90-4287

TECHNICAL ACTIVITIES 1989 ELECTRON AND OPTICAL PHYSICS DIVISION

C. W. Clark, Acting Chief

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards
and Technology
National Measurement Laboratory
Center for Atomic, Molecular,
and Optical Physics
Electron and Optical Physics Division
Gaithersburg, MD 20899

Prepared for
U.S. DEPARTMENT OF COMMERCE
National Institute of Standards
and Technology
Gaithersburg, MD 20899

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

NIST

NISTIR 90-4287

TECHNICAL ACTIVITIES 1989
ELECTRON AND OPTICAL
PHYSICS DIVISION

C. W. Clark, Acting Chief

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards
and Technology
National Measurement Laboratory
Center for Atomic, Molecular,
and Optical Physics
Electron and Optical Physics Division
Gaithersburg, MD 20899

Prepared for
U.S. DEPARTMENT OF COMMERCE
National Institute of Standards
and Technology
Gaithersburg, MD 20899

February 1990

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

TABLE OF CONTENTS

Foreword:

In November, 1989, the name of NIST's Radiation Physics Division was changed to the Electron and Optical Physics Division. The new name more accurately summarizes the Division's Functional Statement, which is given below; the Division's basic activities and staffing were unaffected by the name change. During the period reported upon here, Dr. William R. Ott was the Division Chief; in November 1989 he assumed full-time duties as Acting Deputy Director of the Center for Atomic, Molecular, and Optical Physics, and Dr. Charles W. Clark was appointed Acting Division Chief.

The Division is composed of three groups, the activities of which are summarized separately in Sections 2-4. A summary of calibration services, and lists of publications, talks, and other relevant activities, are contained in sections 5-12.

The Division's staff welcome outside interest in their programs. Additional information may be obtained from the individual scientists named herein, or from Dr. Charles W. Clark, Acting Chief, Electron and Optical Physics Division, B206, Metrology Building, National Institute of Standards and Technology, Gaithersburg, Maryland 20899: telephone (301) 975-3709; FAX (301) 975-3038; INTERNET: Clark @ ENH.NIST.GOV

NOTE: Certain commercial equipment, instruments, or materials are identified in this report in order to adequately specify the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

FUNCTIONAL STATEMENT

Electron and Optical Physics Division (571): Provides the central national basis for the measurement of far ultraviolet and soft x-ray radiation; conducts theoretical and experimental research with electron, laser, ultraviolet, and soft x-ray radiation for measurement applications in fields such as atomic and molecular science, multiphoton processes, radiation chemistry, space and atmospheric science, fusion plasma diagnostics, microelectronics, electron spectroscopy, surface magnetism, and solid state and materials science; determines the fundamental mechanisms by which electrons and photons transfer energy to gaseous and condensed matter; develops advanced electron- and photon-based techniques for the measurement of atomic and molecular properties of matter, for the determination of atomic and magnetic microstructure, and for the measurement and utilization of ultraviolet, soft x-ray, and electron radiation; develops and disseminates ultraviolet, soft x-ray and electron standards, measurement services, and data for industry, universities, and government; and develops and operates well-characterized sources of electrons and photons including the NIST synchrotron ultraviolet radiation facility (SURF II) and several specialized polarized electron radiation facilities.

I. OVERVIEW

The Electron and Optical Physics Division focuses on measurement programs related to the use of electron, laser, ultraviolet, and soft x-ray radiation in the energy range from about 5 eV (250 nm) to 1 keV (1.3 nm).

In support of this mission, radiation standards and advanced measurement techniques are developed. Through our standards program, the Division provides the central national basis for the measurement of far ultraviolet and soft x-ray radiation. The NIST synchrotron ultraviolet radiation facility (SURF-II) and a detector calibration facility based upon well-characterized photoionization chambers serve as national radiation standards. Measurement services are available for the calibration of the quantum efficiency of UV photodiodes and the spectral responsivity of vacuum ultraviolet spectrometer systems.

Through our electron measurements program, new types of electron sources and detectors are developed to investigate the properties of matter on an atomic scale. For example, specially designed spin-polarized electron sources and detectors are used to determine fundamental atomic scattering properties and to measure surface magnetism. A scanning tunneling microscope (STM) is being used to provide "images" of surfaces on an atomic scale and to study relationships between macroscopic material properties and surface microstructure.

With the goals of improving standards and understanding the fundamental physical phenomena upon which they are based, the Division also conducts theoretical and experimental research on the electronic structure of atomic and molecular systems, the interaction of the systems with photons and electrons, and radiation deposition and energy transfer processes. Theories are developed for the scattering and transport of electrons in materials of fundamental and technological interest. New techniques and instrumentation are developed to study radiative reactions with matter, including photoexcitation and photoionization processes and non-linear effects in intense laser fields. Studies are underway to relate the behavior of condensed matter systems to their fundamental atomic and molecular properties.

The Division has two major research facilities: a dedicated synchrotron ultraviolet radiation facility (SURF-II), and a microstructure measurement research facility.

SURF-II is a dedicated synchrotron radiation facility, consisting of a 300 MeV electron storage ring, a 10 MeV microtron injector, and associated synchrotron radiation beamlines. It produces radiation in a narrow, intense, highly polarized beam with a continuous and accurately known spectrum from the infrared, through the visible and the far ultraviolet, and into the soft x-ray region. SURF-II is unique among synchrotron light sources by virtue of its uniform and precisely known circular orbit. This allows accurate determination of all the spectral and geometrical properties of the radiation and hence its use as an absolute radiometric standard.

This facility serves staff from our own Division, users from other NIST Divisions, and outside users in radiometric standards and calibration work, optical physics research, surface science, biochemistry, spectroscopy, and other research areas utilizing far ultraviolet radiation. It helps to fill a growing demand for radiation in the ultraviolet and soft x-ray region of the electromagnetic spectrum. Of the 11 light ports at SURF, 6 are now instrumented for user applications and for calibration of optical instruments and transfer standard photodiodes. Some of these ports are shared by more than one experimental station. Three of the remaining ports are used for beam current monitoring, electron counting, and machine diagnostics. Most experiments and calibrations can run simultaneously, unless they require special beam parameters.

The microstructure measurement research facility is used to study the atomic and magnetic microstructure of advanced materials, in collaboration with industry. Magnetic microstructure is measured with a spatial resolution of about 500 Angstroms (0.05 microns) by a technique called scanning electron microscopy with polarization analysis. An ultrahigh vacuum scanning tunneling microscope is used to investigate, on an atomic scale, the nucleation and growth of thin films on clean metallic and semiconductor surfaces.

In the same complex, two additional instruments are being developed: a "magnetic" tunneling microscope, to enable magnetic domain measurements with atomic-scale resolution by combining SEMPA and STM technology; and a high current, high resolution SEMPA instrument, to improve SEMPA performance by a factor of 10 in collaboration with Honeywell, Inc., Control Data Corporation, and Perkin Elmer Corporation.

Division staff are also collaborating on two projects at the National Synchrotron Light Source (NSLS) facility at Brookhaven. The first involves radiation probing of exotic materials with soft x-rays. With colleagues from the U. of Tennessee and Oak Ridge National Labs, we are studying core-hole excitation and soft x-ray fluorescence in solid materials of fundamental and industrial significance such as GaAs, quasi-crystals, and high-T_c superconductors. This is being done using an IR-100 award-winning, high sensitivity, soft x-ray emission spectrometer with an efficiency 1000 to 10,000 times higher than conventional spectrometers in the energy range 20 eV to 1 keV.

In the second project, Division staff are part of a consortium of 10 principal investigators from 8 major laboratories representing industry, universities, and government. This "Materials Research Group", funded principally by the National Science Foundation (NSF), is studying surface magnetism using spin-polarized photoemission techniques on materials prepared with molecular beam epitaxy methods. This work is being done on an undulator beamline at NSLS.

As can be seen in the following sections, the Division staff has been active in publishing research papers, providing calibration services, presenting invited talks, sponsoring conferences, providing consultation services, and participating in technical and professional committees. We have also been active in technical collaborations within NIST and with universities, industry, and other government agencies. Some highlights of the past year include:

1. A workshop on SEMPA was organized at the IEEE International Magnetics Conference. About 200 scientists and engineers attended the 1 1/2 hour tutorial. Potential applications were discussed by a panel of scientists from Carnegie Mellon University, M.I.T., Honeywell, Inc., and Control Data Corporation.

2. Our scanning tunneling microscope was used to measure the transition from atomic behavior to metallic behavior in atomic-scale clusters of Fe atoms adsorbed on a GaAs substrate. If the 1-3 nm clusters are considered to be the ultimate magnetic "bit", they would represent a million-fold improvement in information storage density.

3. SURF-II had a record, stored-beam current of 302 mA in March 1989, and a record average of 215 mA during April-September 1989, about 20% higher than last year's record. Increased current means increased flux and usable flux levels are maintained for a longer period. Experiments can be done faster, more sophisticated measurements can be made, and the quality of the work is higher.

4. Special narrow band XUV photometers (filtered detectors) were developed, in collaboration with industry, and calibrated at SURF-II for user applications. One of the photometers, about the size of a human thumb, was flown on a solar sounding rocket.

5. An enhanced XUV optics program was initiated at SURF-II to provide measurement services to scientists and engineers developing and using high efficiency, multilayer, soft x-ray optical devices. New collaborations were established with AT&T Bell Labs, IBM, Lawrence Livermore, Lawrence Berkeley, Princeton University, Johns Hopkins University, U. Arizona, U. Colorado, and Ovonics Corporation.

6. A new "competence" project for "Advanced Studies in Laser Cooling and Trapping" was initiated as a collaboration between three Divisions with expertise in atomic, molecular, and optical physics. The Electron and Optical Physics Division, in collaboration with U. Maryland, is developing a VUV laser source to cool hydrogen atoms to a few 10's of mK.

7. A new data service was established to support the development of advanced methods of elemental and isotopic analysis. The service provides formatted data and application sheets to permit the routine use of laser resonance ionization techniques in analytical chemical measurements.

8. Thirty-two major visiting scientist collaborations were active in FY89: 11 in the Far UV Physics Group; seven in the Electron Physics Group; and 14 in the Photon Physics Group.

II. FAR UV PHYSICS GROUP

A. Far UV Detector Calibrations (L. R. Canfield, N. Swanson, and J. Kerner)

An ongoing calibration service, now listed in NIST Special Publication 250, is the calibration of specially selected far ultraviolet detectors for quantum efficiency in the spectral region 5-254 nm. This is accomplished at two facilities: a dedicated beamline at the SURF-II synchrotron radiation facility for the region 5-50 nm; and a vacuum ultraviolet radiation facility for the longer wavelengths. Transfer standard detectors are made available to outside users involved in a wide variety of research disciplines in the far ultraviolet, such as plasma diagnostics, aeronomy, astronomy, solar physics, etc. This competence has served the radiometric detector needs of the space community for almost twenty years. Over this period, several hundred calibrations have been furnished; during FY89 an additional 26 services were provided.

At present, two types of photoemissive photodiodes cover the entire far UV region: a NIST-fabricated windowless photodiode for the 5-122 nm region; and a MgF_2-windowed photodiode, made to NIST specifications, for the 116-254 nm region. Working standards of both types derive their calibration from rare gas ionization chambers, which are an absolute detector in a portion of the region covered (5-92 nm). For the longer wavelengths, a special windowless thermopile is used to transfer an ionization chamber calibration to longer wavelengths. These standards are then used to calibrate, by intercomparison, outgoing transfer standards of the same type, or to recalibrate similar standards previously issued.

In a collaboration with industry, a new detector type is under study to assess its suitability as a transfer standard in the far UV. This is a new kind of silicon photodiode developed to meet radiometric quality criteria in the far UV. It has been determined thus far that the efficiency of these devices can be far greater than the present standards, reaching an improvement of almost 300 times at the shortest wavelengths. Less sensitivity to surface contamination, a common potential problem with vacuum system environments, is also a benefit as compared with the windowless photoemissive photodiodes. The nature of semiconductor fabrication is such that it lends itself to the relatively economical creation of high-efficiency array detectors for the far UV.

A project is under way to eliminate the dependence of our absolute radiometric scale on thermopiles. These devices have served us well in extending our radiometric scale to wavelengths where there has been no absolute detector, but with their use one pays the penalty of very poor signal-to-noise and the consequent high uncertainty. Thermopiles have been used as uniformly grey detectors in bridging the gap from below 90 nm where the ionization chamber is operative, to 253.7 nm where we are able to tie to mercury lamps based on NIST tungsten lamp standards. In the new project, this dependence will shift to SURF-II as an absolute source. This changeover requires a precise method of measuring the transmission of a monochromator used to interface SURF-II to the transfer standard detectors. The design of a new facility which houses the calibration system for the monochromators and detectors is complete and all components are now on hand or will soon be in track for purchase. We expect the new facility to begin commissioning in FY90.

B. <u>SURF-II Operations</u> (L. Hughey, A. Hamilton, R. Madden, and W. Wooden)

The performance of SURF-II continues to improve. The average beam current for this year is 203 mA (last year it was 170 mA) while the average for the last six months is 215 mA. A new record beam of 302 mA was achieved on March 16, 1989, by SURF operator William Wooden. Beam lifetime at full energy continues to improve as well. The beam current-lifetime product now exceeds 700 mA-hr. SURF-II availability remains high. Throughout the year, beam was provided to users approximately 95% of the scheduled beam time (9 hours/day, 4 days/week) with a high of 98% during the period from August 1988 to January 1989.

The improvements in beam current and in beam lifetime have come about both from changes to existing parts of the system and refinement of others. In the former category, the microtron injector performance has been enhanced by reducing the complexity of the interconnections among the various timing circuits. This in turn reduced the time jitter in the system and thus allowed the operator to make more subtle adjustments during the tuning process. In the latter category, a nearly continual refinement takes place in the programs which control the correction coil currents and RF power while the ring is ramping from injection to full energy. In addition, a periodic evaluation is made of the phase of the RF cavity signal to adjust for maximum lifetime under varying ring conditions.

During FY89, a new cryopump was installed on the microtron. This has reduced the cycle time for repairs or adjustments to the microtron RF cavity or the microtron filament from more than a day to a few hours.

C. <u>SURF-II Users Programs</u> (R. Madden)

SURF-II was used by a variety of NIST and outside users in FY89 for spectrometer and detector calibrations and for research in surface science, molecular physics, and UV and soft x-ray optical physics. Heavy use was made of the surface science beamlines. This group expanded operations this year by establishing a completely refurbished station on BL-1 (Beamline 1) and by moving the earlier experimental chamber to a toroidal grating monochromator on BL-8. The detector calibration beamline, BL-9, was also used extensively for photodiode calibrations and other measurements on optical devices. The high resolution spectrometer on BL-3 was operational this year, doing research on rare gases and molecular nitrogen. The reflectometer on BL-8 was also used heavily in the latter part of the year for the study of multilayer systems, in a cooperative program involving many outside researchers. The high flux normal-incidence monochromator on BL-5, unused earlier this year, is now being used for the experimental development of timing circuitry in preparation for two photon pump-probe experiments, and two outside user groups are preparing to use it during the next year for both gas and solid state experiments.

1. Surface Science Beamline, BL-1 and BL-8 (R. Kurtz and S. Robey, Surface Science Division, CAMOP; R. Stockbauer, Louisiana State Univ.; T. Madey, Rutgers Univ.)

The NIST research efforts in surface science are supported at SURF-II with two beamlines and associated ultra-high vacuum chambers that are used for a wide range of studies of solid surfaces. The principal experimental technique applied in these efforts is ultraviolet photoelectron spectroscopy (UPS), where variable-wavelength photons are used to probe the valence electronic structure of bulk solids and the molecular orbitals of adsorbed species. In addition, photon stimulated desorption (PSD) of ions from surfaces is studied to elucidate the mechanisms involved in radiation damage of materials. These studies have shown that the atomic-scale structure of defects and steps may be revealed by stimulated desorption techniques.

Photoemission has been used to study the initial stages of chemisorption of simple molecules on oxide surfaces. This work, a collaboration with the Instituto Ciencia de Materiales of Madrid, looked at the interaction of H_2O and NH_3 with TiO_2 surfaces and discovered that new models are required for dissociation of these species on oxide surfaces. These models profoundly impact thinking for the mechanism involved in the catalytic activity of these model systems.

As part of the surface standards program, improvements on a technique for measuring electron attenuation lengths have been made. New substrate materials have been used in these overlayer measurements, different measurement geometries have been studied, and a new technique for dosing the surface has been explored. These improvements have resulted in data of improved quality.

The exciting work being pursued on high-temperature superconductors has continued with single-crystal superconductors being investigated. Photoemission measurements that can be compared directly with band structure measurements have been made. In addition, studies of the chemistry of these oxides have been extended to include a wider range of materials and have shown that materials improvements can have a substantial positive impact on the chemical stability of these materials upon exposure to atmosphere.

Since the first application of high-T_c superconductors will come in the area of thin-film devices, the photoemission measurements at SURF-II are being extended to include thin-film superconducting materials produced *in situ*. A research-scale molecular-beam epitaxy chamber is presently under construction to produce the thin films by co-evaporation. Detailed investigations of the factors affecting the epitaxial growth of high-T_c superconductors on different substrates can be pursued as well as such things as the effect of substrate interactions and buffer layers.

The Surface Science Division has played a strong role in developing techniques and instrumentation for studies of both electron- and photon-stimulated desorption processes. A large effort has been devoted to the development of an ellipsoidal-mirror analyzer and this instrument has been installed on BL-1. Initial testing indicates that the analyzer is operating within design expectation. Photoemission and ion desorption spectra have been obtained and the next phase in making the instrument fully operational will involve the refinement of the angle-resolving capabilities. This will allow us to simultaneously measure charged-particle kinetic energies, mass, and angular distribution as a function of the incident photon wavelength that stimulates the emission process. These measurements will result in a more complete description of the systems of interest than had been possible previously.

2. Radiometric Instrumentation Calibration, BL-2 (M. Furst and R. Graves)

The synchrotron radiation from the SURF-II storage ring is used as an irradiance standard for characterizing instrument response over a wide range of wavelengths from 4-400 nm. There were 16 instruments calibrated by 8 user groups over a period of 35 weeks during FY89. Facility users included NASA/Goddard Space Flight Center, North Carolina State University, Laboratory for Atmospheric and Space Physics/University of Colorado, Space Sciences Laboratory/University of California at Berkeley, Lawrence Livermore National Laboratory, and Space Sciences Center/University of Southern California.

Several improvements were made to the facility. A cryopump was added to the beamline at the 11 m station to decrease the amount of time necessary for evacuating user instrumentation and for baking out beamline components for both user stations. The vacuum chamber gimbals drive system was redesigned and the angular range of motion was increased. Data transmission rates for the 17 m station were increased by a factor of four over previous rates.

3. High Resolution Spectrometer, BL-3 (D. Ederer, M. Furst, T. Lucatorto, R. Madden, B. Olsen; M. Ginter and D. Ginter, Univ. of Maryland; R. Morrison, Talladega College; D. Cleary, Naval Postgraduate School, Monterey, CA; H. Morgan, J. Fortna, and M. Seyoum, Univ. of District of Columbia)

In the first set of experiments since being installed at SURF-II, the 6.65 m high resolution spectrometer was used to perform a high resolution photoabsorption study of N_2. The work was motivated by the need of the atmospheric physics community to resolve an inconsistency between plasma density measurements of the F2 region of the ionosphere by various remote sensing techniques. The problem required detailed knowledge of the N_2 absorption cross section near O^+ emission lines. Preliminary measurements made here this year are consistent with lower cross section values proposed by D. Cleary, and it is intended to continue the study in the near future.

New users this year are a group from Univ. of District of Columbia, led by H. Morgan and J. Fortna. They plan to join in improving the N_2 photoabsorption measurements, and to extend studies to other atmospheric gases.

4. Optical Properties of Materials, BL-8 (E. Saloman and J. Kerner; J. Roberts, Atomic and Plasma Radiation Division, CAMOP; R. Keski-Kuha, NASA Goddard Space Flight Center; D. Husk, Univ. of Virginia)

The 2.2 m grazing incidence spectrometer and reflectometer chamber on BL-8 were used to measure reflectivity of various multilayer samples, as well as deposited metal mirrors. The measurements of these samples have been made for the wavelength region between 8 and 50 nm. Samples from different laboratories, including the University of Arizona, the University of Colorado, Johns Hopkins University, NASA, Lawrence Livermore, Lawrence Berkeley, IBM, AT&T Bell Labs, Princeton University, and Ovonics Corporation have been measured. Collaborations with some of these and other institutions, including Bell Labs, have been set up for future experiments in lithography and biological microscopy.

The measurement and vacuum systems have been improved and new sample holders for flat as well as curved samples have been incorporated. In order to properly address the new emerging technology of soft x-ray optics characterization, further improvements of the existing apparatus are planned. Plans for a new computer-controlled monochromator and reflectometer chamber are underway. Plans also include a capability of *in situ* thin film deposition and load-lock sample introduction.

5. Detector Calibration, BL-9 (L. Canfield and J. Kerner)

Beamline-9 is a dedicated detector calibration facility that is routinely used to calibrate standard detectors for the spectral region 5-50 nm. Detectors are calibrated by intercomparison with a working standard, which has been previously calibrated in this same facility using a rare gas ionization chamber as the absolute reference. The continuum radiation from SURF-II is dispersed by a toroidal grating, giving monochromatic light of approximately 0.1 nm bandpass for calibration purposes. The ionization chamber is pressurized with a rare gas, usually neon, while the ultra-high vacuum of the storage ring is protected by a transmitting thin film filter sealed to the ionization chamber.

During FY89, several research activities were also carried out with this facility.

(1) Special thin film filters were characterized for two different groups involved in rocket studies of solar flux, and for one of these groups, a narrow bandpass solid state detector, i.e., an XUV photometer, was calibrated for a similar application.

(2) The photoemission and transmission of diamond thin films was measured, as were several metals interesting as far UV filter materials.

(3) A proportional counter system was assembled and attached to BL-9 to evaluate the purity of the dispersed radiation in the 45-60 Å region. It is extremely difficult to measure the degree of impurity contamination present in the dispersed radiation with the detectors normally calibrated in this system, but the proportional counter, which can be used as an absolute detector, can be quite discriminating against impurities from longer wavelengths. Thus such a counter gives an independent method of absolute detection, and can also be used for the evaluation of scattered light.

(4) A study of special silicon semiconductor photodiodes, optimized for use in the far UV, continues on this beamline in collaboration with United Detector Technology, Inc. These photodiodes have considerably more efficiency than the windowless standards presently used -- as much as a factor of 300 at 7 nm -- and are a likely candidate as an alternate standard for the future. Recent studies on BL-9 have shown immunity to radiation damage in the 5-50 nm region, and the spatial uniformity has been shown to be quite acceptable. In the region 50-160 nm some radiation damage manifests itself with extensive exposure, and this is currently under study. The long-term stability continues to be monitored.

III. ELECTRON PHYSICS GROUP

The Electron Physics Group has ongoing research efforts in electron collision physics including electron-atom collisions, electron-surface interactions, surface magnetism, electron interaction theory, electron polarization phenomena, tunneling and scanning electron microscopy, and electron optics and instrumentation. The wide applicability of electron-based measurement technologies allows us to contribute to the solution of many diverse scientific and technological problems.

In the past year, we have seen significant achievements in all of our areas of research. The STM has been used to characterize metal-induced band gap states and the SEMPA project has coupled theory and experiment to greatly improve our understanding of domain wall structure. The electron atom scattering experiment has obtained its first elastic scattering data and a greatly improved spin detector has been developed for the NSLS polarized photoemission project. Our theory efforts include an important paper on polarized metastable de-excitation and a good start on high-T_c superconductivity. Our interactions with industry continue to be strong, as do our other collaborative efforts.

We continue our focus on interfacial phenomena with special emphasis on the use of microscopy to study microstructures, clusters, defects, growth, and dynamics on the atomic scale. Our SEMPA work involves studying the effects of size, dimensionality, shape, topography and epitaxial substrate on magnetic microstructures. The photoemission experiments focus on understanding magnetic phenomena in novel epitaxial systems through measurements of spin-resolved band structure. Our STM measurements investigate the electronic structure of atoms, molecules, clusters, and microstructures on surfaces. The STM allows us to study the growth of microstructures with atomic resolution. It also permits us to verify, for example, that the novel epitaxial structures we grow have the physical structure we planned and that their observed magnetic phenomena results from our tailoring of the physical structure.

This year, we also have begun new experimental efforts in magnetic scanning tunneling microscopy and the optical control of metal atom beams. In order to concentrate on these new activities, we are phasing out our work on inverse photoemission and temporarily limiting our involvement at NSLS.

A. Magnetic Microstructure Research (J. Unguris, M. Scheinfein, R. Celotta, D. Pierce, M. Kelley and M. Hart; M. Aeschlimann, ETH, Zurich)

We are using SEMPA to investigate the micromagnetic structure of ferromagnetic materials. The SEMPA technique was developed at NIST and involves the combination of an ultra-high vacuum scanning electron microscope (SEM) with electron spin polarization analyzers in order to measure the polarization of secondary electrons emitted from the specimen. In transition metal ferromagnets the spin polarization of the secondary electrons is directly proportional to the polarization of the electrons within the ferromagnet. Polarization analysis of the secondary electrons provides a direct measurement of the magnitude and the direction of the magnetization in the region probed by the incident electron beam. SEMPA can therefore image magnetic structures, such as domains and domain walls, with the highest spatial resolution available of any technique for looking at magnetic structures in reflection. The SEMPA images are quantitative, measuring the magnitude and direction of the magnetization at any one point, and the images of the magnetization are independent of specimen topography, which is, however, measured simultaneously. In addition, SEMPA is an ideal probe of surface and thin film magnetism, because the escape depth of the secondaries is only a few nm.

Our new SEMPA facility, which consists of a JEOL model JAMP-30 Auger microprobe fitted with NIST designed gold film polarization analyzers, has been operating flawlessly for the past year. The SEMPA system can image magnetic structures with a measured spatial resolution of 60 nm (0.06 microns). In addition, the Auger microprobe feature enables us to map the chemical composition with about the same resolution and from the same area as the magnetic and topographic images. This provides us with a unique tool to study the relationships between magnetic microstructure, surface composition, and surface topography. A second SEMPA apparatus, the result of a collaboration between the Electron Physics Group and a commercial manufacturer, is scheduled to come on line in February 1990. In addition to relieving the heavy demand on the current apparatus, the new SEMPA is expected to improve our spatial resolution to 10 nm.

We have investigated the surface magnetic domain structure of a large variety of transition metal ferromagnets such as: iron and cobalt single crystals, iron whiskers, ferromagnetic metallic glasses, and NiFe films of various thicknesses and compositions. An especially interesting domain pattern was observed for a cobalt crystal which had its c axis, the easy magnetization direction, perpendicular to the surface. The domain structure had magnetization components both in the surface plane and perpendicular to the surface. This is the first time that anyone using SEMPA has observed a perpendicular magnetization.

We have also used SEMPA to make quantitative, high spatial resolution measurements of surface domain walls and the fine structures within the domain walls. These measurements tested the accuracy of micromagnetic models that were used to calculate surface and bulk magnetization distributions. The agreement between measured and calculated properties, such as domain wall profiles, was excellent. This agreement gives us confidence that the micromagnetic models can be used to predict magnetic properties that cannot be directly measured by SEMPA, such as domain wall structures inside of the ferromagnet or magnetic field distributions inside and outside of the material.

We are beginning to investigate the magnetic structure of thin ferromagnetic films. The surface sensitivity of SEMPA makes it an ideal tool for looking at films that vary in thickness from a monolayer to a few tens of layers. The films can be deposited and analyzed by Auger spectroscopy, reflection high-energy electron diffraction, and SEMPA, all in the same chamber. In this work we will investigate whether domains exist in thin films, how the domain structures vary with thickness, and how the films magnetically couple to other films or magnetic substrates.

In addition to basic research, we have continued to collaborate with private industry by using SEMPA to help solve applied magnetics problems. One example of this is our work with Seagate Magnetics in which we investigated the magnetic structure of written bits in various hard disc memory media. We found that, in noisy recording media, the written bits were not clearly separated by sharp boundaries, but instead were magnetically bridged together, resulting in low signal-to-noise during read-back.

In addition to Seagate Magnetics, we have worked on applied magnetics problems with Digital Equipment Corp., Honeywell Inc., Imprimus, Phillips Research Labs, and Westinghouse Electric Corp. We have also worked on transferring SEMPA technology by consulting directly with university and industrial labs that are in the process of building their own SEMPA systems and by conducting a SEMPA workshop at the IEEE International Magnetics Conference. These collaborative efforts have been scientifically fruitful, intellectually stimulating, and mutually beneficial.

B. Scanning Tunneling Microscopy (J. Stroscio, R. Dragoset, P. First, D. Pierce, and R. Celotta)

The aim of the STM program is to investigate novel properties of matter that occur in small-size structures on the nanometer scale, and to develop advanced techniques which further the application of scanned electron probe techniques. The STM operates by bringing a sharp probe tip to within atomic dimensions of a specimen. A current flows from the tip to the surface by the quantum tunneling of electrons due to the proximity of the tip to the surface. By scanning the tip over an exposed surface, information is obtained about the structural and electronic properties of the examined specimens. The device operates with a lateral resolution of 2-3 Å, and thus is a natural tool for examining the physics of small-scale structures. This is particularly meaningful as microfabrication technology is reaching the ultimate limit (which is one atom) in devices with structures on the order of 100 Å (0.01 μm) wide.

We have been examining metal structures grown on GaAs(110) surfaces. GaAs is thought to be the semiconductor of the future because of its high speed properties. One of the experiments we have focused on this year is growing epitaxial Fe films on GaAs, with the intention of future studies on the magnetic properties of thin films in coordination with SEMPA experiments. In these experiments we have shown that the Fe grows by initially forming small 3-dimensional clusters instead of a continuous monolayer film. By monitoring how the tunneling current changes with electron energy, we have determined that small clusters are not metallic and larger ones with greater than 35 atoms display fully metallic characteristics. In addition, in this work we have been able to spectroscopically image (by imaging at different electron energies) the gap states that form in the GaAs semiconductor due to the presence of Fe clusters on the GaAs surface. These results are the first to show direct evidence for metal-induced gap states, which have been predicted in theories of metal-semiconductor interfaces.

In examining ultimate limits in physical properties of small-scale structures, we have investigated one-dimensional Cs structures on GaAs(110) which are only two atoms wide and many hundreds of atoms long. These structures thus represent the smallest possible metal-atom lines or "wires" that could be made and offer insight into the physical properties of such small-scale structures. Using the STM, we have shown that such narrow "wires" are not metallic, even though bulk Cs is metallic, and hence these atomic "wires" would not conduct electricity if used in devices.

A second STM is currently being completed. It has an advanced design allowing much higher scanning speeds than the previous instrument. The instrument is housed in an ultra-high vacuum system with sample characterization facilities such as low energy electron diffraction and ion sputtering. The system also has two additional instruments, a field ion microscope to prepare ultra-sharp single atom tips and an electron spin detection system coupled with the STM. The aim of this system is to extend the study of magnetic microstructure to atomic dimensions. The electron spin detector will be used to measure the spin of electrons scattered from the surface during tunneling in the STM. The STM has already demonstrated a scanning ability 10-50 times faster than the older instrument. Detection of spin-polarized electrons from the STM junction will proceed in FY90 with the hope of opening up a new frontier in micromagnetism.

C. Electron - Atom Collisions Studies (M. Kelley and J. McClelland; S. Buckman, Australian National U.)

Our purpose is to study, in as complete a manner as possible, the interactions important in low energy collisions between electrons and atoms. We use optical state preparation techniques to prepare beams of electrons and atoms in well-defined quantum states and perform scattering measurements to determine the dependence of various collision cross sections on the initial state of the incident electrons and atoms. Such state-selected experiments provide substantially more information about the collision than is available from conventional measurements of differential scattering cross sections. We are particularly interested in the influence on the collision of the spin state of the incident electrons and atoms. Determination of this spin dependence provides direct information about both exchange and the spin-orbit interaction, and provides a stringent reliability test for current theoretical scattering calculations.

We have made spin-dependent measurements for both elastic and inelastic scattering. The most recent elastic scattering measurements were performed at an incident electron energy of 20.0 eV, at scattering angles in the range from 20 to 140 degrees. Our results show a strong dependence in the scattering cross section on the relative spin orientations of the incident electrons and atoms, indicating that exchange effects are rather important in collisions at this energy. The spin-orbit interaction is seen to play a less important role at this energy. Comparison of state-of-the-art electron scattering calculations with these measurements demonstrates the need for further theoretical work on this collision system.

We have also studied inelastic scattering by way of superelastic scattering from the first excited state. Spin-polarized and oriented sodium atoms are prepared in the excited 3P state by optical pumping with circularly polarized light. By detecting only electrons that have de-excited these atoms and gained the 2.1 eV excitation energy of the atoms, we are able to study the 3S - 3P transition with great detail. Our most recent measurements were at an incident energy of 17.9 eV. This incident energy, for superelastic scattering, corresponds to inelastic excitation from the ground to the first excited state at an incident energy of 20 eV. We find that exchange effects, while still significant, play a somewhat less important role in the inelastic collisions at this energy than in the elastic collisions.

A systematic search was also carried out for a spin dependence which requires that both exchange and the spin-orbit interaction play a significant role during the collision. This effect would cause the cross section for scattering to some angle to depend on the spin orientation of the target atom, independent of the spin of the incident electron. In the absence of either exchange or the spin-orbit interaction, this dependence must vanish. We observe both exchange and spin-orbit effects near minima in cross section for elastic scattering at incident energies from 20 eV to 100 eV, but, within our experimental precision, find no evidence of this joint effect.

Our current efforts are directed at extending the energy range in which our elastic and superelastic measurements are possible. We wish to perform elastic scattering measurements at energies below the ionization threshold of 5.1 eV, where theoretical calculations are expected to be quite good. We will then be to able provide both elastic and inelastic data over the range of energies from somewhat below to several times the ionization threshold. This is an important energy region for many physical processes, but for which many current scattering calculations have severe difficulties.

D. Spin-Polarized Photoemission at NSLS (D. Pierce and R. Celotta)

We have been participating in an effort at the National Synchrotron Light Source (NSLS) to study novel magnetic systems created *in situ* by molecular beam epitaxy (MBE). To date, the work has concentrated on the establishment of a spin-polarized, angle- and energy-resolved photoemission apparatus on the U-5 beamline of the UV storage ring.

This project is unique in a number of ways. First, the research team consists of 10 principal investigators from 8 institutions nationwide. These are national labs (NIST, Argonne, NRL, and NSLS), universities (Rice, Texas at Austin, and Northwestern), and an industrial lab (AT&T Bell). This group functions both as an NSF Materials Research Group as well as an NSLS Participating Research Team. Second, the beamline is the only spin-polarized facility in the United States and the only one in the world with a movable spin analyzer to permit angular studies. Third, it is one of the few beamlines in the U.S. to have an MBE capability. Finally, because of the demanding nature of the experiment, we are fortunate to have the highest flux UV beamline at NSLS. It is based on an undulator currently installed in a straight section of the ring. During the next year this same group, acting as an Insertion Device Team, will install a new state-of-the-art undulator now under construction.

The beamline has been used to take spin-polarized photoemission data. In the first experiment, our colleagues at NSLS examined the angle-resolved spectra of Fe(110) both in a clean state and with adsorbed sulfur. The ability to make both angle- and spin-resolved photoemission measurements extends greatly previous work and, even in the first experiments, calls into question previous interpretations made in the absence of spin-resolved data.

Measurements have begun on the Fe/Cu(100) and Fe/Pd(100) systems. The first few layers are thought to grow epitaxially as fcc Fe, as opposed to the normal bcc form. The object of the experiment is to observe the magnetic properties, e.g. anisotropy, Curie temperature, remanence, magnetization, etc., as a function of layer thickness and growth methodology, and to correlate them with the spin-dependent electronic structure we measure. The lattice is expanded in going from Cu to Pd, which should promote ferromagnetism. Furthermore, from alloy data Pd is expected to be polarizable, which may lead to interesting electronic and magnetic structure effects for the thin films. Analysis of the data is currently in progress. We expect this facility to greatly extend our ability to study new and interesting magnetic systems.

We have decided to limit our participation in experiments at the facility owing to other priorities. We will maintain our commitment to provide our state-of-the-art spin polarimeters for the experiment. However, we expect to carry out spin-polarized photoemission measurements only when we perceive an exceptional scientific opportunity, or when there is a demand for particular information for our experimental program at NIST.

E. <u>Electron Optics</u> (M. Kelley and M. Scheinfein)

We continue to update our capabilities for the design and characterization of new electron-optical instruments. Sophisticated numerical algorithms are used to compute electrostatic and magnetic lens fields, and improved methods of determining the optical properties of these fields are used. Paraxial and aberration properties can be accurately determined for both electrostatic and magnetic lenses. Non-paraxial, all-order, electrostatic ray-tracing is also used for accurate modeling of novel designs. Furthermore, a third order matrix method has been developed for use in the design and characterization of our electron optical systems.

Significant effort has been spent on the electron optical design of a polarized electron detector for a scanning tip microscope. A tunneling tip may be pulled away from the surface, and electrons may be extracted by applying a potential between the sample and the specimen. This scanning field emission tip microscope will be used to probe magnetic microstructure of surfaces. The magnetic microstructure is accessible through analyzing the spin polarization of the electrons excited near the surface of the specimen. It is hoped that this instrument will have 100 Å spatial resolution.

Finally, the electron optical properties of an inhomogeneous field Wien filter were investigated using the matrix method. The inhomogeneous field Wien filter possesses point-to-point focusing. It also may be used as an electron spectrometer, mass filter, and spin rotator. We plan on using the longitudinal-to-transverse spin rotation with the point-to-point focusing properties of the Wien filter in future SEMPA implementations to eliminate the need for the 1/4-sphere deflector and one of the electron spin detectors.

F. Electron Theory (D. Penn)

Our purpose is to study various aspects of electron-electron interactions in solids with application to high-T_c superconductivity and surface magnetism.

We have completed the first theory of spin-polarized metastable de-excitation spectroscopy. Metastable spin-polarized He^* atoms incident on a Ni surface undergo de-excitation in a process which yields electrons from the Ni. The number produced is observed to depend on the relative spin of the Ni and the He^* atoms. The normalized difference in the ejected electron intensity produced by He^* atoms with opposite spin polarizations increases dramatically with increasing kinetic energy of the electrons. We find that the experimental results can be reproduced by theory only with the use of a realistic potential for the Ni electrons in the vacuum region. With such a potential it is found that He^+ ions which result from the He^*-surface interaction are neutralized approximately 4.5 Å from the Ni surface, a much larger distance than given by previous estimates. We also show that the experiment reflects the polarization of Ni electrons at the He ion and it is estimated that the Ni polarization at the Fermi energy and far from the Ni surface is -20%.

In collaboration with Prof. M.L. Cohen (U.C. Berkeley) the effect of local fields on superconductivity is being studied. We have completed a theory of the total dielectric function which forms the basis for the present work. The total dielectric function approach allows the inclusion of both coulomb and lattice screening in a single dielectric function and thus allows a unified approach to superconductivity that includes local field (lattice) effects. We will proceed by developing a specific model for the dielectric function to examine the interplay between T_c, electron-phonon coupling, local field effects, and lattice stability.

IV. PHOTON PHYSICS GROUP

The Photon Physics Group investigates the interaction of electromagnetic fields with atoms and molecules in various environments in support of radiation measurements and standards programs important to NIST and the outside technical community. This work includes theoretical and experimental studies on the electronic structure of atomic and molecular systems in field-free environments, in crystalline environments (atomic effects in solids), and in strong external fields. The focus is on VUV photoexcitation and photoionization in gases and solids and on multiphoton laser-atom interactions.

Collaborative work is directed toward the laser cooling of atomic hydrogen, laser isotope separation and analysis through resonant multiphoton ionization, and the identification of highly excited states suitable for a soft x-ray laser. For many of the activities, the synchrotron radiation from NIST-SURF-II or Brookhaven-NSLS is used as a source of tunable vacuum ultraviolet and soft x-ray radiation.

A. Generation of Coherent VUV (P. Lett and T. Lucatorto; T. McIlrath and Q. Li, U. of Maryland)

Two exciting scientific opportunities have recently arisen within CAMOP: the possibility of laser cooling atomic hydrogen and the possibility of making a precise test of the theory of two-electron quantum-electrodynamics (QED) and relativistic corrections through the measurement of the Lamb shift in ground state He. The cooling of atomic hydrogen will require the efficient generation of coherent radiation at the Lyman-α wavelength, 121.6 nm; the experimental determination of the He ground state Lamb shift requires radiation at 120.4 nm. We shall attempt to generate these two wavelengths by exploiting the recent advances in laser technology represented by the Ti:sapphire laser and the β-barium borate (BBO) non-linear crystal.

The presently proposed upconverison schemes would use tunable Ti:sapphire or dye lasers and BBO non-linear crystals to generate radiation in the range of 205 nm to 208 nm which is then used in resonantly enhanced, four-wave $(2\omega_1 - \omega_2)$ mixing schemes in mixtures of Kr:Ar or Xe:Ar. The new capability for efficient generation of radiation in the range 205 nm to 215 nm provided by BBO allows us to effectively pursue these $2\omega_1 - \omega_2$ schemes which should have considerable resonant enhancement of efficiencies as compared to those previously obtained; preliminary estimates based on early experiments with BBO lead us to expect four-wave mixing efficiencies of 10^{-3} (as opposed to 10^{-4}-10^{-5}).

The development of sources to laser cool hydrogen will be done in two stages. First we shall build a 10 Hz source to cool hydrogen confined in a magnetic trap or "bottle". Such traps have been constructed by several of our colleagues. One uses a He dilution refrigerator to cool spin-aligned hydrogen to a temperature of T=80 mK. These atoms can be trapped for a period of many minutes. The application of a pulsed 10 Hz laser source of Lyman-α will cool the trapped H to approximately 7.5 mK, which would allow further experimentation on Bose-Einstein condensation and collisions at ultra-cold temperatures to proceed.

The second stage will be the development of a more powerful source to decelerate H formed by dissociation of H_2 at liquid nitrogen temperature (77 K). This capability will free us from the need to use a He dilution refrigerator. This source will use either a series of 100 picosecond mode-locked pulses at a 100 MHz repetition rate in a 10 microsecond macro-burst or a single 5 microsecond pulse to decelerate and cool the hydrogen beam. The construction of such a source will advance the state of the art in coherent VUV generation and benefit other areas such as spectroscopy and plasma diagnostics.

The experience gained in developing the Lyman-α source will be applied to developing a 120.285 nm source for the precise measurement of the He ground state energy. Presently the spectroscopy group in the Atomic and Plasma Radiation Division has an ongoing program to provide highly accurate laser spectroscopic measurements (uncertainties of several MHz) of many He excited state energy levels, including the 1s2s ^1S. Because the ground

$1s^2$ ^1S is over 21 eV from the lowest single-photon allowed excited state, no laser measurement has yet been made of the ground level, and the best present value is derived from conventional grating-based spectrometry with an uncertainty of 4.5 GHz. We plan to measure the $1s^2$ ^1S-$1s2s$ ^1S energy separation by a laser-induced two-photon transition between the two levels with the 120.285 nm source. The preliminary accuracy is expected to be in the range of 150 MHz or about 30 times better than the present status. This measurement will be compared to the new theoretical values of the two-electron Lamb shift being calculated by Peter Mohr in the Atomic and Plasma Radiation Division and others.

B. Soft X-Ray Emission Studies of Advanced Materials (D. Ederer and D. Mueller; T. Callcott, U. Tennessee; J. Rubensson, U. Uppsala)

Soft x-ray fluorescence can provide important information about the electronic states of solid state materials. Fluorescence measurements can be used to study the properties of alloys, impurities, clusters, surface layers, organics, and other fragile compounds. A novel, high sensitivity soft x-ray spectrometer especially designed for fluorescence measurements has been in operation at the NSLS for almost three years now and is the proud accomplishment of a joint NIST - Tennessee-Oak Ridge National Laboratory collaboration. Recent experiments have proven it to be one of the best instruments in the world for soft x-ray fluorescence measurements.

The unique capabilities of the instrument have attracted a number of collaborators including scientists from U. Hawaii, U. Connecticut, U. Uppsala, AT&T Bell and Bellcore Laboratories, and the NIST Institute of Materials Science and Engineering (IMSE). The collaboration with AT&T has focused on studies, of AlGaAs and GaAs semiconductors, whereas our work with Bellcore concentrated on an investigation of thin film samples of $YBa_2Cu_3O_{7-x}$. Through collaboration with our IMSE colleagues, we have continued our studies of the $YBa_2Cu_3O_{7-x}$ and Bi-Sr-Ca-Cu-O superconducting ceramics. This last area of research has been funded as part of a DoC initiative on high temperature superconductors.

A few of the highlights of this program are:

1) High-T_c Superconductors:

We have made use of soft x-ray emission spectroscopy to examine the electronic structure of bulk $Bi_2Sr_2CaCu_3O_8$ and $Nd_{1.85}Ce_{0.15}CuO_4$ samples, and to compare the electronic structure of thin film $YBa_2Cu_3O_{7-x}$, and $Bi_2Sr_2CaCu_3O_8$ samples with the electronic structure of well-characterized bulk samples of these materials. Our results are in good accord with current theoretical models. This fact is particularly significant because of the key role theoretical modeling of the electronic density of states has in the development of a physical understanding of the superconducting process. Because soft x-ray emission spectroscopy probes the bulk below the surface, our results were not sensitive to changes due to possible loss of oxygen from the surface region when superconducting cuprates are exposed to ultra-high vacuum at room temperature.

2) Electronic Structure of Semiconductor Materials:

Dramatic changes in the silicon $L_{2,3}$ emission spectrum are observed as the excitation energy is varied from the 2p binding energy at 100 eV to 144 eV. It is proposed that a spectator electron, close to the bottom of the conduction band, influences the valence band electrons. The observations indicate that shake up is important in the excitation process and that the population of low-lying levels, via the initial state shake up, influences the high-energy excited silicon L emission spectrum.

3) Instrumentation Improvements:

This year we have put a transmission grating monochromator into service. This device selects a narrow band of the continuum radiation from the storage ring to excite the fluorescence. Fluxes between 10^{12} and 10^{13} photons/sec are readily obtainable in a band width of about 4 eV. Results have been obtained from the superconductor materials and from the silicon samples as described in a) and b), respectively.

A new position sensitive detector that has two orders of magnitude less noise and a factor of two more sensitivity than the old CCD detector has been installed at the soft x-ray spectrometer at the National Synchrotron Light Source. This detector system will permit us to obtain higher quality data in a shorter time, and to examine samples that are more dilute or more fragile than those we were able to examine to date. For example, now it will be possible to study structure changes due to radiation damage in polyimides. These polymers are of great importance to the semiconductor industry.

C. Synchrotron-Laser Hybrid Experiments: Quenching the Fluorescence from a Core-Excitation (D. Ederer and D. Mueller; R. Shuker, Ben Gurion University; T. Ferret, American University)

Interest in synchrotron-laser hybrid experiments has been on the increase during the past few years and a number of laboratories have initiated programs to use this new research capability. A number of experiments have been performed with cw and low repetition rate laser and synchrotron sources, but only one other group has synchronized a mode-locked laser to the storage ring frequency, thereby gaining control of the time interval between the laser and synchrotron radiation (SR) pulses at a high rate. We have synchronized a Nd:YAG mode-locked laser and VUV radiation by locking the laser to the NSLS synchrotron rf frequency.

This project is heading in the direction of developing new technology to explore the nanosecond and ultimately the pico and subpicosecond time regime in the VUV and soft x-ray region of the spectrum. In our first attempt to test the feasibility of the technique, synchrotron radiation was used to quench the fluorescence from a core-excited solid. The localized electron-hole pair is similar to a Rydberg state. The results of the experiment can be used to infer the radiative lifetime of the exciton. Initial measurements were inconclusive. Another run is planned for FY90.

D. Resonance Ionization Mass Spectrometry Data Service (E. Saloman)

The techniques of Resonance Ionization Spectroscopy (RIS) and Resonance Ionization Mass Spectroscopy (RIMS) have demonstrated high elemental sensitivity and the potential for almost 100% efficiency. They should become most valuable tools for analytical chemistry. For these techniques to meet their potential, they must be made available to practicing analytical chemists. Presently much of the information needed to apply RIS and RIMS is scattered in several atomic data bases, which contain much more information than the chemists would need. It is the object of this project to organize the available data and supplement it with calculations where the many gaps exist to provide the needed information to permit the application of RIS and RIMS to routine use in analytical chemistry.

We produced the first ten data sheets in an initial simplified format for the new Resonance Ionization Mass Spectrometry Data Service. These sheets were made available for comment by researchers working in the RIS area. The RIS community showed considerable diversity in the types of RIS schemes that they believed were most important to include and as a result an expanded data sheet format was designed which included several schemes per sheet.

We calculated and collected the required information and produced the first ten data sheets for the RIS/RIMS data service in the highly expanded format. Data sheets were prepared for the elements Fe, Pb, B, C, Au, Si, As, Ge, Zn, and Cd. Arrangements were made with the editor-in-chief of the widely read analytical chemistry journal, Spectrochimica Acta Part B, for publication on a continuing basis of the RIS/RIMS data sheets in that journal. The first ten data sheets have been accepted for publication. In addition a database of RIS/RIMS work has been established.

E. Resonant Ionization for Isotope Separation and Ultrasensitive Analysis (T. Lucatorto; Q. Li and T. McIlrath, U. Maryland)

In most present applications of RIS, the selectivity of the resonantly enhanced ionization is used to distinguish between different elements but not different isotopes of the same element. (A notable exception is the laser isotope separation project at Lawrence Livermore Laboratory.) We have been using high resolution, Doppler-free RIS to explore the potential of using the optical isotope shift to add isotopic selectivity to the ionization process as a means of improving isotope abundance sensitivity in analytical mass spectrometry and of developing viable techniques for producing separated isotopes. We are currently engaged in two experiments: a study of the ac Stark effect in the $5p^5nd$ series in Xe at low n (n=5) and at intermediate n (n>13); and a study of efficient ionization pathways in Ca.

The ac Stark effect causes a shifting and broadening of the resonance in the multiphoton ionization process, a factor that can affect RIS selectivity markedly. We have chosen to look at the ac Stark effects that would arise when an intense IR laser is used to produce efficient ionization of the resonantly excited atoms. The model now used to calculate the ac Stark shifts for Rydberg levels predicts a blue shift nearly equal to the pondermotive potential of a free electron in the laser field. Recent experimental results disagree with these calculations by over a factor of two. Our work is intended to check these experiments and extend the range of the measurements in an effort to resolve the discrepancies.

Research on bone demineralization in weightlessness and in certain diseases has created large demands for samples highly enriched in the rare isotopes ^{46}Ca(0.003% natural abundance) and ^{48}Ca (0.18% natural abundance). Enriched samples are now produced by a Calutron (a large scale electromagnetic isotope separator) at costs ($3000/mg for ^{46}Ca and $260/mg for ^{48}Ca) that seriously limit the level of biomedical research activity in this field. Our goal is to find an effective Doppler-free resonant ionization pathway that will allow efficient laser isotope separation with existing laser technology. Plans are to collaborate in this research effort with Eastern Analytical Inc., a company that is part of the University of Maryland Technology Advancement Program.

F. Atomic Properties and Data (E. Saloman)

Relativistic multi-configuration Dirac-Fock methods have been applied to the calculation of atomic and ionic energies and transition probabilities. The initial study has been completed: an investigation of the energies and oscillator strengths in the ground state configuration of the sulfur isoelectronic sequence. Results have been obtained for all transitions within this configuration for the 77 ions from sulfur to uranium. They demonstrate striking effects in the f-values corresponding to atomic numbers where different configurations become important. A report on these effects was published in Physical Review A. The detailed data were published in Atomic Data and Nuclear Data Tables.

This work is a collaboration with the Atomic and Plasma Radiation Division.

G. Theoretical Atomic, Molecular, and Optical Physics (C. W. Clark; L. Pan and S. Blodgett-Ford, U. Maryland; S. Buckman, Australian National Univ.)

As in the past few years, theoretical AMO physics in the Photon Physics Group focused on the understanding of high-order multiphoton processes and on core excitation and resonance phenomena in photoabsorption and electron-atom collisions.

(1) The study of high-order multiphoton processes within the past year concentrated primarily on the understanding of high-harmonic generation. This phenomenon, which is under experimental investigation at CEA Saclay (France) and the University of Illinois at Chicago, involves the generation of harmonic radiation in gas samples irradiated by intense lasers, the harmonic order ranging up to 30 in some cases. These

observations offer the prospect of generating coherent radiation in the soft x-ray range, controlled by optical techniques applied to a driving laser that oscillates in the visible or infrared. The total yields of high-harmonic radiation that have been obtained to date are still small. However, the experimental observations show, surprisingly, that the yield does not decrease monotonically with increasing harmonic order, but rather exhibits a broad "plateau" region. In other words, in some conditions it is possible to generate 33rd-order harmonic radiation with approximately the same efficiency as 9th-order radiation. This feature obviously holds great promise for practical application, and its elucidation has been a major goal of our theoretical effort.

We have applied the Sturmian function methods developed in the past two years to the computation of the nonlinear frequency-dependent susceptibilities of hydrogen and hydrogen-like ions for harmonic order up to 70, in the context of lowest-order perturbation theory and, recently, with the next-lowest-order correction included. The principal technical achievements of this work consist of: (1) concise description of low-order susceptibilities over the entire range of frequency by quantum defect techniques; (2) computations of frequency-dependent susceptibilities to the highest order yet reported; (3) the extension of the Sturmian method to treat photoabsorption in the continuum by use of a complex coordinate rotation technique; and (4) the first evaluations of next-order corrections to the nonlinear susceptibilities. The main qualitative conclusions we have derived from this work are as follows:

1) The plateau phenomenon has an analogue in perturbation theory, and the onset of the plateau region observed experimentally in the noble gases occurs at values of intensity and harmonic order similar to those predicted by perturbation theory for atomic hydrogen.

2) The next-order corrections are large, which implies that perturbation theory for high-harmonic generation fails at much lower intensities than was previously thought.

We have had extensive collaboration in this work with a group at Lawrence Livermore Laboratory, that performs non-perturbative calculations with which we have made critical comparisons, and we have been in regular communication with experimental groups at CEA Saclay and the Princeton Plasma Physics Laboratory.

A new direction of research on this problem was initiated in the summer of 1989, when we began a program of direct numerical integration of the Schrödinger partial differential equation for a hydrogen atom in a time-varying radiation field. Although this work requires much further development, it has resulted to date in a functional computer code that calculates the atomic dipole moment as a function of time. This code gives correct results in the weak-field limit (as judged by comparison to perturbation theory), and exhibits a plateau for harmonic generation in strong fields.

Other related aspects of research in multiphoton processes have dealt with the description of the final state of an electron ejected from an atom by a strong radiation field and with the frequency-dependent polarizabilities of systems bound by short-range forces.

(2) Theoretical work on photoabsorption and electron collisions was done largely in collaboration with experimental groups. The most successful venture consisted of a description of the electron energy loss spectrum (EELS) associated with 4d excitation of Ba in the ceramic $_{Y}Ba_2Cu_3O_{7-x}$, as measured at Innsbruck (Austria), and York U. (England). Comparison of these spectra with the total photoyield spectra acquired by the Far Ultraviolet Physics Group (as described in last year's Annual Report) showed that, even at primary electron energies of 2 keV, major EELS features were not present in the photoyield spectrum. A quantitative theoretical analysis showed that these features could be accounted for by non-dipole transitions allowed in the Bethe-Born approximation. A simple statistical model was invoked to explain the EELS spectrum at low primary energy, so that the Ba 4d loss spectra may now be considered to be understood over the full range of experimental practice. The appreciable strength of octupole 4d - 4f excitation observed in Ba suggested that the corresponding feature in Cs might exhibit high sensitivity to the valence state, as was suggested in our previous work. Experiments at Innsbruck undertaken in the summer of 1989 appear to have confirmed this, in that a strong line associated with a $4d^9 4f\ ^1F_3$ state is found in CsO but not in Cs metal.

Work with Guest Scientists from Dublin City University (Ireland) and U. of Hamburg, West Germany, led to striking new results in the absorption spectra of transition metals. The anomalous 3p absorption spectrum of Cr was thought to be fairly well understood through our previous year's study of isoelectronic Mn^+. Our interpretation suggested that Cr^+ would provide a critical test of the overall picture. The anomalous spectrum of Cr derives from a strong mixing of $3p^5 3d^6 4s$ valence and $3p^5 3d^5 4snd$ Rydberg states; simple Hartree-Fock calculations indicate that this mixing should be more pronounced in Cr^+ which lacks a 4s electron. The measured absorption spectrum of Cr^+ does indeed show a significant transfer of oscillator strength into the Rydberg region; the transition between Cr and Cr^+ is thus much unlike the transition between Mn and Mn^+, in which the absorption spectrum is essentially the same. Analysis of all of the sharp 3p - ns features in the Cr^+ spectrum has been completed, and has resulted in an accurate value of the ionization limit. Interpretation of the broader 3p - nd features is not yet complete.

Contributions were made to studies of the effect of negative ion resonances on electron-stimulated desorption of atoms from surfaces, in collaboration with groups from U. of Pittsburgh and the Surface Science

Division. Their conclusions are summarized in the Surface Science Division's annual report. A long-standing project with a group at the Australian National University on critical evaluation of atomic negative ion resonances continued apace. The main original work done by our group on this project consisted of computations of energies and widths of shape resonances in electron scattering by noble gases, and the discovery of similar (yet to be observed) features in electron scattering by halogens and halogen negative ions. Some of these features have been verified by independent calculations undertaken by a group at Johns Hopkins University.

V. CALIBRATION SERVICES PERFORMED

Type of Service	Customer Type*	SP 250 Item No.	Number Calibration or Tests
Far UV radiometric transfer standard detectors (photo-diode calibrations)	1,4-8	40510C 40511C 40520C 40521C 40530C 40561C 40599S	26
Spectrometer calibrations using SURF as an absolute source	5-7	N.A.	16
Totals			42

* Column 2: 1, calibration labs; 2, hospitals; 3, nuclear energy establishments; 4, industry; 5, US government labs; 6, DoD labs; 7, universities; 8, foreign governments.

VI. PUBLICATIONS

A. Publications appearing in print

Callcott, T.A. and Ederer, D.L., "Comment on Unoccupied-Band Narrowing in Na and its Effect on The X-ray Absorption K Edge," Phys. Rev. Lett. 62(11), 1322 (1989).

Callcott, T.A., Zhang, C.H., Tsang, K.-L., Ederer, D.L., Arakawa, E.T. and Kerner, J., "A Transmission Grating Beamline Monochromator for the VUV Synchrotron Light Source at NSLS,: Nucl. Instruments and Methods in Physics Research B40/41, 398 (1989).

Canfield, L.R., Kerner, J. and Korde, R., "Stability and Quantum Efficiency Performance of Silicon Photodiode Detectors in the Far Ultraviolet," Appl. Opt. **28**, 3940 (1989).

Cooper, J.W., Clark, C.W., Cromer, C.L., Lucatorto, T.B., Sonntag, B.F., Kennedy, E.T. and Costello, J.T., "Marked Differences in the 3p Photoabsorption Between the Cr and Mn^+ Isoelectronic Pair; Reasons for the Unique Structure Observed in Cr," Phys. Rev. A. 39(11), 6074 (1989).

Dragoset, R.A., First, P.N., Stroscio, J.A., Pierce, D.T. and Celotta, R.J., "Characterization of Epitaxial Fe on GaAs(110) by Scanning Tunneling Microscopy," in Growth, Characterization and Properties of Ultrathin Magnetic Films and Multilayers, ed. by B.T. Jonker, J.P. Heremans and E.L. Marinero, Mat. Res. Soc. **151**, 193 (1989).

First, P.N., Dragoset, R.A., Stroscio, J.A., Celotta, R.J. and Feenstra, R.M., "Structure of Cs on GaAs(110) as Determined by Scanning Tunneling Microscopy," J. Vac. Sci. Tech. A7, 2868 (1989).

First, P.N., Stroscio, J.A., Dragoset, R.A., Pierce, D.T. and Celotta, R.J., "Metallicity and Gap States in Tunneling to Fe Clusters on GaAs(110)," Phys. Rev. Lett. **63**, 1416 (1989).

Furst, M.L. and Madden, R.P., "Synchrotron Ultraviolet Radiation Facility (SURF-II) Radiometric Instrumentation Calibration Facility," SPIE Proc. 982, 348 (1988).

Gadzuk, J.W., Clark, C.W., "Resonance Enhanced Electron Stimulated Desorption," J. Chem. Phys. **91**, 3174 (1989).

Gould, P.L., Lett, P.D., Watts, R.N., Westbrook, C.I., Julienne, P.S., Phillips, W.D., Thorsheim, H.R., and Weiner, J., "Associative Ionization of Ultra-Cold Laser-Trapped Sodium Atoms," in Atomic Physics 11, ed. by S. Haroche, J.C. Gay and G. Grynberg (World Scientific, Singapore, 1989) p. 215.

Hoffman, A., Guo, X., Yates, J.T. Jr., Gadzuk, J.W. and Clark, C.W., "Electron-stimulated Desorption and Surface Species Conversion: Oxygen on the Pd(111) Surface," J. Chem. Phys. 90, 5793 (1989).

Hughey, L.R., Lean, J.L., Kostkowski, H.J. and Saunders, R.D., "Comparison of the NIST SURF and Argon Mini-Arc Irradiance Standards at 214 nm," Appl. Opt. 28, 3246 (1989).

Kelley, M.H., Unguris, J., Scheinfein, M.R., Pierce, D.T. and Celotta, R.J., "Vector Imaging of Magnetic Microstructure," in Proceedings of 24th Annual Conference of the Microbeam Analysis Society, Asheville, N.C., July 1989, ed. by P.E. Russell, (San Francisco Press, San Francisco, 1989) p. 391.

Korde, R. and Canfield, L.R., "Silicon Photodiodes with Stable Near-Theoretical Quantum Efficiency in the Soft X-Ray Region, Proceedings of Technical Program on X-Ray Instrumentation in Medicine and Biology, Plasma Physics, Astrophysics and Synchrotron Radiation," International Conference on Optical Science and Engineering, Paris, France, April 1989, ed. by R. Benattar, p. 57.

Kurtz, R. and Ederer, D.L., "Performance of the SURF-II High-Throughput Toroidal Grating Monochromator," Nucl. Inst. and Method. A 266, 425 (1988).

Lett, P.D. and Gage, E.C., "Effects of Colored Pump Noise on Intensity Correlations of a Single-Mode Dye Laser," Phys. Rev. A39, 1193 (1989).

Lett, P.D., Westbrook, C.I., Watts, R.N., Rolston, S.L., Gould, P.L., Metcalf, H.J. and Phillips, W.D., "Atoms Laser-Cooled Below the Doppler Limit," in Frequency Standards and Metrology, ed. by A. De Marchi (Springer, New York, 1989) p. 264.

Lett, P.D., Phillips, W.D., Rolston, S.L., Tanner, C.E., Watts, R.N. and Westbrook, C.I., "Optical Molasses," J. Opt. Soc Am. B 6, 2084 (1989).

Madden, R.P., "News from SURF," Synchrotron Radiation News, March/April 1989.

McClelland, J.J., Scheinfein, M.R. and Pierce, D.T., "Use of Thorium as a Target in Electron-Spin Analyzers," Rev. Sci. Instr. 60(4), 683 (1989).

McClelland, J.J., Kelley, M.H. and Celotta, R.J., "Superelastic Scattering of Spin-Polarized Electrons From Sodium," Phys. Rev. A 40(5), 2321 (1989).

Mueller, D., Kurtz, R.L., Robey, S.W., Stockbauer, R.L., Shih, A. and Toth, L., "Resonant Excitation of an Oxygen Valence Satellite in Photoemission from high-T_c Superconductors," Phys. Rev. B 39, 4768 (1989).

Mueller, D., Shih, A. and Hemstreet, L.A., "Synchrotron Radiation Studies for Thermionic Cathode Research," IEEE Transactions on Electron Devices 36, 194 (1989).

Pan, L., Clark, C.W. and Taylor, K.T., "High Harmonic Generation in Hydrogenic Ions," Phys. Rev. A. 39, 4894 (1989).

Pan, L., "The Volkov-like Coulomb Continuum," J. Mod. Opt. 36, 877 (1989).

Pan, L., Taylor, K.T. and Clark, C.W., "Computation of the ac Stark Effect in the Ground State of Atomic Hydrogen," Phys Rev. Lett 61, 2673 (1988).

Perera, R.C.C., Zhang, C.H., Callcott, T.A. and Ederer, D.L., "Electronic Bonding of Buried Interfaces Determined by Soft X-Ray Emission Spectroscopy," J. Appl. Phys. 66, 3676 (1989).

Phillips, W.D., Westbrook, C.I., Lett, P.D., Watts, R.N., Gould, P.L. and Metcalf, H.J., "Observation of Atoms Laser-Cooled Below the Doppler Limit," in Atomic Physics 11, edited by S. Haroche, J.C. Gay and G. Grynberg, (World Scientific, Singapore, 1989) p. 633.

Pierce, D.T., Scheinfein, M.R., Unguris J., and Celotta, R.J., "Magnetic Microstructure of Thin Films and Surfaces: Exploiting Spin-Polarized Electrons in the SEM and STM," in Growth, Characterization and Properties of Ultrathin Magnetic Films and Multilayers, ed. by B.T. Jonker, J.P. Heremans, E.L. Marinero, Mat. Res. Soc. 151, 49 (1989).

Pierce, D.T., "Spin-Polarized Electron Microscopy," Physica Scripta, 38, 291 (1988).

Saloman, E. and Kim, Y.-K., "Energy Levels and Transition Probabilities in the Ground State Configuration of the Sulfur-Like Ions," Atomic Data and Nucl. Data Tables 41, 339 (1989).

Saloman, E., "A Resonance Ionization Spectroscopy/Resonance Ionization Mass Spectrometry Data Service," in Resonance Ionization Spectroscopy 1988, ed. by T.B. Lucatorto and J.E. Parks (The Institute of Physics, Bristol, 1989) p. 255.

Scheinfein, M.R., Unguris, J., Celotta, R.J. and Pierce, D.T., "The Influence of the Surface on Magnetic Domain Wall Microstructure," Phys. Rev. Lett. 63, 668 (1989).

Scheinfein, M.R., "Definition of Ultimate Spatial Resolution," Ultramicroscopy 28, 359 (1989).

Scheinfein, M.R., Pierce, D.T., Unguris, J., McClelland, J.J., Celotta, R.J. and Kelley, M.H., "Improved Low-Energy Diffuse Scattering Electron-Spin Polarization Analyzer," Rev. Sci. Instrum. 60(1), 1 (1989).

Scheinfein, M.R., "Second Order Transfer Matrices for Inhomogeneous Field Wein Filter Including Spin-Precession," OPTIK, 82(3), 99 (1989).

Unguris, J., Scheinfein, M.R., Celotta, R.J. and Pierce, D.T., "Scanning Electron Microscopy with Polarization Analysis Studies of Ni-Fe Magnetic Memory Elements," IEEE Transactions on Magnetics, 25(5), 4204 (1989).

Unguris, J., Scheinfein, M.R., Celotta, R.J. and Pierce, D.T., "Magnetic Microstructure of the (0001) Surface of hcp Cobalt," Appl. Phys. Lett. 55(24), 2553 (1989).

Zhang, C.H., Callcott, T.A., Tsang, K.-L., Ederer, D.L., Blendell, J.E., Clark, C.W., Scimeca, T. and Liu, Y.-W, "Oxygen Partial-Density-of-States Change in the $YBa_2Cu_3O_{7-x}$ Compounds for X=6,6.5,7 Measured by Soft X-ray Emission," Phys. Rev. B, 39(7), 4796 (1989).

B. Publications Submitted or in Press

Callcott, T.A., Zhang, C.H., Ederer, D.L., Mueller, D.R., Rubensson, J.E. and Arakawa, E.T., "The Photon Excitation of Soft-X Ray Emission Spectra," (submitted to Physica Scripta).

Canfield, L.R., Ogawa, H.S., McMullin, D. and Judge, D.L., "Sounding Rocket Measurement of the Absolute Solar FUV Flux Utilizing a Silicon Photodiode," (to be published in the Journal of Geophysical Research).

Canfield, L.R, Mueller, D., Ederer, D.L., Shuker, R., Blendell, J.E., Clark, C.W., Zhang, C.H., Callcott, T.A. and Tsang, K.L., "Soft X-Ray Emission and the Electronic Structure of $YBa_2Cu_3O_x$," (to be published in Synchrotron Radiation News).

Clark, C.W., Pan, L. and Taylor, K.T., "High-order Harmonic Generation by Hydrogenic Ions," in Proceedings of the Third International Laser Science Conference, ed. by W.C. Stwally (1989).

Clark, C.W., Matthew, J.A.D., Ramsey, M.G. and Netzer, F.P., "Electron-excited 4d → 4f Ba Resonances in $YBa_2Cu_3O_{7-x}$: Selection Rules at Intermediate Energy," (to be published in Phys. Rev. A).

Clark, C.W. and Demkov, Y.N., "Making Zone Plates with a Laser Printer," (to be published in American Journal of Physics).

Clark, C.W., "The Frequency-Dependent Polarizability of an Electron Bound by a Zero-Range Potential," (to be published in J. Opt. Soc. Am. B).

Cutkosky, R.D., "Versatile Scan Generator and Data Collector For Scanning Tunneling Microscopes," (to be published in Rev. of Sci. Instrum.).

Ederer, D.L., "Densities of States in LiAl From Soft X-ray Emission Spectra," (to be published in Phys. Rev. B).

Henke, B.L., Gullikson, E.M., Kerner, J. and Oren, A.L., "Design and Characterization of X-Ray Multilayer Analyzers for the 50-1000 eV Region," (submitted to J. of X-Ray Sci. and Tech.).

Hughey, L.R., "Record Capture and Acceleration Efficiency in the SURF-II 300 MeV Circular Storage Ring," (to be published in Proceedings of 1989 Particle Accelerator Conference).

Kelley, M.H., "Spin Polarization, Orientation and Alignment in Electron-Atom Collisions," in Electronic and Atomic Collisions, (to be published).

Kerner, J., Slaughter, J.M., Burkland, M.K., Kearnery, P.A., Lampis, A.R., Milanovic, Z., Schulze, D.W., Falco, C.M., Roberts, J. and Saloman, E.B., "Multilayer Mirrors for 182 Å," Phys. Scrip., special issue (to be published).

Kurtz, R.L., Robey, S.W., Stockbauer, R.L., Mueller, D., Shih, A., Toth, L., Singh, A.K. and Ogofsky, M., "Electron Structure of High-T_c Superconductors Studied Using Photoelectron Spectroscopy," (to be published in Vacuum).

Lett, P.D., Phillips, W.D., Rolston S.L., Tanner, C.E., Watts, R.N. and Westbrook, C.I., "Optical Molasses," J. Opt. Soc. Am. B. (to be published November 1989).

Lett, P.D., Westbrook, C.I., Watts, R.N., Rolston, S.L., Tanner, C.E. Phillips, W.D. and Gould, P.L., "Heterodyne Spectrum of the Fluorescence from Optical Molasses," (to be published in Coherence and Quantum Optics 6, ed. by J. Eberly, L. Mandel and E. Wolf, Plenum, 1990)

Madden, R.P., Hughey, L.R., Hamilton, A., and Furst, M.L., "SURF-II Progress and Opportunities," in Proceedings of the Sixth U.S. Conference on Synchrotron Radiation Instrumentation, Berkeley, CA., August 1989 (to be published).

McClelland, J.J., "Progress on Spin Detectors and Spin-polarized Electron Scattering from Na at NIST," in Proceedings of the Symposium on Polarization and Correlation in Electronic and Atomic Collisions, Stevens Institute of Technology, August 1989 (to be published).

McClelland, J.J., Kelley, M.H. and Celotta, R.J., "Superelastic Scattering of Spin-polarized Electrons from Sodium," (to be published in Physical Review A, September 1989).

Mueller, D., Ederer, D.L., Rubensson, J.E., Shuker, R., Wallace, J., Zhang, C.H., Tai, J., Callcott, T.A., Dong, Q.-Y., Toth, L.E., Ragne, R. and Ogofsky, M., "A Soft X-Ray Emission Spectroscopy Investigation of $Bi_2Sr_2CaCu_2O_8$," (to be submitted to Physica Scripta).

Pan, L., "Treatment of Continuum-Continuum Coupling in the Theoretical Study of Above-Threshold Ionization," (to be published in Atoms in Strong Fields, NATO ASI series, ed. C. Nicolaides, C.W. Clark and M. Nayfeh (Plenum, New York, 1989).

Penn, D.R., Tanuma, S. and Powell, C.J., "Inelastic Mean Free Paths in Solids at Low Energies," (to be published in J. Elec. Spect.).

Penn, D.R. and Apell, P., "Spin-Polarized Metastable Atom De-excitation; Theory," (submitted to Phys. Rev. Lett.).

Penn, D.R. and Apell, P., "Theory of Spin-Polarized Metastable Atom De-excitation," Phys. Rev. B (to be published).

Phillips, W.D., Westbrook, C.I., Watts, R.N., Rolston, S.L., Tanner, C.E., Lett, P.D. and Gould, P.L., "A Heterodyne Measurement of the Fluorescence Spectrum of Optical Molasses," (to be published in Laser Spectroscopy 9, 1990).

Roberts, J.R., Kerner, J. and Saloman E.B., "Soft X-ray Optics Characterization on SURF II," (to be published in Proceedings of Ninth International Conference on Vacuum Ultraviolet Radiation Physics).

Rubensson, J.E, Mueller, D., Shuker, R., Ederer, D.L., Zhang, C.H., Jia, J. and Callcott, T.A., "Excitation Energy Dependence in the $L_{2,3}$ Fluorescence Spectrum of Si," (to be published in Phy. Rev. Lett.).

Saloman, E., "A Resonance Ionization Spectroscopy/ Resonance Ionization Mass Spectrometry Data Service I - Data Sheets for As, B, Cd, C, Ge, Au, Fe, Pb, Si, and Zn," (to be published in Spectrochimica Acta Part B: Atomic Spectroscopy).

Scheinfein, M.R., Unguris, J., Pierce, D.T. and Celotta, R.J., "Surface Magnetic Microstructure," in Magnetism in Low Dimensional Systems, ed. by L. Falicov, (Springer Verlag, Berlin, 1989) (in press).

Scheinfein, M.R., Unguris, J., Kelley, M.H., Celotta, R.J. and Pierce, D.T., "Scanning Electron Microscopy with Polarization Analysis," (to be published in Rev. Sci. Inst.).

Scheinfein, M.R., Unguris, J., Pierce, D.T. and Celotta, R.J., "High Spatial Resolution Quantitative Micromagnetics," (to be published in Journal of Applied Physics).

Slaughter, J.M, Burkland, M.K., Kearney, P.A., Lampis, A.R., Milanovic, Z., Schulze, D.W., Falce, C.M., Roberts, J., Kerner, J. and Saloman E.B., "Multilayer mirrors for 182 Å," (to be published in Proceedings Society of Photo-Optical Instrumentation Engineers Symposiums 1160).

Stockbauer, R.L., Robey, S.W., Kurtz, R.L., Mueller, D., Shih, A., Singh, A.K., Toth, L. and Ogofsky, M., "Resonant Photoemission and Chemisorption Studies of Tl-Bu-Ca-Cu-O," (to be published in AIP Conference Proceedings of AVS Topical Conference on Thin Film Processing and Characterization of High-Temperature Superconductors).

Stroscio, J.A., First, P.N., Dragoset, R.A., Whitman, L.J., Pierce, D.T. and Celotta, R.J., "Dispersion of Evanescent Band Gap States in Fe Clusters on GaAs(110)," J. Vac. Sci. Tech. (in press).

Unguris, J., Scheinfein, M.R., Celotta, R.J. and Pierce, D.T., "Scanning Electron Microscopy with Polarization Analysis Studies of Magnetic Microstructure," (book chapter to be published in Chemistry and Physics of Solid Surfaces VIII, Springer-Verlag).

VII. TECHNICAL PRESENTATIONS BY STAFF MEMBERS

A. Invited Talks

Callcott, T.A. and Ederer, D.L., "A Transmission Monochromotor for the VUV Light Source of NSLS," Conference for the Industrial Application of Accelerators, Denton, TX, November 9, 1988.

Celotta, R.J., "Scanning Tunneling Microscopy," American Physical Society, St. Louis, MO, March 21, 1989.

Celotta, R.J., "Magnetic Microstructure," Naval Research Laboratory, Washington, DC, March 2, 1989.

Celotta, R.J., "Magnetic Microstructure," University of Indiana, Bloomington, IND, Feb. 15, 1989.

Celotta, R.J., "Atoms and Surfaces as Observed with Polarized Electrons," Johns Hopkins University, Baltimore, MD, October 10, 1989.

Clark, C.W., "High Harmonic Generation in Hydrogenic Ions," International Laser Science Conference, Atlanta, GA, Oct. 3, 1988.

Clark, C.W., "Weak-Field Limits and Asymptotic Behavior," North Atlantic Treaty Organization Advanced Study Institute, Kos, Greece, Oct. 10, 1988.

Clark, C.W., "Atomic Physics in the Solid State: Giant Resonances, Excitons, and High T_c Superconductivity," University of Maryland Baltimore County, Catonsville, MD, Nov. 9, 1988.

Clark, C.W., "Highly Excited Atoms," Twentieth Reunion of the Physics Club of Montgomery College, Takoma Park, MD, Dec. 2, 1988.

Clark, C.W., "Giant Resonances in Electron and Photon Excitation of Atoms," NIST Staff Research Seminar Series, Gaithersburg, MD, February 2, 1989.

Clark, C.W., "High Harmonic Generation in Hydrogenic Ions," X-Ray Laser Group Seminar, Princeton Plasma Physics Laboratory, Princeton, NJ, March 3, 1989.

Clark, C.W., "High Harmonic Generation in Hydrogen Ions: Comparison of Perturbative and Non-Perturbative Calculations," University of Rochester, Rochester, NY, June 29, 1989.

Clark, C.W., "Photoabsorption and Electron Energy Loss Spectroscopy of $YBa_2Cu_3O_{7-x}$," Fifth NIST Superconductivity Information Exchange Meeting, Boulder, CO, September 21, 1989.

Dragoset, R.A., "High-resolution Scanning Tunneling Microscopy: Metal Clusters and Thin Films on Gallium Arsenide," Symposium for Innovation in Measurement Science '89, Hobart & William Smith Colleges, Geneva, NY, August 8, 1989.

Ederer, D.L. and Callcott, T.A., "Photon In Photon Out Spectroscopy," Sixth Synchrotron Radiation Conference, Lawrence Berkeley Labs, Berkeley, CA, August 4, 1989.

Ederer, D.L., "Roentgen's Serendipity or Fun With Soft X-Rays," New England Section Meeting of American Physics Society, Wesleyan University, Middletown, CT, April 7, 1989.

First, P.N., "Scanning Tunneling Microscopy of Metals on Semiconductor Surfaces," Physics Department Colloquium, University of Tennessee, Knoxville, TN, October 24, 1989.

First, P.N., "Scanning Tunneling Microscopy of Metals on Semiconductor Surfaces," Physics Dept. Colloquium, Georgia Institute of Technology, Atlanta, GA, May 24, 1989.

First, P.N., "Scanning Tunneling Microscopy of Metals on Semiconductor Surfaces," Solid State Seminar, Brown University, Providence, RI, February 28, 1989.

Hart, M.W., "Spin-Polarized Inverse Photoemission Study of Ultrathin Co Films on Cu(111)," American Physical Society Meeting, St. Louis, MO, March 20, 1989.

Hughey, L.R, "Record Capture and Acceleration Efficiency in the SURF-II 300 MeV Circular Storage Ring," 1989 Particle Accelerator Conference, Chicago, IL, March 21, 1989.

Kelley, M.H., "Spin Polarization, Orientation, and Alignment in Electron-Atom Scattering," XVI ICPEAC Conference, New York, NY, July 26, 1989.

Kelley, M.H., "Vector Imaging of Magnetic Microstructure," 1989 Microbeam Analysis Society Meeting, Asheville, NC, July 18, 1989.

Kelley, M.H., "Measuring the Shapes of Atoms," Sigma Xi Lecture, National Institute of Standards and Technology, Gaithersburg, MD, March 21, 1989.

Kelley, M.H., "Electron-Atom Collision Studies Using Optically State-Selected Beams," NIST Staff Research Seminar, National Institute of Standards and Technology, Gaithersburg, MD, February 2, 1989.

Lett, P.D., "Laser Cooling, Optical Molasses and the Coldest Gas in the Universe," Electrical Engineering Department, University of Wisconsin, Madison, WI, February 23, 1989.

Lett, P.D., "Observation of Atoms Laser-Cooled Below the Doppler Limit," Optical Society of America Annual Meeting, Santa Clara, CA, November 4, 1989.

Lett, P.D., "Laser Cooling, Optical Molasses and the Coldest Gas in the Universe," Physics Department, Marquette University, Milwaukee, WI, February 24, 1989.

Lett, P.D., "Laser Cooling to MicroKelvin Temperatures," Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, March 10, 1989.

Madden, R.P., "SURF-II Progress and Opportunities," Conference on Synchrotron Radiation Instrumentation, Berkeley, CA, August 4, 1989.

Madden, R.P., "UV-VUV Radiometry at NIST," Committee on Optical Radiation Measurements (CORM) Meeting, NIST, Gaithersburg, MD, May 19, 1989.

McClelland, J.J., "Progress on Spin Detectors and Spin-Polarized Electron Scattering from Na at NIST," Fifth International Symposium on Polarization and Correlation in Electronic and Atomic Collisions, Hoboken, NJ, August 2, 1989.

Ott, W.R., "Radiometry at NIST," Arnold Engineering Defense Center, Nashville, TN. February 14, 1989.

Pan, L., "Treatment of Continuum-Continuum Coupling in the Theoretical Study of ATI," North Atlantic Treaty Organization Advanced Study Institute, Kos, Greece, Oct. 10, 1988.

Pan, L., "Computation of High-Order Multiphoton Processes in Atomic Hydrogen," Royal Holloway and Bedford New College, Univ. of London, Egham, Surrey, England, March 31, 1989.

Pan, L., "Computation of High-Order Multiphoton Processes in Atomic Hydrogen," Theoretical seminar, JILA, University of Colorado, Boulder, CO, June 15, 1989.

Pan, L., "High Harmonic Generation in Hydrogenic Ions," Atomic Physics Seminar, The Johns Hopkins University, Baltimore, MD, Dec. 2, 1988.

Penn, D.R., "Total Dielectric Function, Algebraic Sign and Superconductivity," Fifth NIST Superconductivity Information Exchange Meeting, Boulder, CO. September 20, 1989.

Penn, D.R., "Total Dielectric Function, Algebraic Sign, Electron-Lattice Response, and Superconductivity," University of CA at Berkeley, Berkeley, CA, May 29, 1989.

Penn, D.R., "Electron Correlations in High T_c Materials," Visiting Committee on Advanced Technology, NIST Boulder, Boulder, CO, May 2, 1989.

Pierce, D.T., "Surface Magnetic Microstructure," Seventh International Conference on Solid Surface, Cologne, West Germany, September 25, 1989.

Pierce, D.T., "Imaging Magnetic Microstructure with High Spatial Resolution," International Workshop on Monolayer Magnetism, Berkeley Springs, WV, August 15, 1989.

Pierce, D.T., "High Resolution Imaging of Magnetic Microstructure in Thin Magnetic Layers," American Vacuum Society, Murray Hill, NJ, June 14, 1989.

Pierce, D.T., "Magnetic Microstructure of Thin Films and Surfaces: Exploiting Spin-Polarized Electrons in the SEM and STM," Materials Research Society Symposia, San Diego, CA, April 28, 1989.

Pierce, D.T., "Surface Magnetic Microstructure," 2nd International Workshop on Magnetism in Low-Dimensional Systems, San Luis Potosi, Mexico, May 22, 1989.

Pierce, D.T., "Probing Magnetic Microstructure on the Nanometer Scale," American Vacuum Society 35th National Vacuum Symposium and Topical Conference, Atlanta, GA, October 4, 1988.

Saloman, E.B., Inn, G.W. and Lucatorto, T.B., "Data and Standard Reference Materials for Ultrasensitive Analysis," Workshop on Advanced Laser Technology for Chemical Measurements, Argonne National Laboratory, Argonne, IL, May 9, 1989.

Saloman, E.B., "Current Status of RIS/RIMS Data Project and RIS/RIMS Data Sheets," Poster presentation to Department of Energy Onsite Review Panel on OHER Funded Projects at NIST, Gaithersburg, MD, February 9, 1989.

Scheinfein, M.R., "Surface Magnetic Microstructure Using SEMPA," Symposium Eastman Kodak Research Lab., Rochester, NY, July 18, 1989.

Scheinfein, M.R., "Scanning Electron Microscopy with Polarization Analysis," Symposium, Cornell University, Ithaca, NY, June 9, 1989.

Scheinfein, M.R., "Surface Magnetic Microstructure," 2nd International Workshop on Magnetism in Low-Dimensional Systems, San Luis Potosi, Mexico, May 22, 1989.

Scheinfein, M.R., "Observation of the Surface Domain Structure of an hcp (0001) Co Crystal," American Physical Society Meeting, St. Louis, MO, March 21, 1989.

Stroscio, J.A., "Scanning Tunneling Microscopy of Small Metal Structures on GaAs(110)," International STM '89 Meeting, Oarai, Japan, July 9, 1989.

Stroscio, J.A., "Scanning Tunneling Microscopy of Metal Clusters on GaAs(110)," Electrotechnical Laboratory, Tsukuba, Japan, July 18, 1989.

Stroscio, J.A., "Scanning Tunneling Microscopy of Metal Atom Structures on GaAs(110) Surfaces," Institute for Solid State Physics, Tokyo, Japan, July 17, 1989.

Stroscio, J.A., "Scanning Tunneling Microscopy of Small Metal Particles," Condensed Matter Physics Seminar, College Park, MD, April 13, 1989.

Unguris, J., "SEM with Polarization Analysis: Studies of Magnetic Microstructure," International Summer Institute on Surface Science, Milwaukee, WI, August 21, 1989.

Unguris, J., "Magnetic Microstructure Imaging Using Spin-Polarized SEM," Western Pennsylvania Chapter of the American Vacuum Society, Pittsburgh, PA, June 28, 1989.

Unguris, J., "Scanning Electron Microscopy with Polarization Analysis Tutorial," International Magnetics Conference, Washington, DC, March 29, 1989.

B. Contributed Talks

Buckman, S.J., McClelland, J.J., Kelley, M.H. and Celotta, R.J., "Spin-Polarized Electron Scattering from Optically Pumped Sodium at 20 eV," contributed poster to ICPEAC XVI, New York, NY, July 26, 1989.

Clark, C.W., "Ditriakontapole Excitation in High-Temperature Superconductors," NIST Surface Science Lunch Bunch, NIST, Gaithersburg, MD, September 11, 1989.

Clark, C.W., "The Frequency-Dependent Polarizability of an Electron Bound by a Zero-Range Potential in N Dimensions," Conference on Super-Intense Laser-Atom Physics, University of Rochester, Rochester, NY, June 30, 1989.

Clark, C.W., "The Frequency-Dependent Polarizability of an Electron Bound by a Zero-Range Potential in N Dimensions," Gordon Conference on Atomic Physics, Brewster Academy, Wolfeboro, NH, July 5, 1989.

Clark, C.W., "Electron-Excited $4d \rightarrow 4f$ Resonances in $YBa_2Cu_3O_{7-x}$: Selection Rules at Intermediate Electron Energy," Gordon Conference on Atomic Physics, Brewster Academy, Wolfeboro, NH, July 6, 1989.

Clark, C.W., "A Fish Tale," NIST Laser Lunch Bunch, NIST, Gaithersburg, MD, February 23, 1989.

Clark, C.W., "Macintosh - PC Connectivity Issues," NIST Laboratory Computer Users' Group, NIST, Gaithersburg, MD, December 7, 1988.

Costello, J., Kennedy, E.T., Sonntag, B.F. and Clark, C.W., "The 3p Photoabsorption Spectra of Cr and Cr^+," XVI ICPEAC Meeting, New York, NY, July 26, 1989.

Ederer, D.L., Mueller, D.R., Wallace, J., Clark, C.W., Zhang, C.H., Jai, J., Callcott, T.A., Rubensson, J.E. and Shuker, R., "Soft X-Ray Emission and the Electronic Structure of BiSrCaCuO," Ninth International Conference on Vacuum Ultraviolet Radiation Physics, Honolulu, HI, July 16, 1989.

First, P.N., Stroscio, J.A., Dragoset, R.A., Pierce, D.T. and Celotta, R.J., "Characterization of Epitaxial Fe on GaAs(110) by Scanning Tunneling Microscopy," Materials Research Society Meeting, San Diego, CA, April 28, 1989.

First, P.N., Stroscio, J.A., Dragoset, R.A., Pierce, D.T. and Celotta, R.J., "Scanning Tunneling Microscopy of Nanometer-Size Fe Clusters on GaAs(110)," American Physical Society Meeting, St. Louis, MO, March 21, 1989.

First, P.N., Stroscio, J.A., Dragoset, R.A., Pierce, D.T. and Celotta, R.J., "Onset of Metallicity in Fe Nano-Particles on GaAs(110)," 16th Annual Conference on the Physics and Chemistry of Semiconductor Interfaces, Bozeman, MT, February 9, 1989.

Gadzuk, J.W., Clark, C.W., Hoffman, A., Guo, X. and Yates, J.T. Jr., "Shape-Resonance-Enhanced Electron Stimulated Desorption," American Physical Society Meeting, St. Louis, MO, March 20, 1989.

Lett, P., "Observation of Atoms Laser-Cooled Below the Doppler Limit," International Laser Science Conference, Atlanta, GA, October 6, 1989.

Lett, P., "Heterodyne Spectrum of the Fluorescence From Optical Molasses," Sixth International Conference on Coherence and Quantum Optics, Rochester, NY, June 27, 1989.

McClelland, J.J., Kelley, M.H., Buckman, S.J. and Celotta, R.J., "Search for a Joint Spin-orbit and Exchange Asymmetry in Elastic Electron Scattering from Sodium," contributed poster to ICPEAC XVI, New York, NY, July 27, 1989.

McClelland, J.J., Scheinfein, M.R. and Pierce, D.T., "Increased Sherman Function in Electron Spin Analyzers Using a Bulk Thorium Target," contributed poster to ICPEAC XVI, New York, NY, July 28, 1989.

McClelland, J.J., Kelley, M.H. and Celotta, R.J., "Superelastic Scattering of Spin-polarized Electrons From Sodium Atoms," 41st Annual Gaseous Electronics Conference, Minneapolis, MN, October 18, 1988.

Pan, L., Clark, C.W., and Taylor, K.T., "High Harmonic Generation in Hydrogen Ions," Annual Meeting of the APS/Division of Atomic, Molecular and Optical Physics, Windsor, Ontario, CAN, May 18, 1989.

Pan, L., "The Volkov-like Coulomb Continuum," Annual Meeting of the APS/Division of Atomic, Molecular and Optical Physics, Windsor, Ontario, CAN, May 19, 1989.

Pan, L., "The Coulomb-Volkov State and Its Application in the Study of Multiphoton Ionization," Conference on Super-Intense Laser-Atom Physics, University of Rochester, Rochester, NY, June 29, 1989.

Pan, L., "The Coulomb-Volkov State and Its Application in the Study of Multiphoton Ionization," Gordon Research Conference on Atomic Physics, Brewster Academy, Wolfeboro, NH, July 6, 1989.

Pan, L., Clark, C.W. and Taylor, K.T., "The Frequency Dependence of the Complex Dynamic Hyperpolarizability," XVI ICPEAC Meeting, New York, NY, July 26, 1989.

Ramsey, M.G., Netzer, F.P., Matthew, J.A.D. and Clark, C.W., "Electron-Excited 4d → 4f Ba Resonances in $YBa_2Cu_3O_{7-x}$: Selection Rules at Intermediate Energy," XVI ICPEAC Meeting, New York, NY, July 26, 1989.

Smith, M.T., Taylor, K.T. and Clark, C.W., "R-Matrix Theory of Two-Photon Absorption: Application to Carbon," XVI ICPEAC Meeting, New York, NY, July 26, 1989.

Stroscio, J.A., First, P.N., Pierce, D.T., Dragoset, R.A. and Celotta, R.J., "Microstructure of Epitaxial Fe Films on GaAs(110)," American Vacuum Society 35th National Vacuum Symposium and Topical Conference, Atlanta, Ga, October 4, 1988.

Unguris, J., Scheinfein, M.R., Celotta, R.J. and Pierce, D.T., "Scanning Electron Microscopy with Polarization Analysis Studies of Ni-Fe Magnetic Memory Elements," International Magnetics Conference, Washington, DC, March 31, 1989.

VIII. EDITORSHIPS HELD BY STAFF MEMBERS

R.J. Celotta, Series Editor, Methods of Experimental Physics, Academic Press.

C.W. Clark, Topical Editor for Atomic Spectroscopy, Journal of the Optical Society of America B.

K.T. Taylor, M.H. Nayfeh, and C.W. Clark, eds., Atomic Spectra and Collisions in External Fields, (Plenum Publishers, New York, NY, 1989).

IX. SPONSORED SEMINARS AND COLLOQUIA

Bucksbaum, Phillip, Bell Labs, "The Molecular Bond in Intense Fields: Photodissociation of H_2," April 12, 1989.

Buncick, Milan, University of Wisconsin-Madison, "Polymer Applications to the Microelectronics Industry," February 17, 1989.

Carre, Bertrand, IRF, France, "Resonant Photoionization of Excited Sodium, Studied by Laser and Synchrotron Radiation Excitation," August 11, 1989.

Codling, Keith, Reading University, England, "Processes Using Covariant Mapping," April 28, 1989.

Cohen, Marvin L., University of California at Berkeley, "Some Perspectives on High Temperature Superconductivity," May 19, 1989.

Crance, Michele, Laboratoire Aime, France, "Multiphoton Ionization of the Hydrogen Atom in a Strong Field," May 5, 1989.

Della Torre, Edward, George Washington University, "Micromagnetics of Small Particles," October 14, 1988.

Demkov, Yurii, Leningrad State University, "James Clerk Maxwell and the Mendeleev Periodic Table," February 7, 1989.

Eyler, Edward, Yale University, "Precise Laser Spectroscopy of Two-Electron Systems," October 17, 1988.

Fink, Manfred, University of Texas at Austin, "Toward Accurate Measurements of Electron Spin Polarization," October 20, 1988.

Florescu, Viorica, University of Bucharest, "Perturbed Wavefunctions for the Hydrogen Atom in a Uniform Harmonic Electric Field and Applications," September 15, 1989.

Gailite, Erna K., Latvian Academy of Sciences, "Multiphoton Ionization and Above-Threshold Ionization in Hydrogen: Experiment and Theory," September 29, 1989.

Gluskin, Efim S., Institute of Nuclear Physics, Novisibirsk, USSR, "Synchrotron Radiation Research in Novisibirsk, USSR," July 7, 1989.

Kamiya, Itaru, University of Tokyo, "Development of a Field Ion-Scanning Tunneling Microscope and Its Applications," March 30, 1989.

Kennedy, Eugene, N.I.E.D., Dublin, Ireland, "XUV Photoabsorption Studies of Atoms and Ions," September 7, 1989.

Kumar, Vijay, Physical Research Laboratory, Ahmedabad, India, "Atomic Physics at PRL," August 3, 1989.

L'Huillier, Anne L., CEA Saclay, France, "Harmonic Generation in Strong Laser Fields: Influence of Ionization and Propagation," July 24, 1989.

Long, James, Naval Research Lab, "Combined Laser-Synchrotron Radiation Experiments on the NSLS X-ray Ring," February 15, 1989.

Lorentz, Steven, University of Oklahoma, "Low-Energy Electron Scattering on Sodium," August 9, 1989.

Meier, Felix, ETH, Zurich, Switzerland, "Epitaxial Magnetic Films and Laser Induced Photoemission From Fe," August 11, 1989.

Morgan, John D., Harvard University, "Precise Variational Calculations for Atomic Helium," February 17, 1989.

Miller, John C., Oak Ridge National Laboratory, "Nanosecond and Picosecond Multiphoton Ionization of Weakly Bound Molecules," March 16, 1989.

Nicolaides, Cleanthes, National Hellenic Research Foundation, Athens, Greece, "Many-Electron, Many-Photon Theory of Atoms in Strong Fields," December 15, 1988.

Puntajer, Anna K., University of Innsbruck, Austria, "Asymmetries in Intense Laser-Free Electron Scattering," October 3, 1988.

Rife, Jack C., Naval Research Lab, "Soft X-ray, Multilayer-Coated Gratings -- Performance and Applications," March 29, 1989.

Standage, Max C., Griffith University, Brisbane, Australia, "Electron-Photon Coincidence Experiments Using Laser Excitation Techniques," April 3, 1989.

Sundaram, Bala, Johns Hopkins University, "Localization Theory for RF Floquet States," January 24, 1989.

Taylor, Kenneth, Royal Holloway and Bedford New College, Surrey, England, "Rydberg States of Molecular Hydrogen in a Magnetic Field," December 16, 1989.

Tonner, Brian P., University of Wisconsin-Milwaukee, "Photoemission Microscopy of Surfaces Using Synchrotron Radiation," February 13, 1989.

Walker, J.C., Johns Hopkins University, "Inter-Layer Interaction in Magnetic Superlattices," April 17, 1989.

Weiss, Paul S., Pennsylvania State University, "Tunneling Scanning Microscopy at 4K," June 21, 1989.

Williams, J.F., University of Western Australia, "(e,2e) Coincidence Studies of Atomic Hydrogen," October 26, 1988.

Wong, Tamae M., University of Pennsylvania, "The Electronic Structure of Cs/GaAs and GaAs," September 22, 1989.

Wuilleumier, Francois, Laboratoire Pour l'Utilization du Rayonnement Electromagnetique, Orsay, France, "New Facilities for Atomic Physics at Super ACO," October 28, 1989.

X. TECHNICAL AND PROFESSIONAL COMMITTEE PARTICIPATION AND LEADERSHIP

Robert J. Celotta

Member, General Committee, International Conference on the Physics of Electronic and Atomic Collisions.

Charles W. Clark

Chairman, National Academy of Sciences/National Research Council Committee on Line Spectra on the Elements - Atomic Spectroscopy.

Co-Director, NATO Advanced Study Institute, "Atoms in Strong Fields."

Co-Chairman, Conference on Lasers in Science and Technology, Amman, Jordan.

David L. Ederer

Organized a session on the industrial and scientific application of third generation synchrotron radiation facilities at the Conference for the Industrial Application of Accelerators, Denton, TX, October 1988.

Program Committee for the 6th Synchrotron Radiation Conference, Lawrence Berkeley Labs, August 1989.

Lanny R. Hughey

Member, Design Review Board for Title I Design of the Vacuum System of the Argonne National Laboratory Advanced Photon Source 7 GeV Electron Storage Ring.

Thomas B. Lucatorto

Co-chairman, 1989 International Conference on the Physics of Electron and Atomic Collisions (ICPEAC XVI).

Member, Program Committee, 5th International Symposium on Resonance Ionization Spectroscopy and Its Applications, 1990.

Robert P. Madden

Member, Optical Society of America Nominating Committee.

Member, Calibration and Stability Working Group of the Ozone Trends Panel.

Coordinator, International Radiometric Intercomparison of Solar Irradiance Monitoring Experiments.

Member, International Committee for the International Conference on Vacuum Ultraviolet Radiation Physics.

Member, Council of U.S. Synchrotron Radiation Laboratory Directors.

Member, International Committee of the International Conference on X-Ray and VUV Synchrotron Radiation Instrumentation.

Member, DARPA Advisory Committee for Oversight of the Development of a Synchrotron Source for Lithography.

Member, NSLS Program Advisory Committee at Brookhaven National Laboratories.

Member, Advisory Committee for the U.S. National Synchrotron Radiation Instrumentation Conference.

William R. Ott

Member, DoD Panel on Optics Technology Applications, October 1989.

DoD Liaison, SDI-Related Metrology at NIST.

Daniel T. Pierce

Member, Editorial Board, Journal of Electron Spectroscopy.

Program Committee and International Advisory Committee, Fourth International Conference on Electron Spectroscopy, Honolulu, Hawaii, July 10-14, 1989.

XI. MAJOR CONSULTING AND ADVISORY SERVICES

L.R. Canfield advised and consulted with numerous people from industry, academia and Government agencies on applications of detectors and standard detectors in the far ultraviolet.

L.R. Canfield consulted with Raj Korde of the United Detector Technology on matters involving semiconductor photodiodes in the far ultraviolet.

L.R. Canfield consulted with H. Ogawa and D. Judge concerning narrow-bandpass detector systems for solar flux determinations in rocket flight experiments.

R.J. Celotta and D.T. Pierce consulted on the production and detection of polarized electrons with researchers from Brookhaven, AT&T Bell Labs, Bell Communications Corporation, University of Texas, MIT, Argonne National Laboratory, Perkin Elmer Corporation, and the Naval Research Laboratory.

C.W. Clark advised the X-ray Laser Group at Princeton Plasma Physics Laboratory on atomic physics problems associated with x-ray laser development.

D.L. Ederer consulted with Rupert Perera at Lawrence Berkeley Labs in the study of property of multi-layers.

D.L. Ederer consulted with staff at Bell-Corp. to obtain thin film superconductors.

L.R. Hughey consulted with Design Review Board for Title I design of the Vacuum System at the Argonne National Laboratories.

R.P. Madden consulted for NASA by serving on the "Spacecraft Instrument Calibration and Stability" Working Group of the "Ozone Trends Panel" contributing to the report to Congress entitled "Present State of Knowledge of the Upper Atmosphere 1988: An Assessment Report" as required under the Clean Air Act Amendments of 1987. Public Law 95-95.

R.P. Madden, at the request of the Director of the Earth Science and Applications Division of the Office of Space Science and Applications, NASA, is coordinating an international round-robin intercomparison of solar irradiance monitoring space experiments.

R.P. Madden is on the Defense Advanced Research Projects Agency (DARPA) Advisory Committee for the Brookhaven X-ray Lithography Synchrotron Source Program.

R.P. Madden is on the Program Review Committee for the Brookhaven National Laboratory (BNL) National Synchrotron Light Source.

W.R. Ott consulted with staff from the Lawrence Livermore Labs, Lawrence Berkeley Labs, U. Arizona, Lockheed, and AT&T Bell Labs on XUV optical properties of multilayer devices and measurement services and research opportunities available at NIST/SURF-II.

W.R. Ott consulted with staff at the Arnold Engineering Development Center, Tennessee, on radiation measurements involving infrared, ultraviolet, and soft x-ray radiation.

W.R. Ott participated in a DoD review panel on Optics Technology Applications.

XII. SPONSORED WORKSHOPS

C.W. Clark was co-director of a NATO Advanced Study Institute, "Atoms in Strong Fields," Kos, Greece, October 9-21, 1988.

R.A. Dragoset organized and chaired the Surface Analysis session of the Symposium for Innovation in Measurement Science '89, Hobart and William Smith Colleges, Geneva, NY, August 8, 1989.

M.H. Kelley organized, jointly with Kurt Becker of City College of New York and Paul Neill of University of Nevada-Reno, the 5th International Symposium on Polarization and Correlation in Electronic and Atomic Collisions, Stevens Institute of Technology, Hoboken, NJ, August 2-4, 1989.

T.B. Lucatorto organized and chaired the Research Advisory Committee Symposium on Gas Phase Pump and Probe Experiments, NIST, Gaithersburg, MD, February 10, 1989.

D.T. Pierce was co-chair (with Prof. Leo Falicov, Department of Physics, University of California, Berkeley) of Department of Energy Council on Materials Sciences Panel On "Surface, Interface and Thin-Film Magnetism," Santa Fe, NM, June 18-21, 1989.

J. Unguris organized the Scanning Electron Microscopy with Polarization Analysis workshop at the International Magnetics Conference, Washington, DC, March 29, 1989.

NIST-114A
(REV. 3-89)

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

BIBLIOGRAPHIC DATA SHEET

1. PUBLICATION OR REPORT NUMBER
NISTIR 90-4287

2. PERFORMING ORGANIZATION REPORT NUMBER

3. PUBLICATION DATE
APRIL 1990

4. TITLE AND SUBTITLE
Technical Activities 1989
Electron and Optical Physics Division

5. AUTHOR(S)
Charles W. Clark

6. PERFORMING ORGANIZATION (IF JOINT OR OTHER THAN NIST, SEE INSTRUCTIONS)
U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
GAITHERSBURG, MD 20899

7. CONTRACT/GRANT NUMBER

8. TYPE OF REPORT AND PERIOD COVERED

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (STREET, CITY, STATE, ZIP)
Electron and Optical Physics Division
Center for Atomic, Molecular and Optical Physics
National Measurement Laboratory
NIST
Gaithersburg, Md.

10. SUPPLEMENTARY NOTES

☐ DOCUMENT DESCRIBES A COMPUTER PROGRAM; SF-185, FIPS SOFTWARE SUMMARY, IS ATTACHED.

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

This report summarizes technical activities of the NIST Electron and Optical Physics Division during Fiscal Year 1989. These fall into five general areas: soft x-ray radiometry, operation of the SURF-II synchrotron storage ring; electron microscopy and basic surface physics; soft x-ray emission studies; and multiphoton processes. A listing is given of calibration services, publications, talks, and other relevant activities of the Division's staff.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)
electron physics; multi-photon processes; optical physics; SEMPA, scanning tunneling microscopy; synchrotron radiation.

13. AVAILABILITY
[X] UNLIMITED
[ ] FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NATIONAL TECHNICAL INFORMATION SERVICE (NTIS).
[ ] ORDER FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, DC 20402.
[X] ORDER FROM NATIONAL TECHNICAL INFORMATION SERVICE (NTIS), SPRINGFIELD, VA 22161.

14. NUMBER OF PRINTED PAGES
55

15. PRICE
A04

ELECTRONIC FORM