8. Doctoral Program and Graduate Research

by Raymond H. Hughes and Paul C. Sharrah

First Doctoral Programs

Under the Presidency of Lewis Webster Jones in 1949 it was determined that it was time to initiate doctoral programs within the graduate school. (Ref. 3, p. 233)

The newly appointed graduate dean, Dr. Virgil W. Adkisson, was instructed to proceed carefully but ambitiously with this program. The departments, as a starter, were to offer a better selection of advanced undergraduate courses as deemed appropriate! Physics, for example, decided in the early 1950's, to require a thesis for the M.S. degrees as a part of this effort to strengthen the departmental program.

Virgil W. Adkisson, Graduate Dean when the expansion into Ph.D. programs took place principally in the 1950s and 1960s.

The first thing Dr. Adkisson did was to visit a number of graduate programs both regionally and nationally seeking to ascertain what the move into offering doctoral work would entail. A graduate affairs committee of broad representation within the university was appointed as a study and advisory group to the dean.

The first doctoral programs were initiated in 1950-51. These were in biochemistry (at the Medical Center), education, chemistry, economics, English, history (discontinued in 1952), and philosophy. Physiology and pharmacology were approved later.

Physics was one of the departments approved for a doctoral program in 1959 as a part of a second group of programs. These included animal sciences, botany and bacteriology, comparative literature, physics, psychology, zoology, and engineering. In the next few years doctoral programs were approved also for business administration, agronomy, anatomy, microbiology, instrumental sciences (at the Graduate Institute of Technology in Little Rock), and mathematics.

A third significant expansion was authorized in 1970. These programs were history, plant pathology, and entomology. These last two programs were implemented after reaccreditation and improved funding had been provided.

The graduate school enrollment in 1948 had been 272 students (Ref. 2, p. 159) but had risen to 1,659 by spring 1971 (Ref. 3, p. 234). By fall 1993 there were a total of about 35 clearly defined doctoral programs on the Fayetteville campus and a graduate school enrollment figure of 2,150 students. (Information courtesy Professor David W. Hart, Associate Dean, Graduate School.) Forty-four years of progress since that day in 1949 when it was decided to develop doctoral programs!

Physics Proposal

The Ph.D. program in physics was approved in 1959 even though the manpower and research support and other visible assets in physics were quite limited. There were only four active members of the physics faculty: C. Y. Fan, R. H. Hughes, H. M. Schwartz, and P. C. Sharrah. About all that could be said for the department was that there was a strong desire to succeed!

Of course it seemed necessary for the major University in the State to go that route, but this fact alone was not sufficient. Considerable work had to be done by the University and especially the physics faculty!

A few details concerning the physics doctoral proposal and the process of gaining its approval are in order here.

The proposal was submitted by the Physics Department to the Graduate School in 1958. The graduate dean and the graduate council, after a private session, sent the proposal back for certain clarification of points and rewriting by its principal author, Professor R. H. Hughes.

The chairman of physics, Professor Paul C. Sharrah, was called to another meeting of the graduate council in the graduate dean's office. Arts and Sciences Dean Guerdon D. Nichols was also brought in for this conference.

One of the members of the graduate council leaned over to Sharrah and whispered, "I know why you are so calm and self-confident. You know that we are going to approve your proposal ultimately". Suddenly Sharrah was calm and self-confident.

At one point, after about thirty minutes of discussion, Graduate Dean Adkisson turned abruptly to Dean Nichols and said, "If we decide to give the go ahead to physics, will you give them your complete backing?" Dean Nichols looked at Sharrah and said quietly but sincerely, "Yes."

Dean Adkisson and Associate Dean Aubrey Harvey came to the department to talk directly with the physics faculty. The meeting was in Room 1, the only air-conditioned classroom in the physics building. The meeting was short, only about thirty minutes. We were becoming rather self-conscious and even apologetic about our obvious limitations. But it was Dean Adkisson who volunteered that we would be given approval to proceed because there was a clear unanimous desire on the part of the department to go ahead.

The doctoral program in physics was approved in 1959 with the stipulation that the department obtain NDEA (National Defense Education Act) Title IV fellowships to support the doctoral program. These Federally funded four-year fellowships gave the student a stipend comparable to an assistantship and a monetary supplement to the department to support the student's research effort.

The Ph.D. program was fortunate to be born in the early post-Sputnik era (the Russian Sputnik went into orbit in 1957) when Congressional cold-war concern over possible Russian scientific and technological dominance led to a Federal push to develop graduate programs in science and engineering. Neither the university nor the physics department had the resources to begin the Ph.D. program; hence, the stipulation by the Graduate School to obtain the fellowships was most relevant.

Proposals were written promptly for the NDEA Title IV fellowships. Four were provided by the initial proposal. These fellowships were to be a vital part of the physics programs for the next several years. Many of these NDEA Title IV fellows are teaching in various colleges and universities today. This was the goal of that program.

Two other Federal fellowship programs soon became available. These programs provided NSF Traineeships and NASA Traineeships; funded by the National Science Foundation and the National Aeronautics and Space Administration respectively. These new programs forced the departments to compete with each other University wide for these fellowships. These two programs, like NDEA Title IV, also supported the student's research programs as well as providing their stipends.

A one-time grant from the Baldwin Piano Company came at a propitious moment in the early 1960's and made possible the purchase of certain critical items. One such item was a helium vacuum leak detector.

Thus these three fellowship programs not only provided critical funds to assist the department to develop the doctoral program but also made it possible to attract promising students into the new graduate program. These special fellowship programs became less critical when reasonable research grant funding became available in physics. The funding of the graduate students on research assistantships supplemented by teaching assistantships became fairly adequate.

Program Evolves

The creation of the Ph.D. program in 1959, under the energetic stewardship of Prof. Hughes, led to the first Ph.D. graduate in 1964 (William R. Pendleton). This together with a growth in faculty led to the creation of a number of new graduate courses: Goldstein-level Advanced Mechanics, Jackson-level Electrodynamics (two semesters), Statistical Mechanics, Mathematical Methods of Physics, and several post-quantum mechanics courses: Advanced Quantum Theory (two semesters), Solid State Physics, and Atomic and Molecular Physics. Actually, an undergraduate course in Solid State Physics was created in the 1950s, and was taught through the 60s by Prof. Day, using the text by Kittel which first appeared in 1953. This course was dropped when the graduate course was put in its place. With the arrival of Prof. Salamo in 1975 and subsequent quantum opticians, courses in Quantum Optics, Laser Physics (and lab), and Optical Prop-erties of Solids were added, bringing the graduate program to essentially its present state.

The original physics Ph.D. program initiated in 1959 was modeled principally after the University of Wisconsin plan since the principal author was a recent Wisconsin graduate. The program initially made the Master of Science degree an integral part of the Ph.D. program. The M.S. degree was a serious research degree, requiring a Master's thesis. It was expected that the student would take a written Master's examination at the end of the second semester of graduate study. The student had two opportunities to pass the Master's examination.

The student also had to pass a preliminary doctoral written and an oral examination as well as his final dissertation oral. It was expected that the student would take the doctoral preliminary examination no later than the end of the sixth semester of study. The student had two opportunities to pass the preliminary examination also.

The doctoral requirement included passing examinations in two foreign languages conducted by the respective language department. For several decades in this century the science doctoral programs in the United States required a European language prominent in science and research. Thus students in physics studied German and French, and sometimes Italian and sometimes Russian. The 1971 physics program at the University of Arkansas required a reading knowledge of German and French.

But by the second half of the twentieth century physics and the other sciences had become stronger in the United States and most of the relevant publications were in English. Thus the foreign language requirements were being relaxed. For a brief time, a computer language would be approved in place of one of the foreign languages! By 1975 the Ph.D. candidates in physics at the University of Arkansas no longer had a foreign language requirement.

The two examination system, master's and doctoral preliminary examinations, quickly evolved to a single examination, a preliminary examination only for the doctoral candidates. Thus the master's degree lost its role as a stepping stone to the Ph.D. degree and at the present time essentially all Ph.D. students at Arkansas by-pass the master's degree.

The first Ph.D. degree in physics was granted in 1964 under the direction of Dr. R. H. Hughes.

Faculty Recruitment

One significant potential advantage gained with the introduction of the Ph.D. program was the ability to interest better qualified young Ph.D.s to apply for a position at Arkansas and to retain some of the qualified physics faculty already here. We had already lost Brenton Stearns and Berol Robinson, two very competent young physicists! Dr. Stearns went to Tufts University and Dr. Robinson went to Case-Western Reserve and eventually to UNESCO (United Nations Scientific and Cultural Organization) in Paris, France. We lost Z. V. Harvalik to the Ft. Belvoir Army Research Center. We kept R. H. Hughes and H. M. Schwartz. We kept Paul Sharrah; otherwise, he probably would have moved to Oak Ridge permanently to do neutron diffraction re-search on structure and momentum distribution studies!

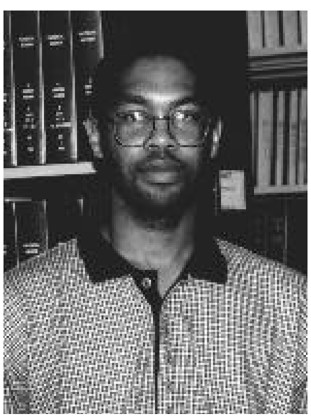
However faculty recruitment was still difficult because in the 1960's there was a shortage of applicants nationwide and the effort required to build up the faculty, as indicated above, was demanding, to say the least. One or two of the faculty, Sharrah and sometimes Hughes, or sometimes Schwartz, or Zinke would attend the national combined meeting of the American Physical Society and the American Association of Physics Teachers in New York every January. We would work continuously at the placement service room for the two or three days.

This was a very large and active meeting in those days. This effort would be repeated almost every spring at the American Physical Society meeting in Washington, D. C. More than once the airplane fare and personal expenses were the responsibility of the chairman; although we were usually reimbursed. To quote one of the presidential candidates in 1992, "it was a dirty job but someone had to do it."

But even with this gallant effort we returned more than once from one of these meetings with not a single serious applicant. It wasn't all perfect! After returning to the campus, many letters were written to departments and to new Ph.D.s and many telephone calls were made. Likely candidates were brought in for an interview and we always got at least one colloquium presentation from them!

Charles E., Jones employ-ed in 1962.

Even though there frequently was a critical need to hire more faculty to adequately man the teaching as well as develop the doctoral program, there was a sincere effort only to fill the positions with physics faculty of promise. Sharrah tells how the teaching assignments were very much on the increase after the Korean War and the department didn't know how it would teach all the classes one January. A man with less than average credentials stood there in New York and begged permission to get on the train with him and come to Fayetteville to teach that January. That is just the opposite condition now where many inquiries and applications from above average individuals result following the announcement of an opening in physics.



Dr. Michael Henry initiated a research program in the fall of 1995.

During the first ten years of the Ph.D. program we hired, in fairly rapid sequence, O. H. Zinke, G. T. Clayton, S. M. Day, C. E. Jones, A. S. Hob-son, C. B. Richardson, R. J. Anderson, F. T. Chan, and Michael Lieber.

Interestingly enough, most of the above individuals were employed as a result of information obtained through other contacts not directly related to the APS placement service! S. M Day, for example, applied from Rice University after Sharrah, almost belligerently on the telephone, asked the head of physics there, Prof. Bonner, if they produced any physics Ph.D.'s with an interest in and appreciation of teaching! One earlier applicant from Rice had clearly come on the interview just for a free trip!

The next ten years brought Carol J. Webb, D. O. Pederson, G. J. Salamo, Rajendra Gupta, Claud H. Lacy, and P. W. Milonni.

Since 1980 the new faculty additions have been S. P. Singh, Larry S. Merkle, Howard J. Carmichael, W. M. Harter, A. M. Hermann, Reeta Vyas, Z. Z. Sheng, Urbano Oseguera, Min Xiao, Julio Gea-Bana-cloche, William F. Oliver III, J. Brad Shue, Gay Stewart, and Mark E. Filipkowski. Dr. Michael Henry of Alabama A. & M. joined the faculty August, 1995, and is doing research in optics.

Thus the faculty has increased in size from the typical number of three or four during the 1930's up through the 1950's to twelve in 1969 and fifteen in 1993 and 18 in 1995. There were only five on the faculty in 1959, when the Ph.D. program in physics was started, including one who devoted all his time to teaching and directing the elementary laboratory! Some of this information is summarized in the Appendices.

Graduate Students

The graduate student enrollment was to increase also beginning in 1959 with the initiation of the Ph.D. program in physics. During the early and middle 1950's there would typically be four or five graduate students pursuing a master's in physics at any given time. The number of graduate students in physics grew to over ten by the early 1960's and continued to increase slowly to a total of twenty-four by 1981 and to over forty by 1995!

In the early years of the doctoral program, there would be at least three and as many as six graduate students on one of the three fellowships described above. There would also be six or eight teaching assistants and three or four on research assistantships.

Sometimes the research and teaching assistantship assignments were combined for students who expressed a strong desire to become teachers. Most of the graduate students on the NDEA Title IV Fellowships served at least one year, usually the last year, as classroom assistants. They attended all of the lectures in one of the large introductory sections, usually University Physics, assisted in taking the attendance and setting up some of the demonstrations, graded some of the papers, and made themselves available to substitute as lecturer in the course if needed. It was wonderful training for the graduate students and greatly enhanced the management of these courses. A number of these former graduate students have indeed become successful teachers, an expressed goal of the early NDEA Title IV fellowship program.

Most of the graduate students came from smaller colleges. For many years they were the principal sources of Ph.D. bound students nationwide. This has been changing slowly during the last few decades so that now the major portion of the Ph.D. bound graduate students in the United States come from the Universities.

Teaching and Research Fields

Dr. Ham continued his research in acoustics until 1957. The research efforts listed below will not include the acoustics work of L. B. Ham or the nuclear work of Berol Robinson or James Scobie or Matti Nurmia, because they had retired or had moved on before the doctoral program in physics was started. A cosmic ray neutron research effort conducted by Paul C. Sharrah and H. M. Schwartz was initiated in 1951 and concluded in 1953. Also the work of Z. V. Harvalik and Willard R. Bennett ("pinch effect") and Albert Sauer and Brent Stearns are not included because they came and went before the Ph.D. program was initiated in 1959.

The doctoral research areas have included atomic spectra and isotope shifts, x-ray diffraction studies of liquids, proton excitation studies and lifetime measurements, laser optics and laser physics, laser spectroscopy, quantum optics, chaos, particle physics, plasma physics of exploding wires, theoretical work on atomic

UA professors visit Redstone Arsenal in Huntsville, Ala., 1966. Left to right: Dennis Akhurst, head of electrical engineering; Melvin K. Anderson, electrical engineering; Paul C. Sharrah, physics chairman; a graduate student in electrical engineering; Otto H. Zinke, physics; and James R. Couper, chemical engineering.

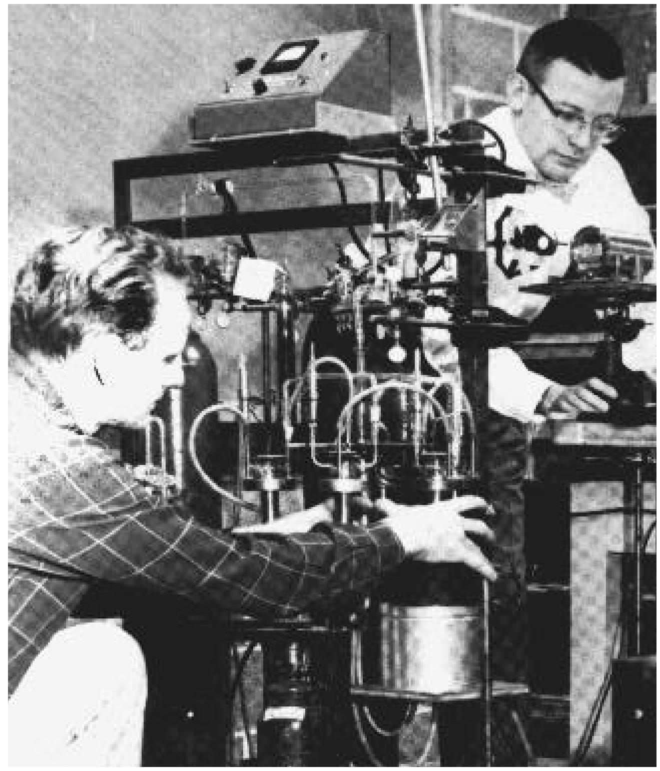
and molecular structure, thermodynamics and optical studies of levitated microscopic particles, superconductivity, only to mention a few.

The physics faculty have consistently received doctoral research support and major equipment grants throughout the years. While the department has never really been involved in "big science," consistent "good physics" research has been in progress.

The department throughout the years has received research support money from the Air Force Office of Scientific Research, the Office of Naval Research, the Atomic Energy Commission, the National Science Foundation, the Department of Defense, the Department of Energy, the National Aeronautics and Space Administration, and the Arkansas Science and Teaching Authority. The department also received some financial support from the Baldwin Piano Company at a very critical time in the early stages of the doctoral program as well as research funding from the Southwest Electric Power Company. The remodeling and expansion of the Dickson Street Physics Building in the 1990s was made possible, in a large part, by a Facilities Renovation grant by the National Science Foundation.

There are certain other worthy activities not directly related to the doctoral research program that should be mentioned. H. M. Schwartz published a scholarly treatise on Relativity Theory. A. S. Hobson received an advance from the Macmillan Publishing Company to assist with the writing of a new text Physics: Concepts and Connections. A one-time grant was made by the National Science Foundation to Carol Webb to install a telescope in the Droke Observatory. A one-time grant was made by the Atomic Energy Commission to Dr. O. H. Zinke for teaching equipment in nuclear physics. Thus teaching equipment grants were received from the National Science Foundation, the Atomic Energy Commission and the National Defense Education Act through proposals written by R. H. Hughes, Carol Webb, Paul C. Sharrah, O. H. Zinke and Richard J. Anderson. Gregory J. Salamo, Surendra Singh, Min Xiao, William F. Oliver III, and Gay Stewart have received grants in recent years from the NSF in support of instructional programs.

George W. Kirsch, research shop machinist was one of the significant assets to the physics research program. He built numerous items in the 1950s



R. H. Hughes and physics student Ted Donaldson with Fabry-Perot interferometer used with Littrow spectrograph to study fine structure effects due to isotope shifts.

A review of the major doctoral research fields as they developed and the manpower involved will be presented below in approximate chronological order of the development of the initial project.

Also included are personal messages from present and recent faculty members describing their teaching and research interests. These "memos" preserve a little of each person's style. Each quotation is printed with only minor editorial change except for some deleting of material covered elsewhere.

The faculty talk about their teaching experiences and other matters also in "memos" in Chapters 5, 6, and 7 similar to the research and teaching "memos" printed below. Certain other selected letters and "memos" are included in the earlier chapters.

Faculty Memos

ATOMIC PHYSICS AT ARKANSAS

Atomic Physics research at Arkansas began with the arrival of R. H. Hughes fresh out of the University of Wisconsin graduate school in the Fall of 1954. He inherited a Hilger Littrow spectrograph located in the northeast corner of the basement (Room 8). Nearly the entire east wing of the basement was devoted to chemistry and geology

Travis S. Walton (left) driving his boat at a Physics Department picnic, ca 1965.

at the time. The research services machine shop operated by George Kirsch, assisted by Leonard Gabbard, was located in Rooms 14 and 15. Professor Berol Robinson of the Physics Department occupied Room 9 as his office and laboratory where he collaborated with chemist R. W. Fink in nuclear experiments. The desk in Room 9 was previously used by W. R. (Pinch Effect) Bennett while he was here at Arkansas for a short period of time (necessary to obtain a divorce).

The following "memo" prepared in 1993 by Dr. R. H. Hughes, Emeritus University Professor, is a good summary of his research activities in atomic physics.

"The Littrow spectrograph allowed Hughes to cross it with a large-aperture all-invar Fabry-Perot interferometer for high resolution spectroscopy. A study of isotope shifts in the medium weight elements began using separated isotopes obtained from the Oak Ridge National Laboratory. Liquid-air cooled hollow cathode discharge tubes were used. Federal support for the effort came in the form of contracts from the Air Force Office of Scientific Research (AFOSR). The isotope shift work lead to construction of an atomic beam light source to reduce the Doppler width of the emission lines.

"Hughes received a call in the late 50's from Air Force Office of Scientific Research asking if he could use $50,000 and if he could to write a quick proposal. He did write a proposal, of course. A study of the polarization of light produced by electron impact on gases was funded in 1959 as promised. Included in the proposal was a plan to detect the Lyman-alpha line of positronium, an idea suggested by Dr. C. Y. Fan when he was at Arkansas. A feasibility study was eventually made on the Lyman-alpha line with Dr. O. H. Zinke.

"In the meantime Fan, who briefly joined the faculty from the University of Chicago in the late 50's, wrote a proposal with Hughes as co-principal investigator to study auroral emissions produced by proton impact on atmospheric gases. The proposal was set to be funded in 1960 by the Air Force Cambridge Research Center (AFCRC). The funding papers were on the desk ready to be signed when the newly elected President Kennedy froze funds and announced the United States intention to put a man on the moon. The proposal was funded the next year with Hughes as the sole principal investigator since Fan had departed to go back to the University of Chicago to continue his cosmic ray work. The AFCRC funding allowed the construction of an 0-120 kV positive ion accelerator to begin at Research Services. The UA Research Services electronics specialist Travis Walton did a masterful job of building the first of the two pasitineion accelerators used by Hughes and his students for their significant work in atomic collision studies. Chemistry and Research Services had moved most of their activities out of the Physics building and the geology department graciously gave up their use of Room 17 for housing the new accelerator.

"While the first accelerator was being built, spectroscopic work began using the 400-kV chemistry machine. Mykola Saporoschenko, a classmate of O. H. Zinke and a new faculty member, helped in setting up the initial experiments. Dr. Saporoschenko's tenure at Arkansas was also brief. He wanted to get married but the town of Fayetteville offered little opportunity, since he hoped to marry a girl associated with the Russian Orthodox Church! Dr. Saporoschenko was a native Russian and Dr. Schwartz was fluent in Russian but he often complained of Schwartz's accent!

"The atomic research program was so successful that an expansion in the faculty was proposed to Dean Adkisson of the Graduate School. He agreed to the hiring of three faculty in the field. Professor C. B. Richardson, and R. J. Anderson were subsequently hired. The third appointment failed to materialize.

"NDEA Title IV funds given to W. R. Pendleton, the first Ph.D. graduate (1964), allowed the construction of a pulsed electron beam apparatus used for the study of atomic excited state lifetimes. The technique produced several papers, later with R. J. Anderson. The technique was also used by Lynn Hatfield to make the first precision measurement of the Lamb shift in the n=4 level of He^+.

"The positive-ion accelerator proved to be the basis of many publications, theses, and dissertations. The topics of research were so many that a second accelerator was built with NSF funds. The 0-30 kV accelerator was used to produce fast neutral beams. A time-of-flight technique was developed which allowed the measurement of the population of fine structure states in fast hydrogen atoms produced by electron capture by proton impact on gases. The technique also allowed the same type of measurement in the excitation of ground state hydrogen atoms by impact on gases. The above work was cited as the basis for the election of Professor Hughes as a Fellow in the American Physical Society in 1968.

"The measurements of absolute cross sections for excitation by electron, ion, and neutral atom impact required the calibration of optical detectors with standard optical lamps obtained from the National Bureau of Standards. Such standard lamps were available for visible emissions but not for the vacuum ultraviolet. A project was funded by NASA to develop a vacuum ultraviolet standard lamp using electron impact on metals and in particular using transition radiation which should be calculable. The project showed promise but was cut short by a NASA funding crunch.

"At the same time a proposal to develop a laser-generated multicharged ion source was funded by NSF Nuclear Physics. The idea was to use a high-repetition high-power laser focused on a solid surface to produce a hot plasma. R. J. Anderson became co-principal investigator.

Richard J. Anderson

"The Nd:YAG laser laboratory facility was initially supported by the University. The laboratory was also used by the Department to push arguments toward the development of a laser physics program. Professors Greg Salamo and Raj Gupta were hired.

"The laser ion source progressed to the study of multicharged ion impact on solid surfaces and was supported by NSF Solid State Physics and NSF Atomic and Molecular Physics with D. O. Pederson as co-principal investigator.

"This brings us up to the present Physics Department renovation and the dismantling of the ion source facility. Hughes retired in the Spring of 1990 as Emeritus University Professor. The above work provided many theses of both Master's Degrees and Ph.D. degrees and earned Hughes the Arkansas Alumni Blue Key award for research in 1984. He served as Research Director for 35 Master's Degrees and 19 Ph. D. degrees. Support was provided by the Air Force Office of Scientific Research, Air Force Cambridge Research Center, NSF Atomic and Molecular Physics, NASA, NSF Atmospheric Physics, NSF Nuclear Physics and NSF Solid State Physics."

The above "memo" prepared by Dr. Raymond H. Hughes in 1993 and edited March, 1995, summarizes the development of the atomic physics research program at Arkansas.

R. J. Anderson joined the faculty after receiving his Ph.D. from the University of Oklahoma in 1966. He was a student of Chun Lin, who not long afterward filled the vacancy on the faculty of the University of Wisconsin resulting from the death of Professor Julian Mack, R. H. Hughes' major professor. Anderson and Hughes teamed together on several research ventures most notably the development of a laser multicharged ion source initially supported by the Nation Science Foundation Nuclear Physics division and later the NSF Solid State Physics division. Anderson collaborated with G. J. Salamo on a grant from the Atmospheric Sciences division of the NSF. Anderson became the director of the Arts and Sciences Honor's Program in 1983 and served to 1989, spending one-half time in physics. He has been working with the National Science Found-ation in Washington, D.C. since 1989.

Richard J. Anderson (1966-1989) describes his work in the following research and teaching memo dated January, 1993. He provides information on Summer Institutes and Student Science Camps in Chap-ter 6 and on the Honors Program in Chapter 7.

RESEARCH- "In 1966 when Anderson joined the Physics faculty the Department had already established a reputation for research in atomic collision physics. Professor Ray Hughes was principal investigator on several federal grants in this area and offered Anderson the opportunity for collaboration on a series of experiments in atomic lifetime measurements using time-resolved spectroscopy. Although Anderson subsequently received his own external support for atomic physics experiments from the Research Corporation and the Atmospheric Sciences Section of the National Science Foundation (NSF), the Anderson-Hughes collaboration lasted over twenty years in several areas including a project in heavy-ion beam physics supported by NSF's Nuclear Science Section. When Greg Salamo, whose expertise was in laser physics and non-linear optics, joined the faculty Anderson and Salamo discovered mutual research interests in photo acoustic spectroscopy and atomic collision processes. A second successful collaboration was initiated by Anderson. The Salamo-Anderson collaboration continued after Anderson left the University to join the staff of the National Science Foundation. In 1992 they worked together on joint projects conducted at the U.S. Army Research Laboratory (Ft. Belvoir, Virginia) under the direction of Dr. Ed Sharp. This most recent work is in the area of optical signal processing and photo refraction."

TEACHING-"In 1966 the normal teaching load in the Department was at least nine hours per semester. Anderson, like most new Ph.D.'s was assigned to teach a typical mixture of introductory and specialty courses. Throughout his tenure at the University Anderson demonstrated a strong interest in classroom teaching. Innovation was a special interest of his that manifested itself in various ways: class rocket launches from the lawn of Old Main; team teaching of introductory courses; increased emphasis upon student composition skills; and physics laboratory development. The latter led to his service as Director of the Introductory Physics Laboratories. As Laboratory Director Anderson instituted workshops for the graduate laboratory instructors, introduced several new experiments into the curriculum, and supervised the editing and publication of a Physics Laboratory Manual. The manual was printed on-campus and sold to each of the approximately 1,000 students enrolled in the laboratory courses each year. Proceeds from the sale of the manual were used by the department to establish a Physics Scholarship Fund.

"Anderson's interest in physics education led to a successful collaboration with Dr. Glen Clayton in the early 1970s to develop an innovative Bachelor of Arts degree program for the Department. The B.A. curriculum involved new approaches in both the classroom and the laboratory including emphasis upon the teaching of acoustics and sound; practical electronics; optical physics and holography; and atomic and nuclear processes. The curriculum received wide-spread acceptance by students and recognition by the American Association of Physics Teachers (AAPT) national organization. It attracted students who were interested in physics, but who did not want to be research physicists and prepared them for careers in a variety of areas (e.g. medicine, law, secondary teaching, business, and technical marketing and sales). In 1981 Anderson received the College of Arts and Sciences Master Teacher award and the Alumni Association Award for excellence in teaching and research. His service on the editorial board of the Physics Teacher magazine and the AAPT's Committee on Physics in Higher Education allowed the Department to gain input to the national debate on physics education." Dr. Richard J. Anderson, January 1993.

X-RAY DIFFRACTION STUDIES - LIQUIDS

The following information was provided by Dr. Paul Sharrah, March 1993.

"The editor's words are all through this document but it is only fair that a brief statement about his teaching and research activities in the department is in order. The first of two teaching challenges I faced in the 1940's was to teach an atomic physics course (Pittsburgh Staff text) to about eight or ten chemistry and physics students. The second teaching challenge was the organizing and teaching of an x-ray course. This course met the needs of the pre-medical students and included a third lecture each week emphasizing x-ray diffraction theory. The third lecture part of the course was used by the chemistry and physics majors. By the late 1940's the three-hour x-ray course was redesigned to be used for the chemistry and physics majors only.

"I was always the teacher most likely to get the overload. Someone in authority announced in the late 1940's that Sharrah would never amount to anything because he was too good at teaching! In a slightly more friendly vein someone else said that Sharrah was too good for the University and wouldn't stay! I haven't figured that one out either. I did stay!

Glen T. Clayton
(1959-1971)

"A stimulating period of research started in 1951 when the Oak Ridge National Laboratory division of metallurgy under my direction sponsored a new thrust into neutron diffraction studies of liquid metals. This was based on the early work of Zernicke and Prins and Debye and Menke and later B. E. Warren of MIT and N. S. Gingrich and his group of students at the University of Missouri. This was followed up by Kruh and Sharrah using an improved design of a diffractometer based on the bent and ground salt crystal used as a focusing monochromator. This work was funded by the AEC and later by an NSF grant to Glen T. Clayton.

"The next big quantum leap came when R. H. Hughes and I negotiated the establishment of the Ph.D. program in physics in 1959. That and the other duties of the department, including much teaching, was to be my interest for my twelve years as physics department chairman!

"Teaching laboratory demonstrations in NSF institutes and the directing of AEC/NSF institutes for high school teachers of chemistry and physics and NSF institutes for JrHS teachers were stimulating and productive activities. Giving guest lectures on physics demonstrations at William Jewell College, Howard Payne College and the University of Tulsa was also interesting and productive.

O. H. Zinke (1959-1988)

"A particular exciting experience was the activating and management of the small but very useful Spitz planetarium with the twenty foot dome. The students and I made it a great success with the public and school groups and the University students. Lisa Lovett, Eliot Neel, Dianne McGuffy, Nancy Watson, and several other students did much work there.

"I was retired in 1982 and taught part time for three years and worked as an advisor one semester for the College of Arts and Sciences. I am sitting here looking out the back window of my office at home typing this on a Macintosh computer.

"It has been an "invigorating Ozark experience". Thanks to everyone who has made this trip such a pleasure. I have many fond memories of students and faculty and also the townspeople here!" Paul C. Sharrah, March 9, 1993.

Quoting from the Physics Department Newsletter-Spring 1994, "But from the research point of view, Sharrah's two main accomplishments both related to the study of liquids. Working first in the summer of 1951 at the metallurgy division and later with the chemistry division of the Oak Ridge National Laboratory, some interesting work was done on neutron diffraction studies of molten lead and bismuth alloys using the original graphite reactor there.

"Then Sharrah, with Dr. R. F. Kruh of chemistry, built in physics in 1956 an AEC sponsored x-ray diffraction facility for the study of liquids. This machine was the center of research performed by several students for master and Ph.D. degrees, and was much used by Dr. Glen T. Clayton and his students on grants from the National Science Foundation. This x-ray machine and a similar unit built at Oak Ridge were the first to make use of a bent and ground crystal focusing monochromator. The idea came to Sharrah when he was studying with Professor Newell S. Gingrich at the University of Missouri. This made it possible to study the diffracted x-rays from the surface of a flat sample, and was especially good for studying liquid metals. It also had the considerable advantage of eliminating any contribution to the diffracted radiation of the useless incoherent Compton scattered x-rays."

Glen T. Clayton was an undergraduate and graduate student here on campus and did his Ph.D. work at the University of Missouri under Gingrich, who was also Paul Sharrah's mentor. Glen first collaborated with Paul and Bob Kruh in this study of x-ray diffraction from liquid surfaces. He directed several Ph.D. and Master's theses before leaving Arkansas in the 70's to be a Dean at Stephen F. Austin University in Texas. He had a short but successful tenure until his untimely death there.

PLASMA PHYSICS - EXPLODING WIRES

Stephan M. Day, second chairman (1969-1975) seen in his NMR laboratory, Room 108, ca 1968.

Professor O. H. Zinke came to the University in 1959 from the University of Missouri, where he was a faculty member. He had also been associated with the Linde Company in Rochester, New York, before joining the faculty at the University of Missouri. He first collaborated with R. H. Hughes who had a contract with the Air Force Office of Scientific Research that included a feasibility study of producing excited states of positronium through charge exchange reactions when positrons pass through gases. He invented a magnetic bridge that he worked with off and on during his tenure at Arkansas. He had support for a study of plasmas produced by exploding wires. He took a 3-year leave of absence from his teaching duties to do a state and world energy study while on campus, financed by the Ford Foundation.

The following is ex-tracted from material supplied by Dr. O. H. Zinke, January 1993.

"Zinke did research on a variety of topics. His work in graduate school was on Auger electrons. He developed and perfected a technique for measuring the temperature of positive ions from high-temperature pulsed plasmas

Charles B. Richarsdson in his laboratory, ca 1970. He was third chairman (1975-1978).

using exploding wire techniques. In conjunction with a course he was teaching on physical techniques in archeology, he found and tested a way to apply alpha-recoil technique to determine the time of firing of primitive ceramics. The AC magnetic bridge was used to make measurements on the heat diffusivities of foils. He formed a company in 1988 called International Validators, Inc. to make use of the AC bridge for nondestructive testing of metals. This work continues largely in collaboration with William F. Schmidt, chair of the Department of Mechanical Engineering.

"In addition to teaching several courses at the elementary and intermediate level, Zinke taught junior-senior and graduate level courses in electronics, electromagnetic theory, mechanics, thermodynamics, kinetic theory, statistical mechanics, nuclear physics, reactor physics, and starting in 1960 a one-year course in modern physics based on the Leighton text.

"In conjunction with the nuclear physics course, he obtained a grant from the Atomic Energy Commission which provided nuclear equipment and a subcritical nuclear reactor. This reactor was transferred to Mechanical Engineering a few years later.

"In the 1960's supplementary material was introduced into the physical science course emphasizing energy and society. A junior-level course was also introduced with this same name. This led to an active participation with the government of Arkansas on energy plans and decisions, and active involvement with the Governor's energy forum and the Southern Regional Energy Board."-Dr. O. H. Zinke, January 1993.

NUCLEAR MAGNETIC RESONANCE

S. M. Day came to Arkansas from Rice University in 1961. He built a research program in Nuclear magnetic Resonance funded by the National Science Foundation. He served two terms as department chairman before stepping up to become Associate Dean of Arts and Sciences at Arkansas and Dean of Arts and Sciences at Miami University in Ohio in 1983.


F. T. Chan, theoretical and experimental work.

ATOMIC PHYSICS - SMALL PARTICLES

C. B. Richardson came to Arkansas faculty in 1966 after serving as a post-doctoral fellow in the laboratory of Professor Hans Dehmelt at the University of Washington. Professor Dehmelt in 1990 became a Nobel Prize winner for his ion-electron trap research. Dr. Richardson has continued to use the rf trap principle putting it to a novel use. A system has been developed so that chemical reactions and other changes taking place in trapped submicroscopic particles can be observed. Mie scattering from a laser beam is used to measure size changes on the trapped particle.

The following material was provided by Dr. Charles B. Richardson January 1993.

"Since 1980 graduate students and I have used the technique of single particle levitation to study various thermodynamic and optical properties. This work has been supported by grants from the National Science Foundation Atmospheric Sciences Division, and its principal thrust has been the investigation of the dynamics of sulfate and nitrate particles because of their prevalence in the atmosphere.

"This dynamics includes evaporation and the interaction with water vapor, both of which affect the transport of such particles from sources such as urban areas.

"Related investigations include the study of phase changes in microscopic particles and the mechanical stability of highly charged liquid droplets.

"Thirteen papers have been published from the results of these studies, including two co-authored by collaborations at Brookhaven National Laboratory and the Naval Research Laboratory.

"Almost continuously during my years at Arkansas I have taught the Modern Physics Laboratory. During the late sixties when I began this assignment the laboratory was largely shaped by the Summer Institutes for high school teachers, a lively and valuable program funded by the Atomic Energy Commission and the

National Science Foundation. Later influences include the Berkeley Physics Laboratory and the Apparatus Drawing Project of the AAPT. Over the years the laboratory when taken by the graduate students has included experiments of a project nature including the Zeeman Effect, the Mossbauer Effect, Raman Scattering, X-ray Spectroscopy, and the Proton Omegatron Effect.

"In its present form the laboratory consists of eight experiments including proton nmr, the Faraday Effect, Thomson electron specific charge measurement, gamma ray spectroscopy, the Franck Hertz experiment, high resolution optical spectroscopy, radioactivity and the range of alpha particles, and thermionic emission. The laboratory is taken by about twenty five students annually, both undergraduate and graduate students." Dr. Charles B. Richardson, January 1993, edited February, 1995.

Michael Lieber joined the department of physics in 1970. He served as the fifth chairman from 1983 to 1986 and he served as vice chairman from 1992 onward. Photograph ca 1985.

Michael Lieber

THEORETICAL PHYSICS

F. T. Chan came to the University in 1969. He received his Ph.D. degree from the University of California at San Diego in 1967 under the tutelage of Dr. Keith Brueckner and served on a postdoctoral assignment at Cornell University from 1967 to 1969. Dr. Chan's interest at the time was theoretical atomic physics, such as two photon emission. Later he collaborated with Dr. Michael Lieber in the study of atomic collisions, verifying some of the excited state measurements done in the atomic collision laboratory of R. H. Hughes. He is currently interested in superconductivity and is directing some experimental work.

Dr. Chan describes some of his research interests in a one-page document he prepared in 1994 for posting on a bulletin board in the physics building.

"The three-dimensional (3D) hydrogen atom played a central role in the early formulation and development of quantum mechanics and is now part of the standard curriculum in modern undergraduate physics.

If the motion of the electron around the nucleus is constrained in a plane by certain boundary conditions, then such a system is called the two-dimensional hydrogen atom. The motion of electrons confined to two dimensions has been of great interest in recent years, in part because of applications to such systems as high-Tc superconductors. Recently, we have carried a thorough study of the two-dimensional hydrogen atom (Phys. Rev. A43, 1186 & 1197 (1991)). In particular, we derived the exact analytic solution for the eigen energy and wave function, both with and without the Chern-Simons field. We plan to study the effect of the transition rates, dc Stark effect, Zeeman effect,.... We also plan to study the two-dimensional Lamb shift problem.

"We currently use laser ablation to fabricate high-Tc superconductors Y-based and Tl-based as well as dielectric thin films. A high-intensity laser beam is directed onto a bulk target (superconductor or dielectric) causing an ablative spray of target material which then deposits onto a substrate (single crystal or amorphous). The advantage of the technique (which is simple to switch from one target to another within a single chamber) is that the target stoichiometry is replicated in the deposited films. We have

D. O. Pederson, fourth chairman of physics (1978-83), later associate dean of Fulbright College and currently vice chancellor for academic affairs with R. J. Anderson (right) director of Fulbright College Honors Program, and currently at NSF section for Research Initiative and Development. Photo ca 1980.

received our large stainless chamber containing an ion gun and a rotating six-target holder and a high powered excimer laser a few months ago. These state of the art equipment will allow us to fabricate larger and more uniform films in a much cleaner environment. I addition to the search for new materials, we will carry out research, characterization, and development of new superconducting thin films for use in high density electronics. In particular, using the laser ablation technique we plan to fabricate single (HTSC)- and tri (HTSC-dielectric-HTSC)-layer samples. The dielectric could be MgO, $LaAlO_3$, CeO_2 and SAT, a new material developed by Penn State. Physical properties of the fabricated films will be studied extensively."

Dr. Michael Lieber came to the University in 1970 after receiving his Ph.D. degree from Harvard, working with Nobel Laureate Julian Schwinger, and three years of post-doctoral research at New York University. Prior to receiving this Ph.D., he had served as Chief of Scientific Problems for a large aerospace company, and before that he had been in on the early development of computers, working at IBM to develop the FORTRAN computer language. Immediately upon his arrival in Fayetteville, he took up heavy responsibilities in teaching. In addition to carrying his load with the beginning courses, he has taught numerous upper level courses. These include Elementary Particles, Plasma Physics, and Advanced Quantum Theory, all courses he developed. A flier prepared in 1994 describes some of his current research interests.

"My research has covered many areas in theoretical and mathematical physics, but the primary area have been quantum electro-dynamics, elementary particles and scattering theory, the latter with an emphasis on three-body problems with applications in atomic physics.

"The three-body problem is famous in both classical and quantum mechanics, but my research has concentrated on the quantum case. In recent years I have been interested in an anomalous situation with regard to so-called "capture" reactions, in which an energetic projectile captures a particle from a composite target, e. g. A + (BC) —>> (AB) + C. An example from atomic physics would be a proton projectile capturing an electron from a target atom, emerging as a neutral hydrogen atom and leaving behind a recoiling positively charged ion. These processes are very fundamental, and experiments studying them are done in many laboratories around the world. Unfortunately, the theory, even when pure coulomb potentials are used (especially when pure Coulomb potentials are used!) proves to be extremely difficult and many approximate techniques have been developed. One of these, the Born approximation usually works well in collision problems at high energies. But in capture processes it fails badly. This failure can be traced to a classical restriction, that capture is impossible with only a single collision, because of the necessity of conserving both energy and momentum. Rather, we must have a sequence of at least two collisions, e.g. A collides with B, raising B to the proper energy for capture but moving in the wrong direction. B then collides with C, changing its direction so as to permit capture by A. Recently, I have discovered that for certain masses of the three particles, this double collision scenario is also kinematically forbidden. I am currently studying the possibility of capture when the masses lie in these regions by means of triple collisions.

"Another three-body process with which I

William F. Oliver joined the faculty in 1992.

have been working is the so-called "breakup" process: A + (BC) —>> A + B + C, i. e. all three particles move away freely. These processes, which include the important atomic problem of ionization by charged particle impact, have particularly interesting behavior when one pair of particles emerge with nearly the same velocity. In any event, my research involves improving methods of calculation of ionization probabilities at high energies."

Dr. Lieber served as department chairman from 1983 to 1986, and as vice chairman from 1992 to date. He served as president of the local chapter of Phi Beta Kappa and on numerous departmental, college, and University-wide committees.

SOLID STATE AND
CONDENSED MATTER PHYSICS

Dr. D. O. Pederson came in 1972 after having been granted the Ph.D. from Rice University in 1971. Dr. Pederson spent a year and a half on a post-doctoral at Texas Tech in 1971-72. He has contributed to the solid state physics work and laser work of the department. He served as department chairman from 1978 to 1983. He also has served as Associate Dean 1983-85, Associate Vice Chancellor (and chief academic officer) 1985-86 and as Vice Chancellor for Academic Affairs 1986 to present. He always kept a foot in the physics department, however, carrying on research in solid state physics which included collaborative efforts with R. H. Hughes and G. J. Salamo.

Larry S. Merkle (1983-89). Went to U.S. Army Night Vision Laboratory.

Professor D. O. Pederson describes certain aspects of his research interests in materials prepared in 1994 in collaboration with Professor Hughes.

"A time-of-flight (TOF) technique has been used to measure the remnant charge of laser-produced pulses of multicharged C^{k+} (k = 1 to 4), Al^{m+} (m = 3 to 6), and Pb^{n+} (n = 2 to 6) ions incident on a clean amorphous Au surface under UHV conditions at various scattering angles. For all angles considered, C and Pb were found to be completely neutralized after scattering from the Au surface. The remnant singly charged state of Al, however, was detected in all instances in addition to neutral Al atoms with charged fraction being ~ 60%. Detailed charge fractions were determined for incident Al^{z+} (z = 3 to 5) with energies 400 eV/z. The results obtained for various incoming angles could be fit to the expected form of a decaying exponential. The charge fractions showed a dependence on the outgoing path while being independent of the incoming path. Although the characteristic velocity for a particular incident Al^{z+} charge state (hence constant energy determined by an electrostatic analyzer) was found to be constant, the inclusive case for all three aluminum incident charge states required an energy-dependent characteristic velocity in order to obtain a reasonable fit for the remnant charge fraction as a function of a decaying exponential. The results are interpreted to be indicative of the importance of the ground state energy level of the projectile as compared to the Fermi level of the metal and how it evolves close to the metal surface as well as the importance of the distance of closest approach of the projectile to the metal first atomic layer." End of D. O. Pederson material prepared in 1994.

Mark E. Filipkowski, employed 1994.

The following paragraph prepared by D. O

Pederson in 1994 describes research interests in the condensed matter program.

"Experimental work in the field of condensed matter physics is focused on ultrasonics on ionic solids, solid electrolytes, and high temperature superconductors; on the development of new high temperature superconductors; and on studies of the optical properties of solid electrolytes and nonlinear optical materials. The ultrasonic work consists of sound velocity and attenuation measurements as a function of temperature in a variety of materials. The optical properties of materials are measured as a function of temperature using laser interferometric techniques in a variety of materials. The fundamental properties of materials can be obtained from these measurements including the elastic constants for single crystals and the sound moduli for polycrystalline materials, anisotropic properties and activation energies of defects, the superconducting transition temperature and its variation with pressure for high temperature superconductors, and the coefficient of thermal expansion and the thermo-optic coefficients for optical materials." End of D. O. Pederson paragraph describing some of the research interests of the department, dated 1994.

The following short resume of his work and interests was submitted by Dr. William F. Oliver III dated January 1993.

"William F. Oliver III, an experimental condensed matter physicist, was added to the faculty during the fall of 1992. Dr. Oliver received his bachelor's degree in physics from the University of Arizona before going to the University of Colorado in Boulder, where he received both an M.S. and a Ph.D. degree in condensed matter physics. His Ph.D. research involved Brillouin light scattering, dielectric and nonlinear optical investigations of incommensurate, ferroelectric, and ferroelastic phase transitions. After completing the Ph.D. degree he took a post doctoral position at Arizona State University where he continued his studies of low temperature incommensurate phases via neutron scattering, which was performed at the Los Alamos Neutron Scattering Center (LANSCE). As a post-doctoral research fellow he was also involved in Brillouin scattering studies of conformational transformations in wet-spun biopolymer films as a function

Gregory J. Salamo joined the faculty in 1975.

of relative humidity and high-pressure laser light scattering studies of liquid glass-forming systems and amorphous materials. Currently a research laboratory is being set up here for tandem Brillouin spectroscopy at high and low temperatures and high pressure. Eighteen articles and two book chapters have been written to date and he has presented research at several conferences both within the United States and abroad.

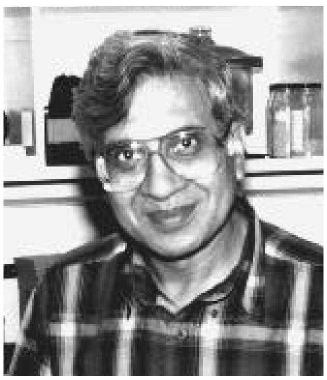
"Since joining the faculty in August 1992, I have taught Advanced Modern Physics to a class of twelve and a graduate level Solid State Physics course. A research proposal to the Arkansas Science and Technology Authority entitled, High Pressure Brillouin Scattering in Condensed Matter Systems at High and Low Tempera-tures was awarded a grant of $50,000 in January 1993." Dr. William F. Oliver, III, Jan. 1993.

L. K. Merkle came to Arkansas from Oklahoma State University in 1983. His research interest was optical damage mechanisms produced by laser interaction on solids. He received a grant from the State to pursue this work. He was deeply involved in the operation of the student activities and served as editor of the physics department Newsletter. He left after seven years to work at Fort Belvoir, Va.

Mark E. Filipkowski joined the physics department Fall 1994 and describes his field of research interest in the material below received March, 1995.

"With the development of techniques for producing materials not found in nature, many new and exciting phenomena have become available for study in the field of condensed matter physics. The latter is that subdiscipline of physics devoted to the study of condensed systems, such as liquids and solids. The investigation of novel man made materials has resulted in the discovery of "new physics" of interest to the general scientific community, and has the potential for the creation of new technologies.

"A significant part of the study of condensed systems involves the examination of magnetic effects. These may range from the influence of the magnetic moment of the helium nucleus on the material phases of liquid helium, to improving the properties of permanent magnets. An example of an important class of new, man-made magnetic materials consists of layered structures, in which ultrathin layers of magnetic metals (e.g. Fe) are sandwiched with nonmagnetic metals (e.g. Al, thus, Fe/Al/Fe). Ultrathin refers to thicknesses of the order of several angstroms, or only a few atoms thick.



Rajendra Gupta employed 1978. He was seventh chairman (1989-1995) and obtained funds for 1992-94 building expansion.

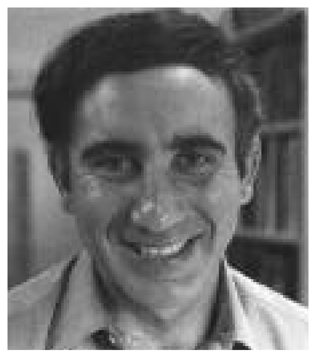
"New physics becomes possible in such systems due to the creation within the nonmagnetic metal of a magnetic polarization induced by the adjacent magnetic metal. The properties of the nonmagnetic metal are thus perturbed in a way heretofore impossible. A complete picture of how this polarization comes about, and the nature and extent of its influence on the properties of the nonmagnetic metal are subjects of an extremely active area of experimental and theoretical physics.

"The goal of my laboratory will be to understand the fundamental physical principles which govern the behavior of layered and other novel magnetic systems. In this way we will contribute to the growth of knowledge in condensed matter physics, and help to lay the ground work for future technological advances.

"The physics of novel magnetic materials will be explored through the use of sophisticated experimental techniques, such as SQUID-(Supercon-ducting Quantum Interference Device) based mag-netometry and susceptometry, nuclear magnetic resonance, and spin-polarized transport. In addition, an extremely profitable set of interdisciplinary experiments becomes possible at the University of Arkansas through combined efforts with optical laboratories within the Department of Physics. These experiments will be devoted to understanding the time dependence of magnetic phenomena using fast optical techniques, and investigation of the coupling of magnetic layers through non-magnetic layers using the method of Brioullin light scattering.

"Since coming to work at the University of Arkansas I have taught a two-semester course in advanced modern physics"

This concludes the report provided by Mark E. Filipkowski March, 1995, and revised May 1995.



Peter Milonni (1982-1989). Continues significant work at Los Alamos Scientific Laboratories.

NONLINEAR OPTICS AND LASER SPECTROSCOPY

Dr. G. J. Salamo joined the physics department faculty in 1975 and immediately established himself as a competent teacher and researcher. Unfortunately the University in the 1970's provided only a few thousand dollars of start up funds so that Salamo actually was able to get started on his work through the graciousness of Dr. R. H. Hughes and Dr. R. J. Anderson. He used their equipment for his first work in the summer of 1975. He also has served the University community as director of the College honors program for the year 1985-86.

Dr. Rajendra Gupta came to the University of Arkansas from a faculty position at Columbia University where he was doing research in atomic laser-spectroscopy. He was co-principal investigator with G. J. Salamo (principal investigator) on an NSF EPSCoR grant which gave impetus to the initial laser research at the

Surendra P. Singh, employed 1982. Eighth chairman, 1995.

University. Dr. Gupta rendered valuable service to the department as chairman of its Graduate Affair's Committee before becoming department chairman in 1989. His yeoman efforts in obtaining funds for the renovation and expansion of the physics building are appreciated by all.

The following "memos" serve to describe Salamo's and Gupta's work very well.

The following material was submitted by Dr. Gregory J. Salamo dated February, 1993.

"My research is presently in two areas. The first is the study of the use of lasers to store information in crystals while the second is the search for the answer to the question "what is light?"

"To store images in crystals we impress on a laser beam an image. The laser light is then directed into the crystal and an image is stored. Our research is particularly concerned with developing the ability to store many images quickly, and to recall them when wanted. To date, we can store 1,000 images taking about 1 millisecond to store or read each one.

"One way to explore the nature of light is to study its interaction with simple atoms. When laser light interacts with an atom its response reveals some of the characteristics of light. In our research we examine both the behavior of the atom and the laser light during the interaction. By comparing the observed behavior with a model we learn how to answer the question "what is light?"

"My effort in teaching has been devoted to two areas. The first is the area of a course called Physics for Architects. This course was developed in order to give architects a better understanding of the role physics principles can play in their ability and creativity as architects. The course has both a lecture and laboratory component and both revolve around demonstrating the "physics" in architecture.

"The second area of teaching activity has been the development of a laser physics course. In this course we try to make the physics principles of lasers clear by presenting both a lecture and a "hands-on" laboratory component. Concepts discussed in lecture take on more meaning when the student "touches" them in the laboratory. The course is designed to give students specific skills in the design, construction and application of lasers." Dr. Gregory J. Salamo, February, 1993.

The following material was provided by Dr. Rajendra Gupta March 1993.

"I am carrying out investigation of photothermal spectroscopy and its various applications. The underlying idea behind photothermal spectroscopy is to create a change in the refractive index of the medium by the absorption of a laser beam (pump beam) and to probe this change by another laser beam (probe beam). There are several ways in which the refractive index change can be measured. For example, the refractive index change produces a change in the optical path length which can be detected as a fringe shift if the sample is placed inside a Fabry-Perot cavity or in one arm of the Michelson interferometer. In general, the refractive index change is nonuniform, therefore it can deflect a probe beam. The deflection is proportional to the gradient of the refractive index. Moreover, if the second derivative of the refractive index is nonzero, the medium acts like a lens and probe beam is focused or defocused. All of these effects are being investigated under varied conditions. The theoretical part of the work is being carried out by Professor Reeta Vyas.

"Our interest in these techniques is stimulated by many and varied applications of the techniques. One such application, which we have investigated a few years ago, is combustion diagnostics. These techniques can be used to measure minority species concentrations, local temperatures, and flow velocities in combustion environments without perturbing the environment. Another possible application is the micromanipulation of optical beams.

"As noted above, the photothermal effect can be used to introduce phase shifts, deflect a beam, and focus or defocus a beam. In terms of ordinary optical elements, this is equivalent to, respectively, a glass slab, a prism, and a lens. The lens can be spherical, cylindrical, astigmatic, converging, or diverging. Thus, the photothermal effect can be used to manipulate optical beams in situations where ordinary optical elements are impractical.

"Our present interest is to study the properties of GaAs quantum-well structures using these techniques." Dr. Rajendra Gupta, March 1993.

QUANTUM OPTICS

Peter Milonni, a theoretician, came to the University from Perkin-Elmer Corporation in 1980, having received his Ph.D. from the University of Rochester. His publication rate was phenomenal, often averaging over one per month. He became the center for a push in quantum optics. His presence quickly resulted in the hiring of Howard Carmichael and then Surendra Singh in the field of quantum optics. Dr. Carmichael specialized in theory and Dr. Singh worked in both experimental and theory aspects of the program. When all three were here Arkansas was considered by many to be a center of quantum optics. Dr. Milonni was also instrumental in bringing Dr. W. G. Harter to Arkansas. Dr. Milonni joined the Los Alamos Scientific laboratories in 1989.

Dr. S. P. Singh joined the physics department in 1982. In addition to his research and teaching described below, he has served as editor of the physics department newsletter.

Howard J. Carmichael (1983-89). To University of Oregon.

The following is extracted from material provided by Dr. Surendra Singh dated January 1993.

Research: "I joined the department as an Assistant Professor immediately after graduating from the University of Rochester in 1982. I began my tenure here by setting up a laboratory to study instabilities and fluctuations in lasers and nonlinear optics. The beginning was difficult. I did not have an office during the first year and it would be almost two years before I had a laboratory of my own. But by the end of my third year we were getting experimental results. This was made possible by a Joseph H. DeFrees grant from Research Corporation and some matching money from the university. The first experiments involved studies of build up of laser light from quantum noise near threshold and tricritical behavior in lasers with saturable absor-bers. I consider these to be our two most useful contributions of this period. We also carried out some important and neat experiments investigating the effects of external noise in lasers. This was a topic of considerable interest at that time. Success with these experiments brought funding from a grudging program director at the National Science Found-ation, who thought funding research at Arkansas was a waste of money.

"Currently, we are studying nonlinear dynamics and quantum and classical effects in a variety of systems in quantum optics. These include lasers and parametric processes such as optical second harmonic generation and frequency downconversion. In nonlinear dynamics we have been studying the temporal response of class-B lasers when either the pump or the loss of the laser is modulated. Such systems are capable of exhibiting an interesting sequence of bifurcations involving transitions between multiple steady-states, oscillatory states and even chaotic states depending on the depth and frequency of modulation and the number of modes in the laser. Experimental investigations are focused on studies of antiphase states, generation of complex waveforms under controlled external perturbations in a multimode Ti-sapphire laser. These studies have potential applications in laser light pulse crafting. For example, waveforms containing time-delayed pulses of different frequencies could be used in state selective time resolved studies of atomic and molecular dynamics.

"In parallel with our work on nonlinear dynamics we have been studying coherence properties of photon beams generated in nonlinear optical processes. We have recently demonstrated how second harmonic generation can be used to probe correlations of photon beams. In the process of frequency downconversion highly correlated photon pairs are produced. These correlated photons pairs offer some intriguing possibilities. Current theoretical interest, in collaboration with R. Vyas, is focused on non-classical effects such as photon antibunching, sub-Poissonian statistics and squeezing in second/sub harmonic generation. Experimental work to observations photon number oscillations in the counting distribution, nonclassical intensity correlations in the homodyne detection of light, and Sub-Poissonian photon statistics in progress. The results of these experiments can only be understood quantum mechanically. Other exciting experiments with these systems include preparation of single-photon states and studies of their interaction with matter.

"We are using a variety of techniques relying on fast photon counting and correlation equipment in these experiments. Nonlinear crystals, carefully designed optical cavities, He:Ne lasers, Ar-ion lasers, a Ti-Sapphire laser, a diode laser, transient digitizers, fast photomultipliers, and a host of other electronic instruments interfaced to two personal computers are available for these experiments.

"Work described here was initiated by a Joseph H. DeFrees grant from Research Corporation and has been supported by grants from the National Science Foundation over the past ten years."

Teaching: "Since joining the department in 1982 I have taught a variety of courses. At the undergraduate level I have taught both large and small sections of University Physics I and II (PHYS- 2053 and 2073) several times. More recently, I have taught University Physics I and II for the honors students. Other undergraduate courses that I have taught include Electricity and Magnetism (PHYS - 3414) and Optics (PHYS-3544). The course in Optics has a laboratory associated with it. This is one of our more popular undergraduate courses at the senior level. In collaboration with G. J. Salamo, I am in the processes of modernizing and revising undergraduate optics laboratory with the help of a grant from the National Science Foundation.

"At the graduate level I have taught Electricity and Magnetism (PHYS - 5313 and 5323) for a number of years. Other graduate level courses have been elective courses. These include Laser Physics (PHYS-5613) and Optical Coherence Theory (PHYS-6623) and Applied Nonlinear Optics (PHYS- 5633). The course on laser theory dealt with basic theory of laser action, resonator design, propagation of laser beams, and different lasers systems. The course on Optical Coherence Theory dealt with classical and quantum theories of optical coherence, temporal and spatial coherence, stochastic processes, interference and diffraction with fluctuating fields, and image processing. Applied Nonlinear Optics dealt with nonlinear interaction of light with matter, harmonic generation, phase conjugation, photorefraction, spontaneous and stimulated Raman and Brillouin scattering. A special topics course on Classical and Quantum Statistical Methods in Quantum Optics was taught in collaboration with H. J. Carmichael (now at U. Oregon). This course dealt with methods and applications of classical and quantum mechanics to describe the statistical properties of the optical field. Similarities and differences between classical and quantum descriptions were also discussed. " Dr. Surendra Singh, January 1993."

The following informative "memo" was received from Professor Howard Carmichael in April 1994. It presents a good description of his work at Arkansas before taking up his new position at the University of Oregon in 1989.

"I began work as an Assistant Professor at the University of Ark-ansas in January of 1983. At this time theoretical work in quantum optics was quite heavily focused on dynamical instabilities and chaos in nonlinear optics. The field had grown out of the extensive work done on optical bistability during the late 1970's and early 1980's, and was coupled to the ever increasing activity in the area of nonlinear dynamics, both in mathematics and physics, during the same period. I continued working in this area for my first


Reeta Vyas, employed full time 1989.

two years at Arkansas and published what I think was my most useful contribution to the field during this time, showing how symmetries in a linear stability analysis connect predictions about optical bistability to a large family of multimode instabilities in passive nonlinear interferometers. I was awarded a Research corporation grant, and later a National Science Foundation grant, together with Peter Milonni, for research in the area of optical bistability, dynamical instabilities, and chaos.

"My interest in these nonlinear dynamics directions waned, however, as I realized that the mathematics was perhaps more interesting than the physics. I wanted to be doing things where the physics was central. Following a summer appointment at the Royal Signals and Radar Establishment in Malvern, England, and a Visiting Lectureship at the University of Texas at Austin, both in 1984, I began concentrating more on questions related to the quantum fluctuations in optical bistability and related systems. The quantum mechanics of optical systems had been my principal interest prior to my excursion into nonlinear dynamics, and this subject had never moved very far from the center of my thinking. I became interested in two related issues. My colleague Jeff Kimble at the University of Texas at Austin and I began thinking about ways of making the quantum effects in optical bistability large so that they might be observed in the laboratory. The answer to this question turned out to be rather obvious; one makes the physical system small so that the nonlinear physics can happen with just a few atoms and photons around. For me, the theorist, this direction lead to a new question. How does one calculate things in this regime? The standard calculation methods in quantum optics were based on small noise expansions, which in one sense were completely self-defeating because they assumed from the outset that what one was calculating was destined to be a small effect. I began working with the positive P representation; this representation allows the quantum mechanical equations of motion to be mapped into a classical stochastic process which can be simulated on a computer, without any restriction on the size of the quantum noise. I eventually discovered that the positive P representation was not the answer I wanted because the representation had technical pitfalls precisely in the large noise regime where it was most needed. Nevertheless, this had its own benefits. It defined a new area of study; understanding the problems with the positive P representation.

"The direction defined by these developments occupied me for the next four years until I left the University of Arkansas in the fall of 1989. A number of things were added to the mix. Squeezed light became the hot topic in quantum optics. Since squeezing is concerned with quantum fluctuations I naturally became involved with this subject. My main contribution in this area was to analyze the theory of photoelectric counting as it applies to the method of homodyne detection based on normal-ordering of quantum field operators. This began an interest in photoelectric detection and its relationship to the quantum measurement problem which has continued as a theme in my work right up until the present time. The work on homodyne detection was followed a little later by work, in collaboration with Surendra Singh and Reeta Vyas, on photon counting distributions in resonance fluorescence. These two studies eventually developed into quantum trajectory theory, a method for treating open quantum optical systems using stochastic wavefunctions. The earliest version of this theory took form during 1989, just before I left the University of Arkansas. In my own work the quantum trajectory method has now replaced the positive P representation for understanding quantum fluctuations in the large noise regime.


Julio Gea-Banacloche employed 1990.

"One further thing contributed significantly to my research during my latter years at the University of Arkansas. As I have said, I began studying small optical systems because the quantum noise in these systems is large. I soon realized that there existed a new, growing area of research, which studies the same sort of systems; although not from the point of view of quantum fluctuations. The research area went by the somewhat overblown name of cavity quantum electro-dynamics (cavity QED). I began working out the connections between things being done in cavity QED and the work I was doing on the quantum theory of optical bistability. The principal result of this activity was the understanding that an oscillatory response I had seen in results for delayed photon coincidence measurements in optical bistability was, in the language of the cavity QED people, a manifestation of "vacuum" Rabi oscillations. Thus began my research in cavity QED, which continues to this day. The renewal of my NSF grant, which was made the year before I left Arkansas, was for work in cavity QED.

"These paragraphs give an overview of the research directions I followed at the University of Arkansas and the way my time in Arkansas defined continuing research interests. I should also mention my graduate students, Perry Rice, Murray Wolinsky, and Paul Alsing, who all contributed to this research. Perry is now an Assistant Professor at Miami University in Ohio. Murray, who left Arkansas with both a Ph.D. in Physics (awarded by the University of Texas at Austin) and a girl friend who eventually became his wife, is now working at Los Alamos. Paul works as a research scientist in the Philips laboratory at Kirtland Air Force Base.


Min Xiao employed 1990.

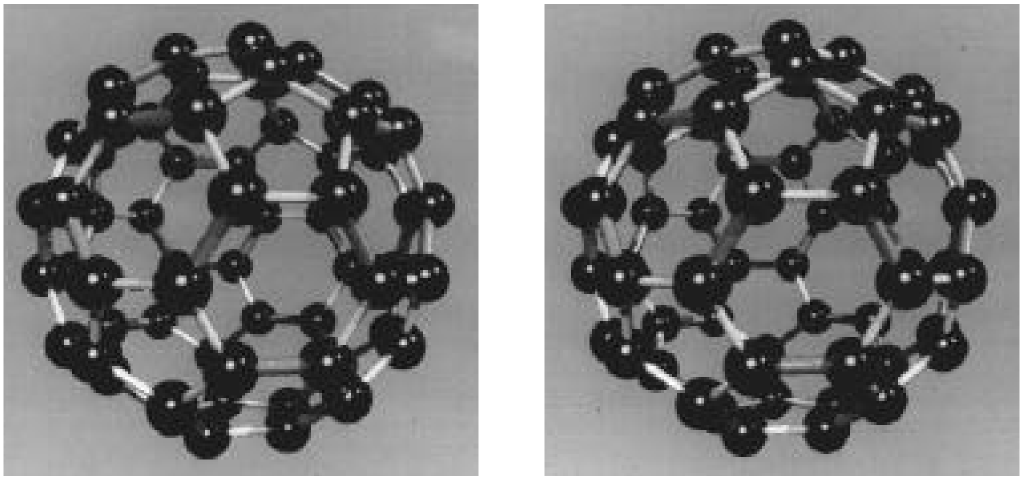
"Of course, one does more as a physics professor than just research. While I was at Arkansas I taught mainly undergraduate courses. I did teach an advanced quantum optics course which I have subsequently taught both at the University of Oregon and at the University of Waikato in New Zealand. I also began working on a book based on lectures given at the University of Texas at Austin while I was on leave there in 1984. It is now ten years later and the book is not finished, but it is close. Hopefully, I will complete it by the end of this year. Having done so I will have completed the last of the projects I started at the University of Arkansas. The less direct connections to my six years there, through research interests and things learned at that time, will certainly continue, however, throughout my career. This was a very productive time. I look back on it with happy memories of hard work and not too much of this paper shuffling baloney." End of E-mail statement transmitted by Dr. Howard J. Carmichael from the University of Oregon in April 1994.

Dr. Reeta Vyas joined the department on a full-time status in 1989 and has already contributed significantly to the teaching program and the research program of the department. She was on a part-time appointment with the department starting in 1984.

The following is from an e-mail document received from Dr. Reeta Vyas dated April 4, 1994, edited and revised March 1995.

"My research interests are in the areas of quantum optics, non-linear optics, and laser physics. We have developed new techniques for studying the quantum statistical properties of light generated in nonlinear optical processes. We have developed realistic models for these states that incorporate dis-sipation and nonlinearity of the atom-field interaction. These studies are centered on the calculations of certain quantum distributions. A recent analytic calculation based on this approach for homodyne detection of light from a parametric oscillator has revealed a rich variety of quantum effects displayed by this light. Examples of these quantum effects include antibunching, subPoissonian statistics, and novel nonclassical correlations, which are dramatic manifestations of quantum interference and collapse of the wavefunction. We are using these techniques to study other nonlinear optical systems. These studies are important not only from the fundamental point of view but also have potential for applications in fields such as atomic spectroscopy, precision measurements, and optical communications.

"We are also studying interaction of these nonclassical states with simple quantum systems



Stereoscopic pictures of Buckyball, courtesy of William H. Harter. Staring at these two pictures can reveal a 3-D image. Try it.

consisting of single two- and three-level atoms. The introduction of nonclassical light in these problems allows us to explore regimes which from the start have no classical analogs. The atom can be in free space or inside an optical cavity. Dissipation due to atomic and cavity decays is included. We are studying these systems in various limits involving weak field, strong field, weak coupling, and strong coupling approximations. All regimes are experimentally accessible. Our aim is to understand how the quantum nature of the atom-field interaction is reflected in the fluctuation properties of the emitted fields. An example of this is provided by the light scattered from a single two-level atom. Such an atom acts as a regulatory gate. It does not allow two photons to be scattered simultaneously. Thus the atom transforms the incident bunched photon sequence from a squeezed source into a more regular photon sequence resulting in a nonclassical reduction of noise. These studies are based on quantum mechanical density matrix equations, phase space representations, and Fokker-Planck equations.

"In collaboration with our Brazilian colleagues we are also investigating squeezing effects associated with the mechanical motion of an atom trapped in time dependent fields. We find that in Paul Trap for small magnetic fields the position quadrature is squeezed most of the time whereas the momentum quadrature is not squeezed. With increase in magnetic field, variances of position and momentum quadratures exhibit interesting patterns in time. We find regions of instability where variances of both quadratures continue to grow with time. Since an important purpose of trapping atoms is to minimize the center of mass motion, these studies will provide a better understanding of any fundamental limits on the residual particle motion.

"During the past ten years, I have taught various courses at the University of Arkansas at both graduate and undergraduate levels. The undergraduate courses include UP I, UPIII, physics for architects, mechanics, and electromagnetism. The advance level courses include theoretical physics, advance mechanics, mathematical methods, and quantum optics. I taught a short course on the recent developments in quantum optics in summer of 1992 at João Pessoa, Brazil."

William H. Harter, employed 1985. Fellow of the American Physical Society 1995.

This is the end of the statement provided by Dr. Reeta Vyas, April 1994, revised and edited March 1995.

Dr. Julio R. Gea-banacloche joined the department of physics January 1990 and describes his research and teaching interests in the e-mail message received March 1994.

"I do theoretical research in quantum optics. Some consider it to be a "watered-down" version of atomic physics since one considers only two or three atomic levels at a time. Over the past few years I have been focusing on the quantum-classical correspondence (the cor-respondence principle) and how it might apply, or not, to the case of radiation interacting with a single atom in a strong-coupling regime. That means a situation where spontaneous emission into other modes has been strongly suppressed. Lately I have started to work with Min Xiao (q.v.) on the theory of some experiments he has carried out on electromagnetically-induced transparency.

"I have taught UPII several times over, UPI twice, and a variety of graduate-level courses, including Math Methods I, Advanced Modern Physics I and II, Classical Electrodynamics I and II, Quantum Optics and Quantum Mechanics.

Allen M. Hermann, left, (1986-89), sixth chairman. Co-discoverer of thallium high-temperature superconductor and an accomplished trombone player. Moved to University of Colorado.

"Three graduate students came here with the express purpose of working with me on my research. I am a member of one of the organizing committees (quantum optics division) for this year's International Quantum Electronics Conference (IQEC '94). I have one NSF grant entitled "Cavity quantum electrodynamics and the quantum-classical correspondence" and had an ASTA grant when I came here. It was entitled "Coherence in open quantum systems."" Dr. Julio R. Gea-Banacloche, March 1994, edited March, 1995.

Dr. Min Xiao joined the physics department in 1990. In January of 1993 Dr. Min Xiao describes his work in the following paragraphs.

"Effects due to quantum fluctuations in non-linear interactions between laser fields and non-linear media have attracted great attention the past decade. Several predictions about the quantum nature of the electromagnetic field, such as photon antibunching, sub-Poisonian photon statistics, and squeezed states of light, were experimentally demonstrated. To use conceptually simple systems (such as the degenerate optical parametric oscillator, the intracavity second harmonic generator system, and a set of two-level atoms interacting with a single cavity mode) to study quantum fluctuations is very interesting, because such systems would provide a meeting ground for microscopic quantum theories and laboratory experiments. Studying these quantum effects is important not only in the fundamental sense, but also due to their potential applications. In some earlier experiments, we have demonstrated, in principle, that precision optical measurements (both in phase and amplitude) can be improved beyond the quantum shot-noise limit by squeezed states of light. These experiments have widened the prospects for the applications of squeezed states to various other precision measurements, such as gravitational wave detection, atomic spectroscopy, optical communication, optical gyroscopes, and optical computing.

"I am now interested in generation and applications of quantum nature of light, such as squeezed states of light and sub-Poissonian photon statistics, both experimentally and theoretically. It is particularly interesting to study interactions between these non-classical fields with two- or three-level atomic systems, where new physical phenomena are predicted to appear and to further improve sensitivity of optical precision measurements where the quantum shot-noise limit has been reached, such as FM spectroscopy.

"I am now working on new schemes of achieving lasing without population inversion in multi-level atomic systems. We have done some theoretical work on searching for more effective up-conversion lasers and for lasers with output intensity fluctuations below the standard shot-noise limit.

"We have built tunable solid-state

(Ti:Sapphire) lasers of different configurations. We use the second harmonic generation and the optical parametric oscillation in and out of the laser cavity to study nonlinear optical dynamic effects. We also generate quantum states from these nonlinear optical processes to interact with atomic systems. We are setting up experiments to test our models of lasing without population inversion in multi-level atomic systems.

"My other research interests include optical diagnostic techniques in materials, such as synthetic diamond films and high temperature superconductive materials.

"I taught Modern Physics Laboratory for graduate students and UP III Laboratory for undergraduate students during the school year 1991 and 1992. These involve standard laboratory experiments.

"I taught Advanced Electrodynamic Theory I and II for two years, during the Fall of 1990 and Spring 1992. These are graduate courses that have some relation to my research field of optics.

"I taught a high level graduate course entitled Optical Coherence Theory. This course deals with classical and quantum coherence theories. Since there was no standard textbook for this course, I taught this course out of research papers in the last then years up to 1992. This course was very closely related to my research in quantum optics, since, by definition, quantum optical coherence is part of the field of quantum optics. Teaching this course requires strong background in my research experience and knowledge." Dr. Min Xiao, January 1993, edited February, 1995.

STRUCTURE AND DYNAMICS OF POLY-ATOMIC MOLECULES

The following is quoted from material provided by Dr. William H. Harter dated January 1993

"If you remember your mechanics courses you might recall the strong resonance effects that occur between two identically coupled oscillators. Now imagine a configuration of sixty identical coupled oscillators and you will begin to picture the newly discovered C_{60} molecule called Buckminsterfullerence or "Buckeyball" for short. Evidence for the soccer ball shaped icosahedrally symmetric C_{60} molecule was found by chemists Kroto and Smalley at Rice University in 1985. Its structure remained controversial until it was identified spectroscopically and produced in larger quantities by physicists Huffman and Kratschmer at the University of Arizona in 1990.

"Their experimental work was stimulated by predictions for C_{60} rotational-vibrational spectra done at the University of Arkansas by William Harter and David Weeks beginning in 1986. A Macintosh program and various computer graphic techniques were used to analyze the 174 vibrational normal modes and their rotational behavior. The Macintosh microcomputer program produces 3D stereo movies of the molecular vibrations. Huffman borrowed this program in 1988. His first indication of the icosahedral structure was four peaks in a 1989 infrared spectrum of carbon soot. As predicted by the theory, only four resonances labeled Tlu escape the strict icosahedral dipole selection rules!

"The icosahedral symmetry of C_{60} is the highest possible symmetry that a molecule can have in three dimensional space. However, it has this extraordinary symmetry only if all the carbon atoms are identical, that is, only if they are all ^{12}C or all ^{13}C. Otherwise, it has no rotational symmetry at all! Here we have a case of the highest ideal or purest form being wrecked by a single neutron. The loss of symmetry has tremendous quantum mechanical effects because of the Pauli principle. ^{12}C has nuclear spin-0 so $^{12}C_{60}$ is a 'Bose-ball'. ^{13}C has nuclear spin-1/2 so $^{13}C_{60}$ is a 'Fermi-ball'. The combinations $^{13}C^{12}C_{59}$ are essentially classical balls but with less symmetry. The effect on the rotational-vibrational spectra is enormous; in a J=50 multiplet where $^{12}C_{60}$ has only two allowed lines, $^{13}C^{12}C_{59}$ will have 202, and $^{13}C_{60}$ will have a virtual continuum of 260 hyperfine structure lines!

"Computer graphical pictures of quantum rotor phase space helps to understand high resolution laser spectra of polyatomic molecules. Prior work here in the physics department has helped to understand laser spectra of molecules such as SF_6, SiF_4, and C_8H_8 and exposed new physical effects. Unusually strong couplings between vibrations, rotations, and nuclear spin moments were predicted and observed in SF_6. Analogous but much stronger effects are likely in the C_{60} molecule. SF_6 is composed of six spin-1/2 nuclei; $^{13}C_{60}$ has sixty! Graduate student Tyle Reimer is beginning to investigate these effects."-Dr. William G. Harter, January 1993.

Dr. Harter was honored for his work by being designated a Fellow of the American Physical Society in 1995.

SUPERCONDUCTIVITY

Dr. Allen M. Hermann came from the Jet Propulsion Laboratory in 1986 to become the sixth Chairman of Physics. He had been honored for some of his work by being designated as a Fellow of the American Physical Society before coming to the University of Arkansas.

His interest in superconductivity served him well here. He and Z. Z. Sheng, who had just received his Ph.D. under Dr. Paul Koroda in chemistry, formed a productive team. Professor Hermann once remarked that Dr. Sheng, who is now Research Professor of Physics, was one of the best chemists that he had ever worked with. Together they formulated the highest temperature superconductor in the world! Dr. Hermann left the University for the University of Colorado in 1989.

"High temperatures" from the standpoint of superconductor development in the late 1980's meant temperatures above liquid helium (4.2° k) and liquid hydrogen (20.4° K). Indeed, the boiling temperature of liquid nitrogen (77.3° K) was considered to be "high temperature" and it was a temperature relatively easy to obtain and maintain. The sublimation temperature of dry ice (195.5° K) is very hot in this frame of reference!

The following note is from Dr. Allen Hermann (1986-1989), famous for his work on high-temperature superconductors when at Arkansas in collaboration with Z. Z. Sheng. He is professor of physics at the University of Colorado at the date of this note, February 27, 1993.

"Dear Paul:

"Thanks for the note of Feb 1, 1993. Thought I'd better pen this before my trip next week to Japan—pardon the cryptic form.

"Research at UAF: discovered (with my post-doc Z. Z. Sheng) the world's highest temperature superconductor, Tl-Ba-Ca-Cu-O. We still hold the record for zero-resistance at about 128° K. This brought support ($1 million) from (then) Governor Clinton and the state legislature.

"Anecdote: (Gov.) Clinton, when he heard me play my trombone at the Fayetteville Hilton, said he'd have gotten us $2 million if he'd known I played so well.

"Left Fayetteville in December 1989 to become Professor of Physics at the University of Colorado at Boulder. Great place! Still working hard on Tl-based superconductors, particularly for thin-film microwave devices. And, of course, still playing my trombone!"

Best wishes,
Allen M. Hermann
Professor of Physics

Zhengzhi Sheng, co-discoverer of high-temperature superconductor.

The following material extracted from a May 1993 report prepared by Dr. Donald O. Pederson gives information relative to the discovery at the University of Arkansas of "high temperature" superconductors in the late 1980's. A little of the feeling of excitement which this work engendered at that period is also introduced.

"Prior to 1987, there was no published superconductivity research in the Department of Physics at the University of Arkansas. It is somewhat remarkable that in a department in which there was no research going on in superconductivity, an event as momentous as the discovery of the thallium high temperature superconductor (HTS) could occur. There was one important though little known connection prior to 1987 that linked the department to the superconductivity community.

"A bright electrical engineering student at the University of Arkansas joined the Department of Physics after his B.S.E.E. to work on a Master of Science degree in theoretical physics that he received in 1961 under Professor H. M. Schwartz. William L. McMillan then went to the University of Illinois where he completed a doctorate in 1964 under Nobel Laureate John Bardeen. McMillan is widely known for his development of an approximation known as the McMillan formula that enables one to predict the transition temperature of strong-coupled superconductors that complements the description of weak-coupled superconductors by the Bardeen-Cooper-Schrieffer (BCS) theory [W. L. McMillan, Phys. Rev. 167, 331, (1968)]. McMillan joined Bell Laboratories in late 1963 where he continued to make contributions to the understanding of superconductivity before he returned in 1972 to the University of Illinois as Professor of Physics.

"McMillan achieved recognition for his accomplishments in the field of superconductivity when he and two other researchers from Bell Laboratories received the 10th Fritz London Prize that the research community awards biennially at an International Low Temperature Conference. The University of Arkansas recognized McMillan for his accomplishments in 1979 with an honorary doctorate. McMillan met an untimely death in a bicycle accident near Urbana in 1984. [*Physics Today,* September, 1985, p. 92] It can only be a matter of speculation what McMillan might have contributed to the understanding of high temperature superconductors that continues to elude the best minds in physics.

"It was only a few years ago in September of 1986 that IBM Zurich physicists Karl Alex Muller and Johannes Georg Bednorz announced signs of superconductivity at near 30° K (-405° F) in lanthanum barium copper oxide (La-Ba-Cu-O). By January of 1987, Paul C. W. Chu at the University of Houston had confirmed these results and Bertram Batlogg and Robert Cava at Bell Laboratories announced that lanthanum strontium copper oxide (La-Sr-Cu-O) became a superconductor at 36° K (-395° F).

"By March of 1987, Chu and his coworkers had replaced the lanthanum in the IBM compound with yttrium and had seen the resistance of the yttrium barium copper oxide (Yt-Ba-Cu-O) drop sharply at 93° K (-292° F). These developments led to an explosion of research and publications in the field of high temperature superconductors (HTSC).

"During the spring of 1987, Allen Hermann was teaching introductory physics and discussed these new discoveries in his class. It was also during the spring of 1987 following receipt of his Ph.D. from the University of Arkansas in nuclear chemistry that Zhengzhi Sheng decided to work in the area of high temperature superconductivity. Sheng discussed the possibility of carrying out some of his ideas with two physics faculty members, Professors F. T. Chan and Allen M. Hermann, who was also chair of the department.

"Sheng's background in inorganic chemistry and experience with rare earth elements enabled him to make yttrium barium copper oxide (Yt-Ba-Cu-O) samples following the discovery by Chu. By the end of the spring of 1987 Sheng felt some urgency in beginning high temperature superconductivity research.

"Hermann, whose research previous to his 1986 appointment at the University of Arkansas included experiments on low temperature superconductors, tested some of the samples Sheng had made. The samples were as good as any samples in the country at the time according to Hermann. After discussions between Hermann and Donald O. Pederson, a member of the physics faculty who was then Vice Chancellor for Academic Affairs, in the Physics Building hallway in May of 1987, university funds were made available from the Graduate School. These funds provided for the appointment of Sheng as a research associate in the Department of Physics to pursue his ideas.

"In August of 1987, Sheng and Hermann announced a new process for creating high temperature superconductors that could be shaped, molded, or formed into wires. That had previously not been possible. Their new process also improved Chu's material to become superconducting at 95° K (-288° F), a slight improvement in the world record. Following this work the Arkansas Energy Office of the Arkansas Industrial Development Commission awarded Hermann and Sheng $140,000 beginning February 1, 1988, to continue work in high temperature superconductors. These funds required approval of the Joint Committee on Energy of the Arkansas General

Assembly and Governor Bill Clinton as authorized under Act 7 of 1981.

"One year after the initial 1986 discovery, Bednorz and Muller were awarded the Nobel Prize. In January of 1988, Sheng and Hermann announced the first rare-earth-free superconductor, thallium barium copper oxide (Tl-Ba-Cu-O), with a super-conducting transition beginning at 91° K (-296° F) which is above the temperature of liquid nitrogen at 77° K (-321° F). On the same day a Japanese group also announced a rare-earth-free superconductor using bismuth instead of thallium.

"On February 15, 1988, Sheng and Hermann announced a new record high of superconductivity at 122° K(-238° F) in thallium barium calcium copper oxide (Tl-Ba-Ca-Cu-O). [Z. Z. Sheng and A. M. Hermann, Nature 332, 138 (1988)] On February 2 the details of the discovery were presented as a poster session paper at the World Congress on Superconductivity in Houston. By March 3, 1988, scientists at IBM Almaden had taken the Arkansas material and the Arkansas discovery and had coaxed it to becoming superconducting at 125° K (-235° F).

"Thus in early 1988, researchers at the University of Arkansas and the Department of Physics led the world in the search for higher temperature super-conductors. More than five years later as of, May 1993, the record still stood. Sheng and Hermann have been widely recognized for their discovery.

Claud H. Lacy, astronomer, employed

"The discovery at Arkansas came about in part because of the involvement of undergraduates in the research. When the undergraduates did some of the preparation work slightly differently, it led Sheng to try a different preparation technique that resulted in the thallium compound.

"This discovery put Sheng and Hermann, the Department of Physics, and the University of Arkansas on the national science map with articles about their work in the *Wall Street Journal*, the *New York Times, National Geographic,* the *Chronicle of Higher Education, Superconductor Week, Newsweek, Science News, Business Week, Research & Develop-ment, Physics Today,* and *Science*.

"Governor Clinton announced on June 15, 1988, an Arkansas Energy Office award under Act 7 in 1981 that was the largest grant from the state in support of a particular research project. The amount of the grant was for $1,007,796 beginning July 1, 1988, and was to continue high temperature superconductivity research. The grant followed a demonstration of superconductivity levitation before the Committee on Energy and Governor Clinton.

"While IBM received the first patent for a thallium compound superconductor as reported in October of 1989 [Robert Pool, *Science* 246, 320, (1989)], it was only for a process of making the compound and not for the compound itself. Sixteen patents had been issued by April of 1993 on the high temperature superconductivity research at the University of Arkansas. The primary patents on the 120° K thallium compound were licensed to Superconductor Technologies Incorporated (STI) with headquarters in Santa Barbara, California, on April 10, 1992. The University and the inventors will receive over $1 million in license fees and 400,000 shares of Class D stock of the company. STI went public on March 9, 1993, at $10 per share and in the week ending April 23, 1993, was trading in the NASDAQ national market (as SupTech) at a low of 61/2 and a high of 83/4 on a volume of just over 200,000 shares.

"During the period of collaboration between Sheng and Hermann, the publications on their research in refereed journals numbered 3 in 1987, 15 in 1988, 13 in 1989, and 1 in 1990, including 3 in Nature and 2 in Physical Review Letters. Hermann left the University of Arkansas in January of 1990 for a position at the University of Colorado. Sheng has continued to carry out research on new high temperature superconducting materials primarily by elemental substitution and has published 28 additional refereed articles over the period 1990-1992.

"Professor William G. Harter became interest-

Prof. S. K. Haynes, Michigan State University Dept. Head, was brought in by the Graduate Dean to review the physics doctoral program.

ed in the levitation effects of the high temperature superconductors in 1988. [William G. Harter, A. M. Hermann, and Z. Z. Sheng, Appl. Phys. Lett. 53, 1119 (1988)] This lead to development of one of the earliest high temperature superconductor magnetic bearings by his doctoral student David E. Weeks who reported on the work in 5 publications. A patent was obtained based on this work also.

"Pederson began looking for additional funding for the high temperature superconductivity effort in late 1990. In early 1991 a group of faculty from physics and engineering submitted a proposal for a thin film center to the National Science Foundation. This proposal was not successful but formed the basis for discussions with the Defense Advanced Research Projects Agency during the spring of 1991. These discussions occurred during a time when DARPA was reducing their support for various superconductivity consortia. DARPA was moving their support to teaming arrangements doing more mission oriented research and development that might take advantage of the advances in not only high temperature superconductivity but also in the development of crystalline diamond thin films. The University benefited tremendously from the guidance of Dr. Al Joseph, formerly with the Rockwell Science Center, and Bruce MacDonald in Senator Dale Bumpers' office in discussions with the Defense Advanced Research Projects Agency and in developing cooperative arrangements with industry.

"The proposed work evolved into support from E-Systems of Dallas, Texas, and Norton Diamond Film of Northborough, Massachusetts, on projects focus-ed on advanced multichip modules (MCM). These modules are substrates upon which the bare semiconducting chips are attached and interconnected using printed circuit techniques, incorporating high temperature superconducting interconnects and thin film substrates. While the advances in high temperature superconductivity gave the University of Arkansas credibility in any project concerned with high temperature superconductivity and certainly opened the door to this additional funding, the goals of both companies and DARPA emphasized the application of high temperature superconductors to improving multichip modules rather than basic material research being carried out by Sheng.

"The High Density Electronic Center (HiDEC) was created at the University of Arkansas to establish the University's presence in the multichip module (MCM) arena. A MCM facility valued at over $1 million was built at the Engineering Research Center to enable MCM research and development to be carried out on campus. The high temperature superconducting thin film development of Chan, Salamo, Sheng and coworkers supported by the bulk HTSC work of Sheng fit very well into the High Density Electron Center (HiDEC) work initially. But as the HiDEC project addressed specific goals of companies and agencies, it moved to more mission directed research and away from curiosity driven research. Chan and Salamo continue to pursue research in laser ablation of thallium thin film superconducting materials using some of Sheng's techniques and provide the closest link between the physics department and HiDEC in

Eugene Wigner of Princeton University shaking hands with graduate student Keith Andrews after his talk at UALR in March of 1984.

the arena of superconductivity.

"The final verse on high temperature superconductivity has perhaps not yet been written. While the discovery of Sheng and Hermann is no longer the world record holder, Sheng continues to pursue new materials with the possibility of new, even higher temperature superconductors ever present. While the University of Arkansas has teamed with industry to do research and development in one aspect of the use of high temperature superconductors, it is an open question whether this will lead to success and expansion of the effort. While the University of Arkansas has licensed its thallium patent to an entrepreneurial company, Superconductor Technologies Incorporated, the success of this company in the marketplace also is an open question.

Professor Norman Ramsey talked to students and faculty in

"While much basic and applied work in high temperature superconductivity remains to be done, the Physics Department's role in the development of a mature technology and an understanding of the phenomenon will depend to a large extent on its current efforts. Regardless of these possibilities, the University of Arkansas, the Department of Physics, and Sheng and Hermann will remain a significant footnote in the annals of important discoveries."

The above very informative and complete report on the spectacular Sheng and Hermann discoveries was prepared for Physics Department Chairman Rajendra Gupta by Donald O. Pederson in May of 1993 and corrected in May of 1995. Dr. Pederson was formerly chairman of physics and is now serving the University in his capacity as Vice Chancellor for Academic Affairs. This report is reproduced here by permission of Dr. Gupta and Dr. Pederson with only minor editorial changes. The complete version is housed in Special Collections of the University of Arkansas Libraries.

Astronomer William A. Hiltner visits ca 1965.

Dr. Zhengzhi Sheng summarizes his work and interests and the ongoing activities in the superconductor laboratory in a flier prepared in 1994 for posting in the physics department.

"The Superconductor Laboratory is the discovery place of the Tl-based superconductors—one of the high Tc superconductor families with the highest Tc and the most useful properties of applications. Since 1987, under the support of the Arkansas Energy Office, the Superconductor Laboratory has discovered a number of new superconductors, especially Tl-based superconductors both in bulk and thin film form. About 20 patents were awarded by the U. S. Patent and Trademark Office, and the patents related to the Tl-Ba-Ca-Cu-O superconductors were transferred to Superconductor Technologies, Inc. for commercialization.

"The ongoing work of the Superconductor Laboratory includes the search for new and even higher temperature superconductors, the improvements of Tl-based and Hg-based superconductors (including high-pressure synthesis), the thick and thin film deposition, and the theoretical understanding of the high Tc superconductivity. It would be necessary to expand the Superconductor Laboratory to a Superconductor Research Center in order to attract more funding. The Center would carry out research on high Tc superconductors in all fields: Basic (theory, basic physical properties, and new material search); bulk and wire (bulks, single crystals, and wires, and related applications); and film (thick films, thin films, and related applications)."

This is the end of the statement by Dr. Zhenegzhi Shen prepared fall, 1994.

ASTRONOMY

Dr. Claud H. Lacy was the second professional astronomer to be employed, having joined the de-partment in 1980. Carol Webb was the first professional astronomer.

The following is extracted from material provided by Dr. Claud H. Lacy dated January 1993.

"I am participating in a collaborative effort with co-workers in Texas, Arizona , and California to determine accurate fundamental astrophysical data about stars in eclipsing binary and multiple star systems. The types of data we are able to provide include orbital parameters, masses, radii, luminosities, and internal structure of the stars. In order to determine these data we need to obtain both the brightness as a function of time (the light curve) of the eclipsing binary and the radial velocities of both stars as a function of time (the RV curve).

"It is possible to measure light curves of these eclipsing binaries with a relatively small telescope. For this purpose we are using telescopes in Chile and at the University of Arkansas Droke observatory near Fayetteville. These telescopes are observing the eclipsing binaries to obtain light curves. Radial velocities are derived from spectra which must be obtained with large telescopes. We are using telescopes at McDonald Observatory in Texas and Kitt Peak National Observatory in Arizona to obtain digital spectra of our program stars. Radial velocities are extracted from the spectra with main-frame computers on campus.

"Numerical models can be fitted to the photometric and spectroscopic data to derive fundamental astrophysical parameters such as the masses and radii of the stars. We can often determine these data to an accuracy of 1% or better at present. We are now experimenting with new techniques to push these investigations to much higher levels of accuracy – better than 0.1%. At these levels of accuracy the observations can serve as a critical test of theories of stellar evolution - theories which cannot match the observations must be rejected. There are now indications that current theories are not capable of explaining all the observations. This may have a profound effect on astrophysical theory.

"Two junior-level astronomy courses are regularly taught: Stellar System Astronomy (ASTR 3053) and Solar System Astronomy (ASTR 3033). The only senior level astronomy course regularly taught is Astrophysics (ASTR 4013), which covers stellar and interstellar astrophysics, extragalactic astronomy and cosmology. We usually have 6 to 10 students in the course."-Dr. Claud H. Lacy-January, 1993, edited February 1995.

Graduate Program Review

There have been two reviews of the Ph.D. program in physics. In the first of these reviews carried out in the late 1960's, Dean Adkisson of the graduate school listed two persons who would be available to come to Fayetteville and spend approximately a week looking over every aspect of the doctoral program within the department. The person chosen by the department to do this review was Professor S. K. Haynes of the department of physics of Michigan State University.

He reported to the department chairman and was given a desk, the old roll top previously used by Ripley and Ham, and he spent the whole week collecting information from within the department and from others.

He wrote his report and sent a copy to the graduate dean and to the physics department chairman. Professor Haynes sympathized with the needs of a growing department and was indeed rather complimentary of our efforts. He reiterated what we already knew and emphasized the need for a stronger base of research support personnel.

The second review of the physics doctoral program was done by a local Committee on Professional Education, called COPE. This study was done in 1980 and the committee visited several departments and studied the program. The department was required to provide in depth information about its program, the grants, the number of degrees, the faculty and graduate student activities, and courses.

It was during this time that the physics faculty decided to emphasize laser physics and quantum optics. Also as a part of the desire to define its program, a report was written in which is was stated that the only way that physics would be recognized on a national scale would be through its research program. While this was doubtless true, there was some objection that teaching was taking a back seat. In fact one rather literary professor on that very select committee wrote a strong dissenting report.

The following is an excerpt from the dissenting or "minority report" dated October 31, 1979 written by Dr. Phillip Bashor of the philosophy department, a member of the Physics Evaluation Committee. The report was sent to John C. Guilds, Dean of the College of Arts and Sciences, with a copy to the physics department chairman Donald Pederson.

"Bernard Madison's report on the Physics evaluation refers to my exception to the research emphasis being made therein.

"I would appreciate the inclusion of the whole paragraph giving context to the statement