RLE currents

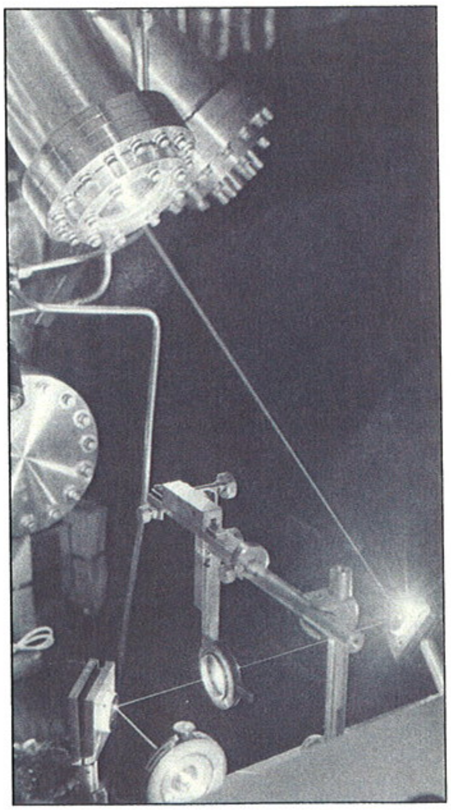
Volume 5, Number 1 • Fall 1991

The Research Laboratory of Electronics at the Massachusetts Institute of Technology

PATHWAYS TO THE FUTURE AT RLE

Forty-five years ago, the Research Laboratory of Electronics emerged from MIT's wartime Radiation Laboratory with an emphasis on radar and physical electronics. Today, the laboratory continues to study all aspects of electronics and optics, but its concern with information processing has led to a large activity in language, speech, and hearing as well. In addition, RLE research groups focus on atomic and molecular physics, radio astronomy, plasma physics, signal processing, electromagnetics, and communications. Research in RLE is highly interdisciplinary, bringing together investigators with many diverse backgrounds. In order to both understand a broad array of phenomena, as well as construct complex systems, studies dwell at the extremes of size (smallest and largest), time, and frequency. Many other themes will also emerge from a broad sampling of RLE research, providing a sense of the vigor and excitement within the laboratory.

Perhaps the most overwhelming characteristic and driving force of much of RLE's research is the rapid growth of new technology. Techniques for making structures only a few hundred angstroms in size have revealed new physics and device opportunities, and fine-tipped electrodes are used routinely to probe the neural basis of behavior. Lasers are used almost everywhere, and complex machines for epitaxial growth allow control at the single monolayer level. Computation plays a central role in much of the lab's research, and small-scale toroidal magnetic confinement systems probe the fundamental properties of plasmas while large-scale cyclotrons provide the focused energy to study surface behavior in electronic materials. Indeed, the continuing discoveries afforded by these technological means are exploited to build the next generation of technology, opening up new areas of study and invention.



During the metalorganic molecular beam epitaxial growth process, a low-power laser beam illuminates the front surface of a thin film in order to enhance its growth rate. Enhanced growth has important implications for selective area epitaxy and in situ *tuning of surface stoichiometry, the numerical relationship of elements and compounds as reactants and products in chemical reactions. (Photo by John F. Cook)*

As the name of the laboratory suggests, electronics has been a continuously evolving research focus, where much of the emphasis is on making ultrasmall structures and devices. In the vertical dimension of growth, single monolayer control allows for a wide variety of quantum wells utilized through "bandgap engineering" to form new devices. In the planar dimensions, however, while lithographic control extends well below 1,000 angstroms, there is new interest in chemical forms of self-organization to provide structures at a degree of resolution that cannot be achieved by any direct, external control method. A whole new area of study, called "mesoscopic physics," explores phenomena in devices which are smaller than a tenth of a micron, but not as small as individual atoms. At this level, new theories of transport are being developed, and the recent discovery of a "single-electron

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FIGURE 1

FIGURE 2

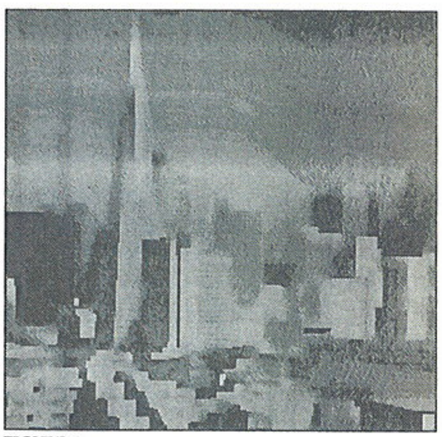


FIGURE 3

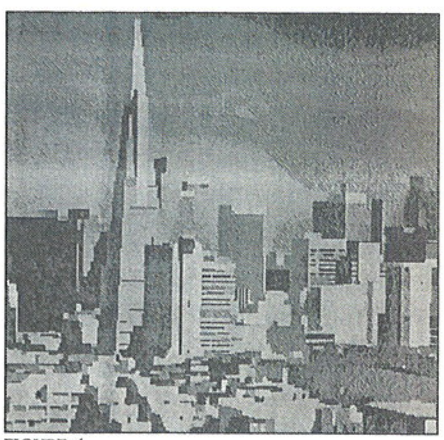
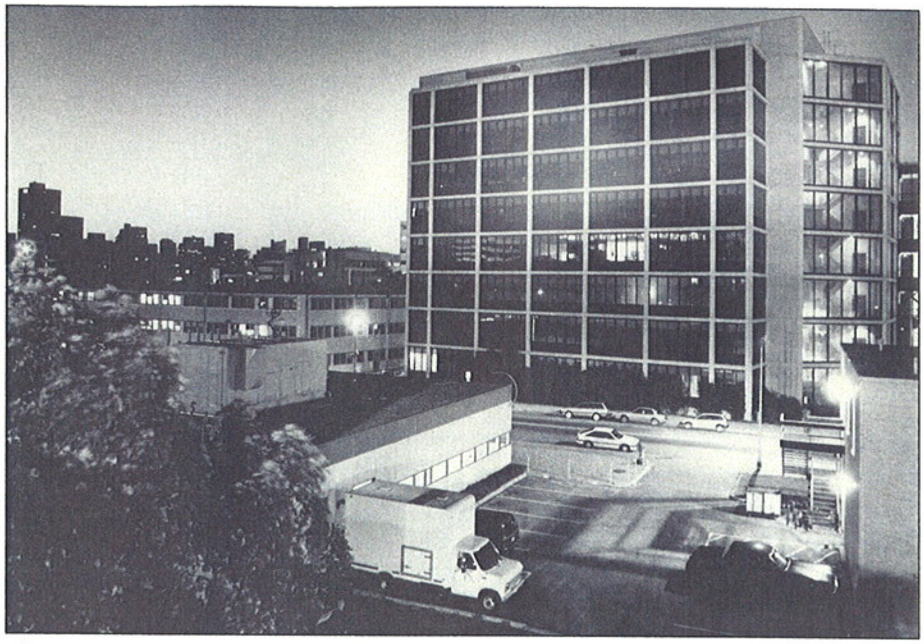


FIGURE 4



The dawn of a new day at the Research Laboratory of Electronics at MIT. (Photo by John F. Cook)

Left: Analog VLSI chips for machine vision are being built in RLE using circuit simulation methods. Figure 1 is an unprocessed 256x256 pixel image of San Francisco. Figure 2 is the result of linear smoothing operations to remove noise, which necessarily blurs the desired image as well. A nonlinear circuit element can be used to restrict the smoothing operation at intensity edges where the brightness changes suddenly (as in Figures 3 and 4). The processing in Figure 4 smoothes out much of the detail that would often be unnecessary in machine vision applications. A 32x32 microchip that can perform this process in a few tens of microseconds is currently being tested.

PATHWAYS TO THE FUTURE

(continued)

transistor," which turns on or off with the arrival of each new electron at its gate, has not only challenged theoretical understanding, but also raises questions as to how these devices can be exploited in novel circuit forms. Innovative techniques for theoretical and experimental surface studies are revealing new surface states and providing increased understanding of the semiconductor growth process at a detailed atomic level. In time, this understanding should form a rigorous basis for the control of epitaxial growth in highly complex devices which are designed and fabricated to atomic-level tolerances.

Optics research centers around the continuing evolution and sophistication of lasers. Future emphasis will be on very small semiconductor lasers, ren-

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RLE

dered highly stable through adaptive modelocking, which are often fabricated in the lab by novel epitaxial techniques. In order to avoid the limiting effects of shot noise, "squeezed states" of light have been introduced through innovative techniques of "rearranging photons." In this way, although the total noise cannot be reduced below the quantum limit, parts of the wave can be constrained to have lower noise. Hence the limits to precision demanded by the uncertainty principle are evaded through redistribution of the uncertainty. Together with the introduction of erbium (Er) into optical fibers to provide distributed gain without electronic amplification, use of these squeezed states of light provides the means for exceedingly long fiber lines (*e.g.*, transatlantic) that don't require active repeaters to restore the signal.

There is great interest in the use of solitons for optical transmission and switching. Solitons are waves whose shape remains invariant with transmission or collision among themselves. These intriguing pulses have dual wave-particle properties, and achieve their uniqueness through a self-organized balance of sharpening (due to nonlinearities) and spreading (due to dispersion). Since solitons can be squeezed more than classical light pulses, they are excellent candidates for future optical systems. RLE continues to emphasize the generation of ultrashort light pulses, which measure only a few tens of femtoseconds in duration. Here is another example of the exploitation of the intrinsic nonlinear properties of optical materials to iteratively delay the phase of the leading edge of the pulse while advancing the phase of the falling edge of the pulse, yielding a pulse whose length is constrained by the inherent response of the materials used rather than by any explicit external control.

Early RLE studies of gaseous discharges in vacuum tubes used for radar has led to a continuing evolution of studies of plasmas and concentrations of charged particles. Motivated by the

(continued on page 4)

SHORT CIRCUITS

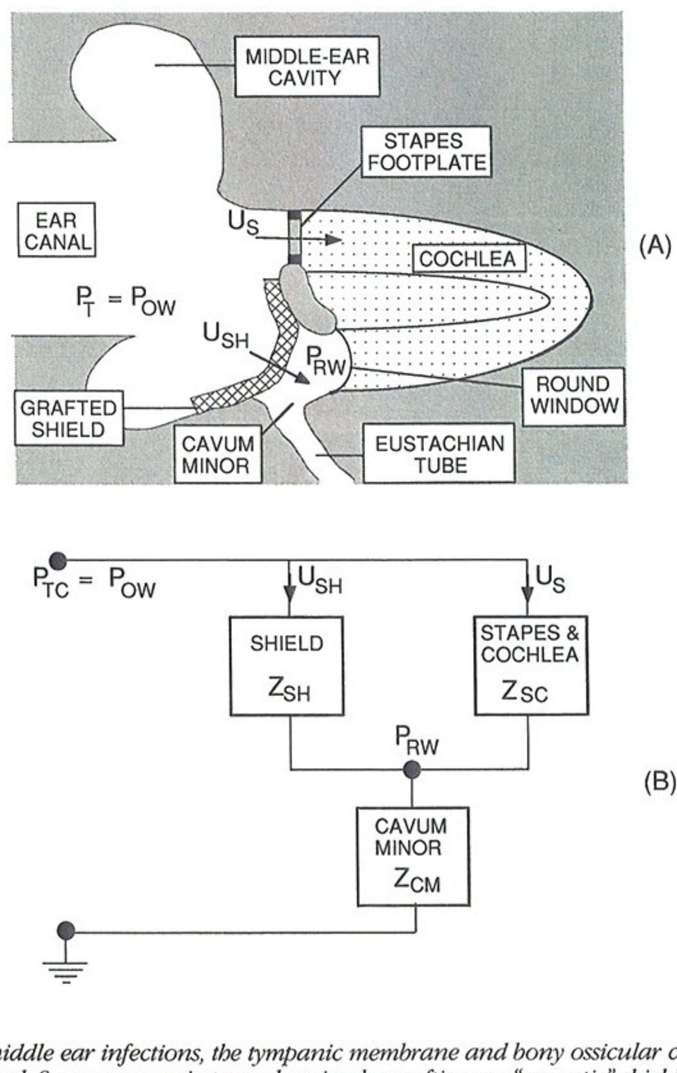
The staff of ***currents*** would like to note the following corrections to the Spring 1991 issue:

Due to an editorial error, Professor Abraham Bers was incorrectly identified in "Please Be Seated" on page 11 as a Physics faculty member. Professor Bers has been affiliated with MIT's Electrical Engineering and Computer Science Department since 1959.

The correct title of RLE's 20th anniversary commemorative booklet, referred to in the "Directors' Profile" section, is *RLE: 1946 + 20*.

The correct name for Harvard University's wartime laboratory, mentioned on page 5, is the Harvard University Radio Research Lab.

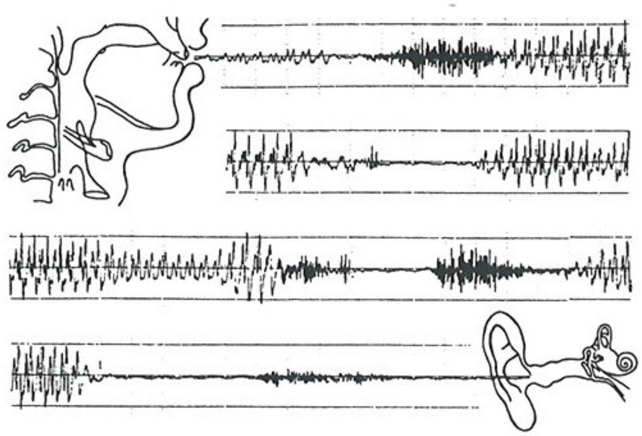
Editor's note: The reference list for further reading on MIT's Radiation Laboratory (pages 10 and 12) mentioned that no single book details the history of the laboratory. Dr. Helen L. Thomas, a former RadLab and RLE employee, reminded us that a history is contained in volume 8 of *The History of Modern Physics 1800-1950*, by Henry E. Guerlac (American Institute of Physics and Tomash Publishers, 1987). Also, a personal history has been written by RadLab staff member Ernest C. Pollard in his book *Radiation* (Woodburn Press, 1982).



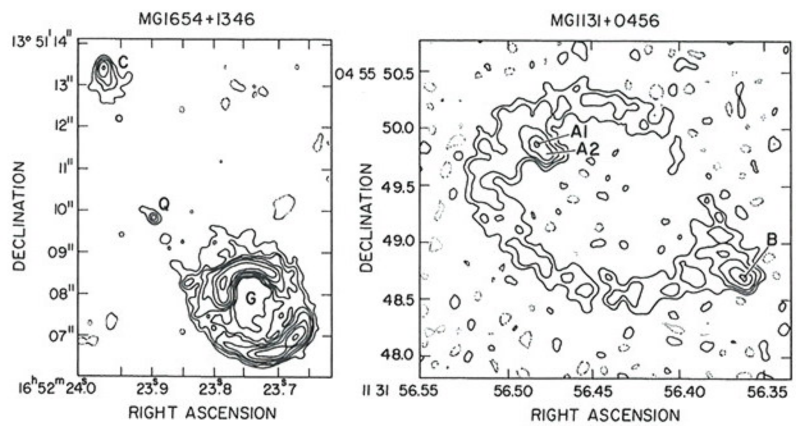
In chronic middle ear infections, the tympanic membrane and bony ossicular chain are often destroyed. Surgeons can improve hearing by grafting an "acoustic" shield into the middle ear. The graft increases pressure between the two cochlear windows by preventing sound from acting on the round window while allowing it to act on the stapes footplate in the oval window. The acoustic-circuit analog (B) shows which constraints on the mechanical properties of the shield and the space that encloses it are important for the operation of the acoustic coupling system.

search for practical fusion methods, the theoretical basis for plasmas in toroidal machines as well as experimental studies of plasma behavior in magnetic tokamaks continue to be developed in RLE. These confined plasmas are extremely complex, and theories of spatio-temporal chaos are being developed to characterize their turbulence-like behavior. Just as self-organization is a property of many of the systems under study in RLE, chaos is also emerging as an important new focus, since it exemplifies the behavior of many nonlinear dynamical systems. In fact, the kind of complexity found in these nonlinear plasmas arises from both chaos and self-organization, whereby the global properties of the plasma are built on local interaction of many particles. Of course, not all plasmas are confined, as in a tokamak, and theoretical studies are characterizing the magnetic connection of large space plasmas. Investigators in the plasma area are also building new devices that will coherently bunch charged particles to provide high-power pulses of coherent radiation over a substantial tunable range of frequencies.

In an increasingly wide set of applications, investigators continue to build on fundamental electromagnetic theory. These range from electromagnetic propagation in the interconnect structures of modern computers, through remote sensing of the Earth's terrain, to the assessment of frequency allocations in microwave landing systems and the electromagnetic behavior of superconducting electronic systems. Satellites are used to sense terrestrial properties, but RLE's radio astronomers also use these space-based platforms to sense atmospheric properties and radio emissions from celestial bodies. The introduction of experimental Michelson stellar interferometers for radio observation of the heavens has led to a succession of very-long-baseline interferometer (VLBI) systems. At first, these systems incorporated several antennas spatially distributed on Earth, but now they are being designed for satellite deployment in orbits nearly 100,000 kilometers above the Earth, providing a tenfold increase in angular resolution over terrestrial systems. The exploitation of satellites to enhance studies of extremely distant structures typifies the technology-driven nature of much of RLE research and illustrates the largest scientific instrument presently contemplated by RLE's scientists.



Steps in the speech chain: On the upper left is a cineradiographic tracing of a speaker's vocal tract pronouncing the sound "n." In the center, the sound pressure signal for the utterance "speech communication" is illustrated. On the lower right, the ear represents the first step in the sequence of audition, perception, recognition, and understanding. In RLE, speech communication research includes studies of normal and impaired speech generation processes, the control and coordination of articulatory movements in speech production, the mechanisms of sound generation in the vocal tract, and the simulation of these processes by a speech synthesizer.



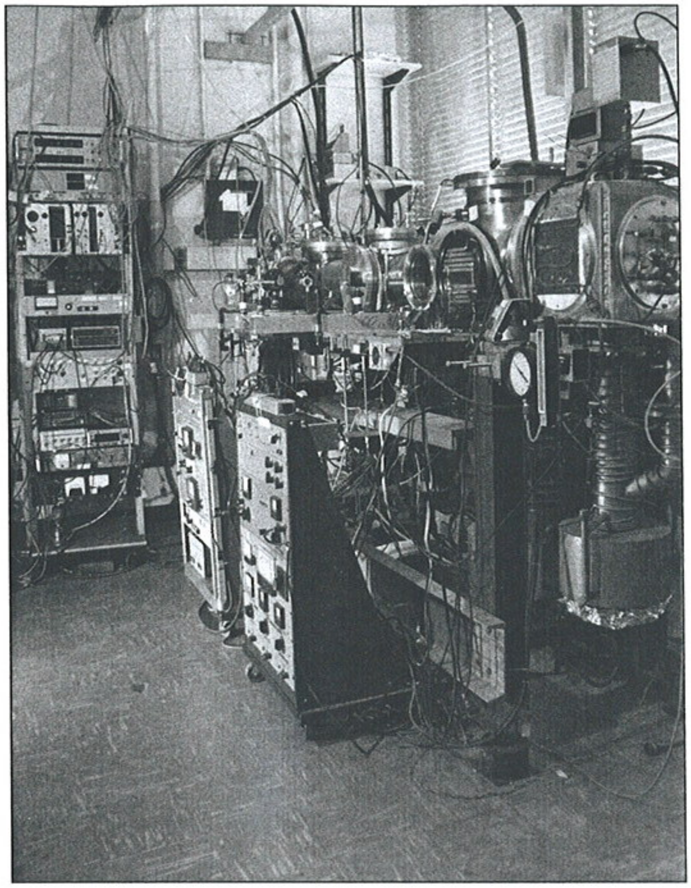
The Einstein ring phenomenon occurs when a radio source is in line with a foreground galaxy whose gravitational field bends the radio object into an apparent ring. An Einstein ring is a particularly symmetric case of gravitational lensing, and received its name when Albert Einstein suggested the deflection of starlight by the sun, followed by the appearance of a ring if the stars were perfectly aligned. These first two examples were discovered by RLE radio astronomers in the MIT-Green Bank Survey.

Another area of basic study emanates from RLE's early focus on atomic, molecular, and optical physics. Precision lasers and gratings, coupled with the ability to isolate atoms and ions in low-temperature magnetic traps, have significantly extended the precision of standards for length, time, mass, and rotation. Following the predictions of quantum mechanics, an "atom interferometer" has been built which provides a wavelength about 10,000 times shorter than light. It is now being exploited for dramatic improvements in metrology. While the theoretical benefit for rotation sensing (used in navigation) is as high as ten orders of magnitude, a practical gain of about three orders of magnitude is being sought which will provide many new capabilities. Adaptations of these techniques are also expected to result in approximately two orders of magnitude improvement in time and mass measurements, heralding the next generation of

A

B

Figure A is a segment of a movie frame displayed on a National Television Standards Committee monitor using the current U.S. broadcast standard. Figure B is a segment of the same movie frame displayed on an advanced television monitor that was obtained using RLE's Advanced Television Research Program's source-adaptive method. This method does not require any modification to the transmitter, thus it is receiver-compatible.



An atom interferometer has been constructed in RLE that uses three microfabricated diffraction gratings to split and recombine a beam of sodium atoms. This device will be used to investigate atomic and molecular structures and probe fundamental questions on quantum mechanics. In the future, atom interferometers will be used to make ultrasmall structures using atom holograms. (Photo by John F. Cook)

atomic clocks and mass spectrometers. (The first practical atomic clock was invented in RLE.) New techniques are also being exploited to create an absolute optical frequency reference accurate to one part in 10^{11}. In the long run, this capability will facilitate the development of techniques for measuring and controlling optical frequencies, as well as provide an improved standard of accuracy for the measurement of length by optical means.

In natural systems, the generation of complexity through nonlinearity and self-organization is apparent, but RLE investigators also build techniques for the correct and optimal design of large, complex systems such as integrated circuits. Tasks that involve the computation of three-dimensional capacitance use bunching techniques similar to those used for coherent radiation generation and the derivation of energy functions for semiconductor surfaces, which reduce the complexity of the problem significantly. Integrated circuit design must deal with another form of complexity due to the use of several levels of abstraction (*e.g.*, circuit, logic, architecture) for design specification and optimization. Techniques are being introduced which manage both the abstraction and compositional hierarchies, providing a design that automatically evolves in these dimensions in a correct and consistent way. These procedures also contemplate the utilization of multilevel optimization in complex systems, where criteria are integrated from each level of abstraction according to a unified performance metric in order to achieve the best overall design. An example of this integration is the recent invention of techniques to combine logic synthesis with procedures to guarantee complete testability of the system. Previously, testing was often treated as an afterthought in the design process and resulted in incomplete testability. Future systems, however, will be designed for complete testing of both static and dynamic behavior, which will be essential for such large, complex systems. Not only can these new design techniques be applied to electronic (*e.g.*, VLSI) systems, but there is also increasing interest in developing a design metatheory, together with a generic set of design tools, that can be utilized in many different fields of design.

Interest in natural language arose from RLE's concern with information generation and reception. At one time, information theory was a major activity in the lab, but there has long been a strong effort to study human communication through natural language, with

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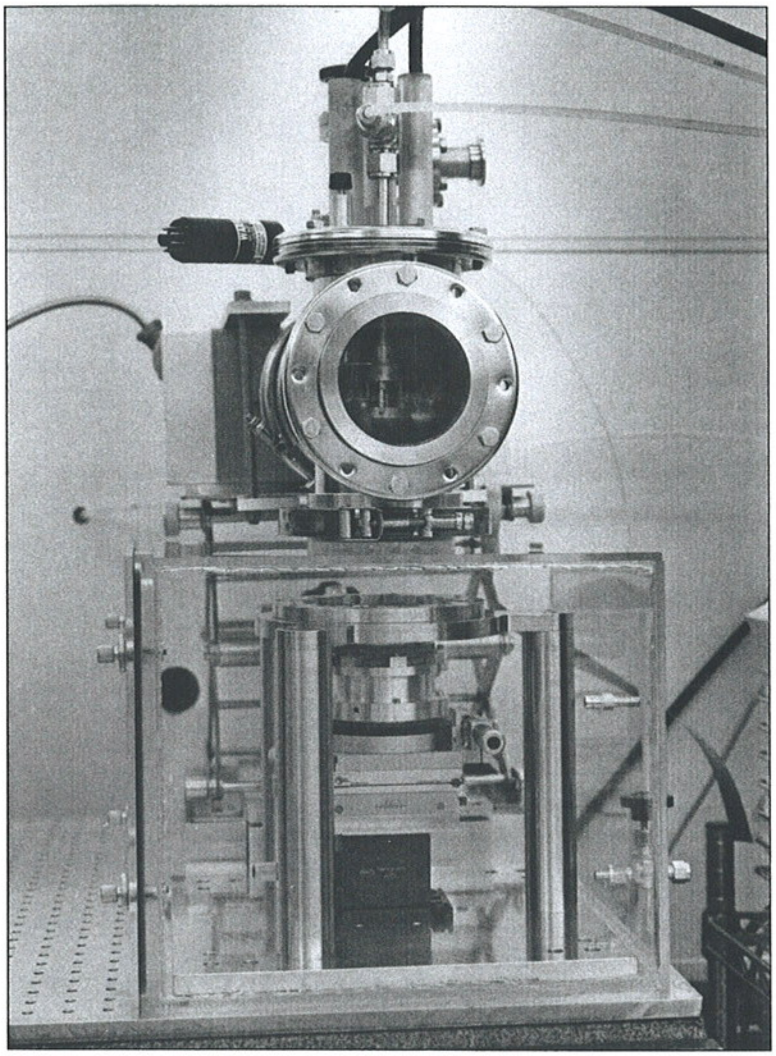
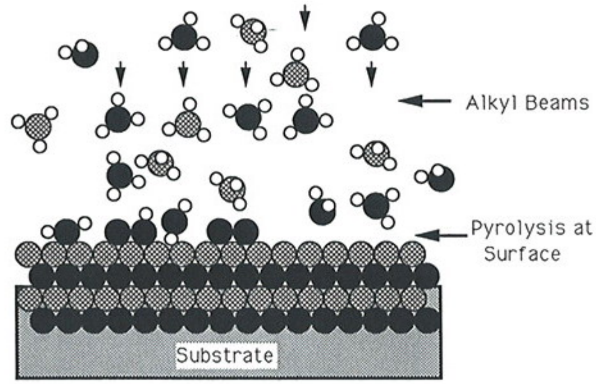


Since 1978, RLE's Submicron Structures Laboratory has pioneered technologies in submicron structures fabrication and explored deep-submicron metal oxide semiconductor field-effect transistors (MOSFETS) and the new field of quantum-effect electronics. This system for x-ray nanolithography is capable of reproducing 20-nanometer features on device substrates. (Photo by Alberto M. Moel)



A schematic representation of the chemical beam epitaxy growth process. As metalorganic and hydride molecules (such as dimethylzinc and hydrogen selenide) impinge onto a heated single-crystal substrate (such as gallium arsenide), thermal pyrolysis of the gases occur. This epitaxially forms a single-crystal thin film of zinc selenide onto the gallium arsenide surface.

particular emphasis on speech and hearing. Speech production has provided a great challenge to both experiment and theory, and the description of articulation (*e.g.*, the motion of the larynx, tongue, and lips) remains a major goal. Great progress has been made in characterizing the acoustic basis of speech production, which has led to successful designs for speech synthesis. Nonetheless, there is still much to understand about the way in which timing and pitch contribute to naturalness in speech, and how speech synthesis systems can be trained to a desired dialect.

Speech perception is an equally complex process, and RLE investigators continue to study the physiology of the auditory periphery as the first way station in the perceptual process. Activity at higher brain centers is also important for perception, and future systems will have to integrate many constraints based on language redundancies in order to match the human ability to understand speech in an infinite variety of environments. To date, speech recognition capability has been based largely on trainable stochastic mathematical models, but performance has been on a slowly improving plateau for some time, and new understanding from basic studies will be needed to continue this progress.

Visual perception models are also being built by RLE's investigators. One highly interdisciplinary study is building a "smart" vision microchip that can detect shapes and motions in real time using custom analog circuitry. In this project, a combination of technology, circuit design and simulation, algorithm innovation, and an understanding of human visual physiology are used to achieve the total fabricated system. This multi-investigator approach to such problems will undoubtedly become more frequent as increasingly complex systems are designed.

The tactile perceptual modality has been studied in RLE for many years, including use of the Tadoma method for communication by the deaf-blind. Recently, interest in the tactile perceptual mode has increased because of its use in teleoperator systems, where remote objects can be manipulated and felt as if the user was physically present in the object's environment. The ability to tactilely detect pressure, shapes, and textures is central to teleoperator systems. This capability is extended further in virtual environments, where computer-controlled fields of stimuli and receptors simulate an environment that does not exist physically. Flight simulators built as virtual environments are an example of such a system. Virtual environments are expected to grow rapidly since there is great opportunity plus a pressing need for comprehensive means of communication between computers and their human users.

RLE's long-standing interest in human sensory and motor performance has always emphasized techniques which alleviate pathological dysfunction and the development of prosthetic aids for the handicapped. Novel hearing aids are being developed in addition to a large project devoted to cochlear prostheses, which utilize arrays of electrodes inserted in the inner ear to improve hearing. Multiple microphone arrays are being used as a preprocessor to help localize sound sources for both of these classes of hearing aid.

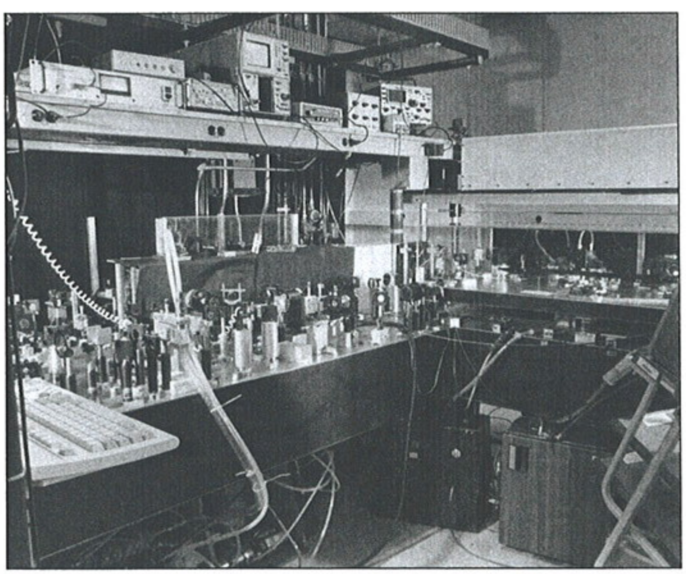
In the visual domain, the original motivation for the lab's research in text-to-speech conversion was to provide a reading machine for the blind, a goal that has already been achieved. Today, a project to design an artificial retina combines novel use of electronic materials, artificial neuronal stimulation, and low-power circuitry that can sense light patterns and generate corresponding stimuli to optical ganglion cells. This interdisciplinary project exemplifies fundamental studies that serve a direct need of society. It is no wonder that faculty and students alike find these efforts highly challenging yet very rewarding.

Virtually all RLE research is concerned with signals, either human or man-made. Accordingly, there has been a long-term emphasis on signal processing, which in recent years has been focused mostly in the digital domain. RLE investigators are designing a high-definition television (HDTV) system which is a *tour de force* of modern signal processing. In HDTV, a complex signal must be squeezed into a small spectral band at low power, transmitted with high resistance to interference and noise, and still provide a very high-quality image at the receiver. Techniques of motion compensation and information coding are designed with human visual perception in mind, regardless of the type of image transmitted.

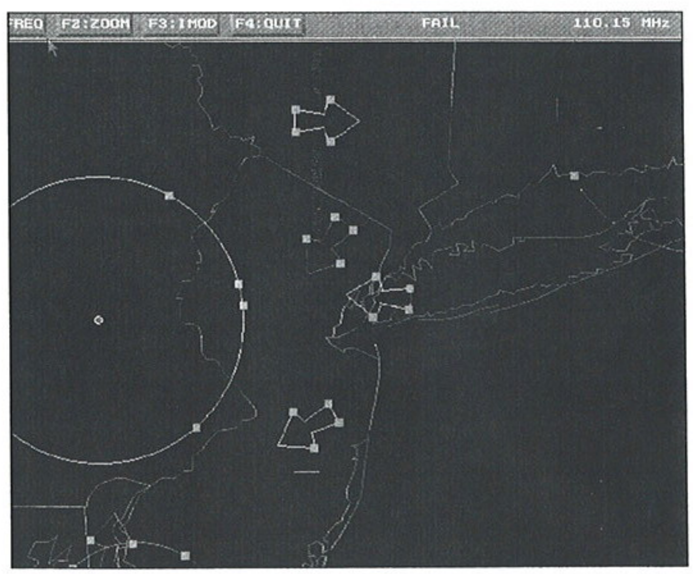
An important new area of research in signal processing is arising from the study of nonlinear dynamical systems by many RLE groups. These systems often lead to chaotic behavior, and also exhibit fractal properties since their corresponding signals have the same structure at any level of scale. $1/f$ noise is an often-cited example of such a signal, and a new class of orthogonal basis functions, called wavelets, has been introduced to describe fractal signals, which are increasingly found in nature.

RLE's evolving research is highly diverse in many respects. There are, however, common themes that characterize the laboratory's future directions. Technology is providing improved probes, permitting the study of individual atoms and carriers, and measurement accuracy is being dramatically extended. Computing is being used everywhere in many ways, including numerical processing, visualization, simulation, experimental control, and environmental creation. The push to extremes of size, time, and complexity continues unabated. Quantum mechanical phenomena and theory are increasingly central to many areas of RLE research. Most phenomena now under study are nonlinear and occur in systems with high complexity, requiring the need to focus on chaos. Self-organized systems are yet another focus as they provide the means to compositionally build on simple, local interactions for large-scale complex behavior. These common themes indicate some of RLE's future research directions that will extend our fundamental knowledge of physical and human systems and establish a foundation for constructing outstanding new systems to serve the changing needs of society.

by Jonathan Allen

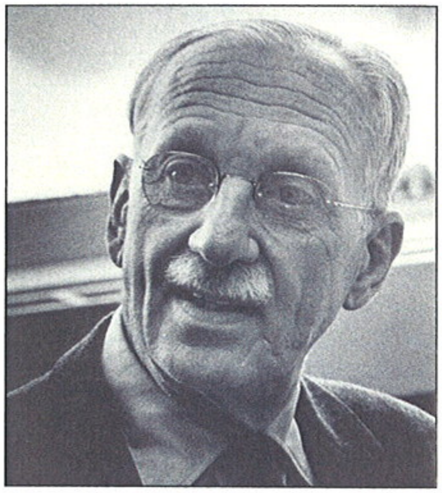


This state-of-the-art femtosecond laser system is used to characterize the next generation of high-speed photonic devices. The short optical pulses generated by this system enable study of ultrafast dynamics in electronic materials. Ultrashort pulse lasers designed and constructed in RLE are used in a variety of studies that include laser modelocking, light-matter interaction, and optical switching and transmission. New solid-state lasers are also used to study high-speed carrier dynamics in metals and semiconductors and to investigate the interaction of pulsed laser light with biological tissue. (Photo by John F. Cook)



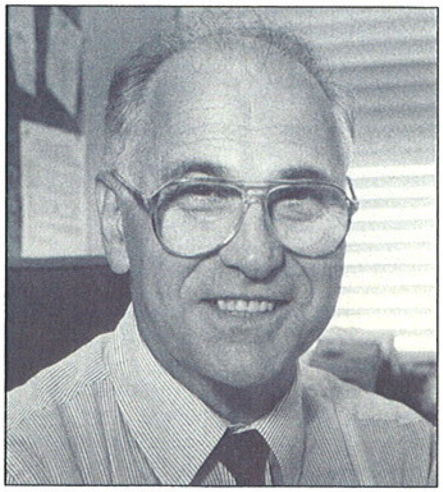
Electromagnetic Stimulation Applied to Landing Systems (EMSALS) is a computer simulation tool that has been used to model and analyze the growing problems of frequency congestion and electromagnetic interference at airports in ten metropolitan U.S. areas. EMSALS analyzes the proposed installations of Instrument Landing Systems (ILS) and Microwave Landing Systems (MLS) by calculating and evaluating a variety of factors to determine the best frequency assignments for these systems. This computer graphic is an interference assessment of a proposed ILS transmitter for runway 29 at Newark International Airport.

circuit breakers



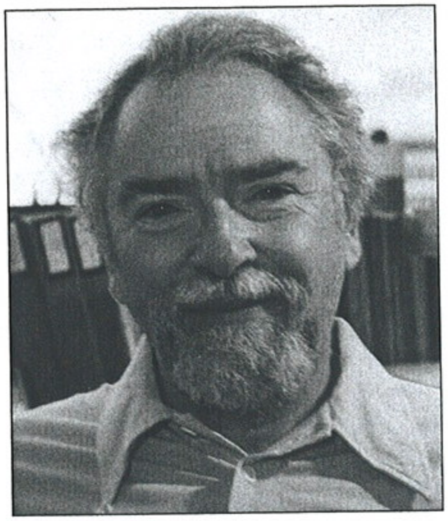
The MIT Physics Department celebrated the 90th birthday of ***Professor Emeritus William P. Allis*** (BS '23, MS '24) on November 15, 1991. After receiving his doctoral degree at the University of Nancy (ScD '25), Professor Allis returned to MIT as a research assistant to study relativity and wave mechanics. In later years, his research involved plasmas in magnetic fields and the behavior of partially ionized gases. In 1941, he joined MIT's Radiation Laboratory, but left to serve as a liaison officer with the Office of Scientific Research and Development. He was decorated the Legion of Merit in 1945 and returned to MIT, where he became affiliated with RLE at its inception in 1946. His studies included the behavior of partially ionized gases and toroidal discharge in hydrogen. During more than forty years on the MIT faculty, Professor Allis also served as NATO's assistant secretary general for scientific affairs (1962-64) and chairman of the American Physical Society's Gaseous Electronics Conference (1949-62), where he became honorary chairman in 1966. In 1989, the society established the Will Allis Prize in Gaseous Electronics. *(Photo by John F. Cook)*

Dr. Sylvia T. Ceyer, Professor of Chemistry, was named recipient of the first William M. Keck Foundation Professorship in the field of energy. Since joining the MIT faculty in 1981, Professor Ceyer's research into the dynamics of molecule-surface interactions has resulted in the discovery of new mechanisms for dissociative chemisorption, desorption, and absorption of adsorbates, and surface reactions. Her work has extended the understanding of molecular precursors, and has identified and clarified the site conversion process and provided a new method for adsorbate synthesis. Recently, Professor Ceyer uncovered a new mechanism for surface reaction involving the fluorine molecule, which may be a source of reactive ion species in a plasma etching environment. *(Photo by John F. Cook)*



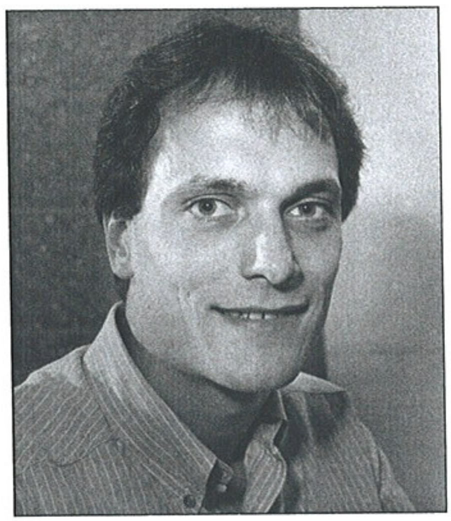
Dr. Bruno Coppi, Professor of Physics, received the annual Leadership Award from Fusion Power Associates of Gaithersburg, Maryland, in June 1991. The Leadership Award, established in 1980, recognizes individuals who have shown outstanding leadership qualities in attempting to accelerate the development of fusion. Professor Coppi, a faculty member in RLE's Plasma Physics Group, was cited for consistently pointing out directions that could lead to practical fusion applications along affordable development paths and presenting a constant challenge to the "business as usual" attitudes that frequently characterize scientific circles. *(Photo by John F. Cook)*

Dr. William F. Schreiber, Professor Emeritus of Electrical Engineering and Computer Science, received the 1991 Gold Medal of the International Society for Optical Engineering (SPIE). The Gold Medal is SPIE's principal award and is bestowed in recognition of outstanding national or international accomplishment in photo-optical instrumentation engineering. Professor Schreiber was cited for his lifelong pioneering work in the field of image processing and electronic imaging systems and, most recently, his contributions to the emerging technology of high-definition television. The award was presented in July 1991 at SPIE's 36th Annual International Symposium in San Diego. *(Photo by John F. Cook)*

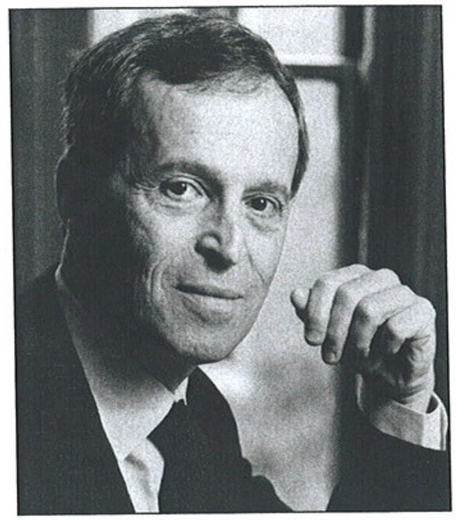


Dr. Thomas F. Weiss (SM '59, PhD '63), Professor of Electrical and Bioengineering and faculty member in RLE's Auditory Physiology Group, was appointed to the MIT Academic Computing Council. Appointments were announced in April 1991 and include representatives from MIT's faculty, staff, and students. The council will serve as a focal point for the educational computing needs of the MIT faculty. In his role on the council, Professor Weiss will advise administrative staff on MIT's academic computing environment, solicit opinions from the MIT community on academic computing, and review changes in academic computing policies. *(Photo by John F. Cook)*

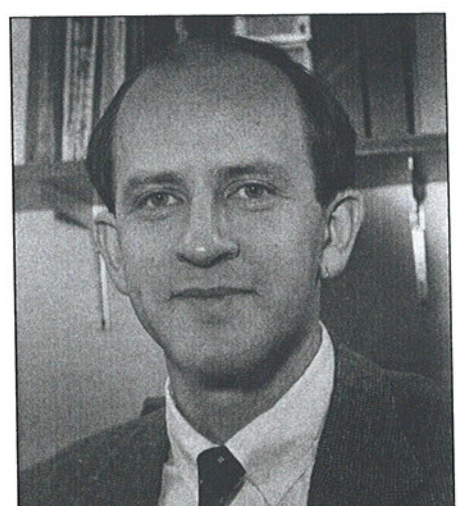
Dr. Peter A. Wolff, Professor of Physics and Director Emeritus of both RLE (1976-81) and MIT's Francis Bitter National Magnet Laboratory (1981-86), announced his retirement after 21 years at MIT. A graduate of the University of California/Berkeley (AB '45, PhD '51), Professor Wolff was a staff scientist at the Lawrence Radiation Laboratory and Bell Telephone Laboratories, Professor of Physics at the University of California/San Diego, and Director of Bell Telephone's Electronics Research Laboratory before joining the MIT faculty in 1970. He also served as Associate Director of MIT's Materials Science Center and head of the Solid-State and Atomic Physics Division. His research involved studies in light scattering, solid-state plasmas, semiconductors, and nonlinear optics. Currently, he is affiliated with the NEC Research Institute in Princeton, New Jersey. *(Photo by John F. Cook)*



Dr. Gregory W. Wornell (SM '87, PhD '91) was appointed to Assistant Professor in the Department of Electrical Engineering and Computer Science. Professor Wornell had been a research assistant and a graduate student in RLE's Digital Signal Processing Group since 1985. A graduate of the University of British Columbia (BS '85), Professor Wornell currently investigates the use of self-similar and fractal geometries, nonlinear dynamics, and chaos theory in problems of signal modeling, signal processing, and communication system design. In May 1991, at the MIT awards convocation, he received the Goodwin Medal which recognizes graduate students for "conspicuously effective teaching." *(Photo by John F. Cook)*



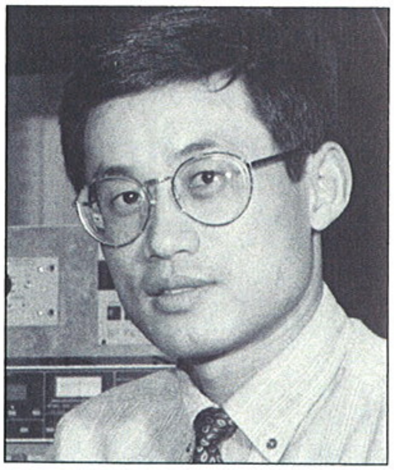
Dr. Harlan Lane, a Research Affiliate in RLE's Speech Communication Group, was awarded a five-year MacArthur Foundation fellowship in June 1991 to continue research on the language and culture of deaf communities. Dr. Lane, a University Distinguished Professor at Northeastern University, was cited for his work to improve the quality of life for the hearing impaired throughout the world and for advancing electronic devices that can restore hearing in deafened adults. He was also recognized for recent work to establish the first official school for deaf children in French-speaking central Africa. Dr. Lane is founder of the American Sign Language-English Interpreting Program at Northeastern University and also conducts research on cochlear prostheses at the Massachusetts Eye and Ear Infirmary. *(Photo by J.D. Levine)*



Dr. Mario A. Svirsky was promoted to Research Scientist in RLE's Speech Communication Group in October 1991.

Since 1988, he has been a postdoctoral associate with Professor Kenneth N. Stevens and Senior Research Scientist Dr. Joseph S. Perkell, and has participated in a variety of studies in speech production for cochlear implant patients and research on feedback mechanisms in speech production. Dr. Svirsky is a graduate of Uruguay's Universidad de la Republica (BS '81, MSEE '83) and Tulane University (PhD '88). Before joining RLE in 1988, he was a research fellow at the Louisiana State University Medical Center. Dr. Svirsky will continue to conduct research and develop experiments on the physiology and acoustics of speech production. *(Photo by John F. Cook)*

Career Development Professorships Awarded in Electrical Engineering and Computer Science



Dr. Qing Hu was appointed Kokusai Denshin Denwa (KDD) Career Development Professor in Communications and Technology for a two-year period beginning September 1, 1991. Professor Hu's research in RLE's Optics and Devices Group uses a variety of techniques to study high-frequency and high-speed electronic devices. These include terahertz superconducting heterodyne receivers and solid-state lasers, high-T_c superconducting Josephson devices, photon-assisted transport in quantum point contacts, and terahertz solid-state lasers using quantum well structures. The KDD chair was established in 1983 to promote teaching and research in communications and technology, and cultural and intellectual relations between the U.S. and Japan. *(Photo by John F. Cook)*

Dr. Leslie A. Kolodziejski was appointed Karl Van Tassel Career Development Professor for a two-year period beginning September 1, 1991. Professor Kolodziejski joined the MIT faculty in 1988, and as an investigator in RLE's Materials and Fabrication Group is currently involved in the molecular and chemical beam epitaxies of novel new material systems, especially in the II-VI compound semiconductor family. She conducts research on the growth, characterization, and device applications of a variety of ternary compounds, and associated multiple quantum well and superlattice structures. The professorship was established by Karl R. Van Tassel (EE '25) in 1985. *(Photo by Paul J. McGrath)*

1991 Presidential Young Investigator Awards

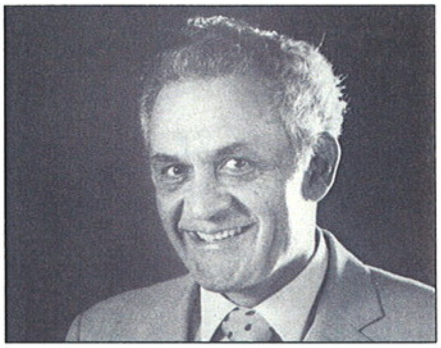
Two RLE faculty members were among eleven MIT researchers and 220 academic scientists and engineers nationwide who were awarded 1991 Presidential Young Investigator Awards by the National Science Foundation. The award is intended to help universities attract outstanding young doctoral scientists and engineers who might otherwise pursue nonacademic careers.

Dr. Jesús A. del Alamo, ITT Career Development Professor, conducts research in RLE's Materials and Fabrication Group that involves high-performance heterostructure field-effect transistors on indium phosphide and gallium arsenide substrates for telecommunications. He also explores new quantum-effect electronic devices based on one-dimensional heterostructures. *(Photo by John F. Cook)*

Dr. Jacqueline N. Hewitt (PhD '86), Assistant Professor of Physics, applies techniques used in radio astronomy, interferometry, signal processing, and image processing to the study of gravitational lenses and nearby dwarf M stars that show evidence of surface activity. Her work in RLE's Radio Astronomy Group includes the identification of several gravitational lens systems and the detection of emissions from low-temperature main-sequence stars with very-long-baseline interferometry (VLBI) arrays. *(Photo by John F. Cook)*

American Academy of Arts and Sciences Elects Two Fellows from RLE

Two RLE faculty members were elected Fellows to the American Academy of Arts and Sciences at its annual meeting in Boston in May 1991. The two were among thirteen others from MIT (including President Charles M. Vest) and 195 nationwide.



Dr. Amar G. Bose (SB '51, SM '52, PhD '56), Professor of Electrical Engineering and Computer Science, has been affiliated with RLE in the area of acoustics and nonlinear systems since 1953. Professor Bose joined the MIT faculty in 1956, and is founder and Chairman of the Board of the Bose Corporation of Framingham, Massachusetts. *(Photo courtesy of Bose Corporation)*

Dr. Patrick A. Lee (SB '66, PhD '70), William and Emma Rogers Professor of Physics, studies the physics of small devices, particularly conductance fluctuations in disordered metals, the scaling theory of metal-to-insulator transition, and the theory of high-temperature superconductors. Professor Lee is a faculty member in RLE's newly formed Quantum-Effect Devices Group and, earlier this year, received the Buckley Prize in Condensed Matter Physics from the American Physical Society. *(Photo by John F. Cook)*

In Memoriam

Professor Emeritus Alan H. Barrett, 64, died July 3, 1991, in Denver, Colorado, after suffering from cancer. A noted radio astronomer, Dr. Barrett was born in Springfield, Massachusetts, and served in the U.S. Navy in World War II. He was a graduate of Purdue University (BS '50) and Columbia University (MS '53, PhD '56), where he pioneered the microwave spectra measurement of high-temperature diatomic molecules.

Before joining the MIT faculty in 1961, he was a postdoctoral fellow at the U.S. Naval Research Laboratory in Washington, and a research associate and instructor at the University of Michigan. At Michigan, Dr. Barrett probed the atmosphere of Venus using theoretical microwave radiation studies and was first to recognize that Venus' thick carbon dioxide atmosphere contributed to its extremely high temperatures. He also designed microwave detection equipment for NASA's Mariner missions.

In 1963, Dr. Barrett and his collaborators in RLE were responsible for the detection, identification, and measurement of the first molecular matter found by radio astronomy techniques in interstellar space. Positive radio identification of oxygen-hydrogen molecules (called the hydroxol or OH radical) enabled radio astronomers to chart the distribution and abundance of OH as well as oxygen and hydrogen in the galaxy. This discovery contributed to a better understanding of the fundamental astrophysical interactions that lead to the formation of galaxies.

Dr. Barrett was appointed Professor of Electrical Engineering in 1965, and became Professor of Physics in 1967. He shared the 1971 Rumford Prize of the American Academy of Arts and Sciences for the first very-long-baseline interferometry measurement of OH radiation, which confirmed his earlier discovery of naturally occurring space masers. In 1977, he was awarded a Guggenheim Fellowship to continue research on the molecular properties of interstellar space. Dr. Barrett sought to extend his innovative techniques for space molecule detection to microwave thermography used in noninvasive breast cancer diagnosis. He also contributed to the NASA series of Nimbus meteorological satellites by developing radio astronomy techniques to probe the Earth's atmosphere in high-altitude balloons.

Dr. Barrett was a Fellow of the American Academy of Arts and Sciences, and a member of the American Astronomical Society, the International Scientific Radio Union, and the International Astronomical Union. He served as an advisor to NASA, the National Science Foundation, the National Institutes of Health, the National Radio Astronomy Observatory, and the National Astronomy and Ionosphere Center.

A memorial service was held at MIT in July 1991. Memorial donations can be made to the Alan H. Barrett Graduate Astrophysics Fellowship Fund, c/o Ms. Catherine Ormond, Department of Physics, Room 6-113, MIT, 77 Massachusetts Avenue, Cambridge, MA 02139-4307. *(Photo courtesy of MIT Museum)*

alumni notes

On June 9, 1991, RLE's Cognitive Information Processing Group held a well-attended reunion in Lexington, Massachusetts. Attendees included (from left): Charles H. Cox, III (ScD '79), former secretary Carol R. Morrison, Michael B. McIlrath (SB '76), Douglas B. Paul (SM '73, PhD/EE '76), Robert J. Shillman (SM '72, PhD '74), Irving R. Englander (SM '70, PhD/EE '78), Robert A. Piankian (SM '72), Robert P. Bishop (SM '76, ScD '80), Thomas F. Quateri, Jr. (SM '75, EE '78, ScD '80), former faculty Murray Eden, Roger S. Putnam (SB/EE '72, SM/EE '75, PhD '83), reunion host Donald S. Levinstone (SB '73, SM '74, PhD '81), Donald E. Troxel (SM '60, PhD '62), Jonathan M. Teich (SM/EE '79, PhD '85), retired service staff Alski Rudnick, Theodore K. Kuklinski (SM/EE '75, PhD '79) with Christopher Kuklinski, former research affiliate M. Sharon Hunnicutt, Eric R. Jensen (SB '64), Victor T. Tom (SB '72, ScD '81) with Corina Tom, Richard S. Goldhor (SB '73, SM/EE '76, PhD '85), Malik M.A. Khan (SM/EE '79, ScD '82), Bruce R. Musicus (SM/EE '79, PhD '82) with Marina Rose Musicus, and Ronald E. Boucher (SM '78). (Photo by John F. Cook)

W. Murray Bullis (PhD '56) recently left his position as Vice President of Research and Development for Siltec Corporation and formed an international consulting company called Materials and Metrology in Sunnyvale, California.

Thomas Kailath (SM '59, ScD '61), Hitachi America Professor of Engineering in the Department of Electrical Engineering at Stanford University, writes, "I fondly remember my days in RLE from 1957-61 and the galaxy of brilliant faculty (Shannon, Elias, Fano, Huffman, Wozencraft, Siebert and many others, when perhaps no other university could boast more than one or two information and communication theorists) and brilliant students (too many to name without embarrassment)." In June 1990, he received an honorary doctorate from Sweden's Linkoping University and recently finished his stay at MIT as Senior Vinton Hayes Fellow and visiting professor in the Department of Electrical Engineering and Computer Science.

Terrence P. McGarty, Jr. (SM '66, EE '69, PhD '71), is Senior Vice President at NYNEX Mobile Communications Company in Orangeburg, New York. He writes, "It's a small world for RLE alumni!" Dr. McGarty occasionally conducts business with ***Irwin M. Jacobs*** (SM '57, ScD '59), his former undergraduate faculty advisor from MIT, who is now Chief Executive Officer of Qualcomm, Inc.

Jerry L. Perry (SB '54) remembers his MIT school days when he and Paul E. Gray (now MIT's Chairman of the Corporation) were lab partners. Since then, he has worked with many electronics, aircraft, and consulting companies on government-funded projects. Most recently, he was Chief Electronics Engineer at the Columbia Research Corporation in Panama City, Florida.

David S. Prerau (SM '66, PhD '70) is Principal Member of the Technical Staff at GTE Laboratories in Waltham, Massachusetts. He recently wrote a book, *Developing and Managing Expert Systems: Proven Techniques for Business and Industry*.

James N. Thurston (SM '43, ScD '50), retired head of the Electrical Engineering Department at Clemson University, plans to write his recollections of the early days of radar at MIT. From his home in Clemson, South Carolina, he writes, "This may not add much to the records of RLE and MIT, but it will give me pleasure to go back over those important days of my life."

CELEBRATING HISTORY

In 1991, two distinguished anniversaries were celebrated: the MIT Radiation Laboratory's 50th and RLE's 45th. The Research Laboratory of Electronics, which was established in 1946, grew out of MIT's wartime Radiation Laboratory (1940-45). Two special events were held to honor the milestones shared by these laboratories. (Photos by John F. Cook)

RadLab 50th Reunion

Former staff members of MIT's Radiation Laboratory gathered at the Hynes Convention Center in Boston for a 50th anniversary reunion on June 11, 1991. The reunion was celebrated as part of the annual International Microwave Symposium sponsored by the IEEE Microwave Society. Many alumni shared not only their reminiscences of the RadLab, but also memories of days at RLE.

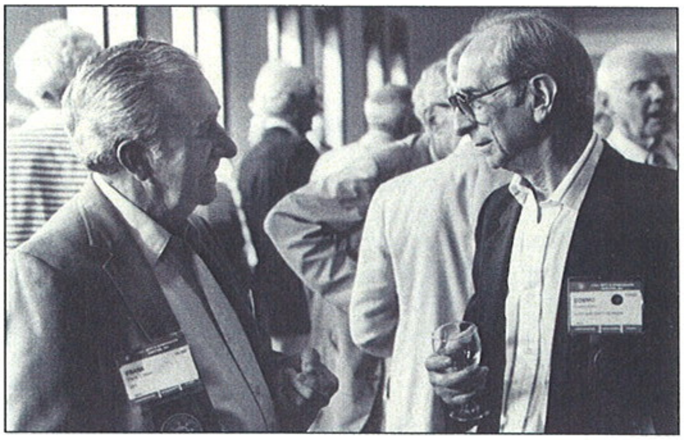
Nobel laureate and symposium keynote speaker Dr. Norman F. Ramsey, Jr., who was the first leader of RadLab's Group 41 (Fundamental Development) and is now on the faculty at Harvard University.

MIT Professors Emeriti Robert M. Fano and William P. Allis, both former RadLab staff and RLE faculty members.

RLE Directors Emeriti Jerome B. Wiesner (left) and Albert G. Hill (center) confer with Robert V. Pound. All three were with RadLab's Group 53 (Radio Frequency).

A reunion of RadLab Group 84 (Theory) alumnae Elizabeth J. Campbell and Kathryn G. Fowler, both of whom also served with RLE.

Professor Daniel Kleppner, RLE Associate Director, with the Ramsey family—Margaret Ramsey Kasschaw and Ellie Welch Ramsey.



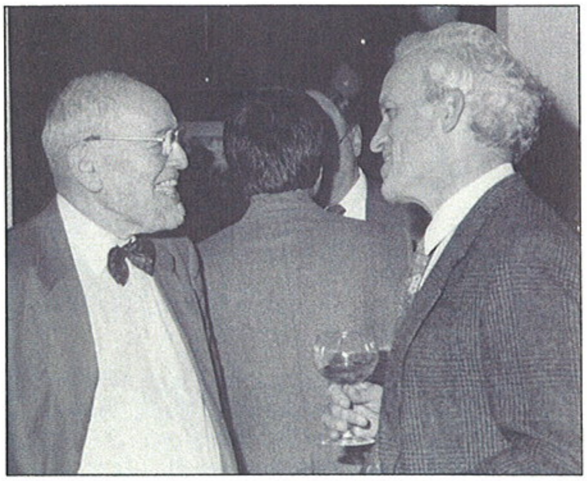
Former RadLab/RLE staffers Frank J. O'Brien and D. Cosmo Papa renew acquaintances.

RLE 45th Anniversary

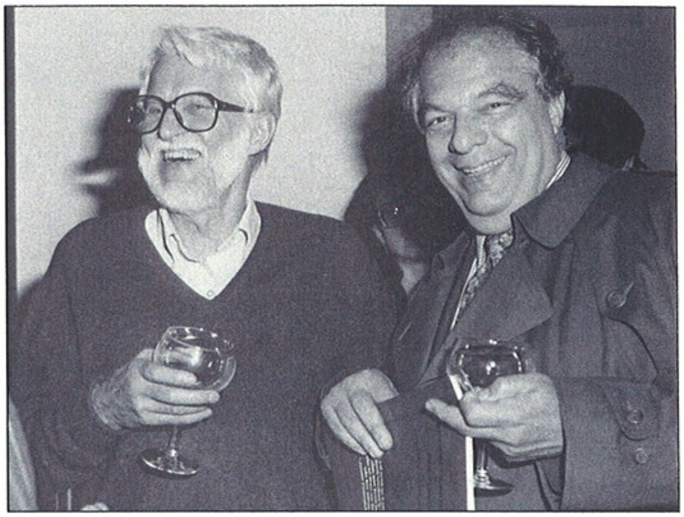
RLE celebrated its 45th anniversary with a festive gathering of faculty, staff, students, and friends at the MIT Museum on October 28, 1991.

Nobel laureate Dr. Norman F. Ramsey, Jr. of Harvard University and MIT President Dr. Charles M. Vest rendezvous with RLE's Director Professor Jonathan Allen.

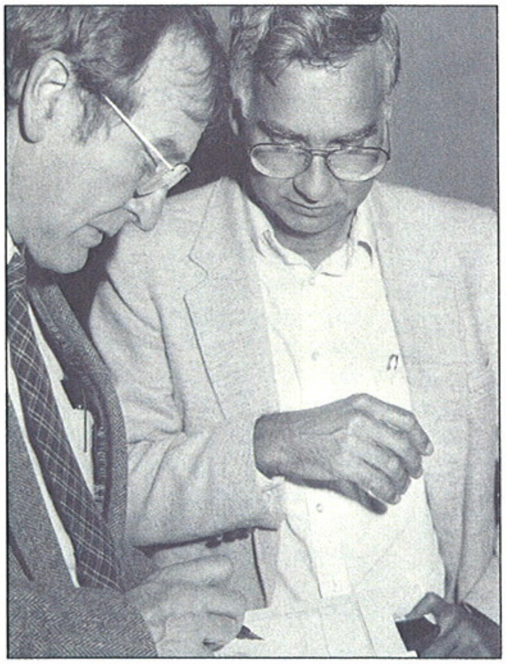
Senior Research Scientist Dr. Robert H. Rediker, Institute Professor Hermann A. Haus, and Professor Qing Hu take in the geodesic atmosphere of the Buckminster Fuller exhibit.



Institute Professor Emeritus Walter A. Rosenblith catches up with Professor Daniel Kleppner, RLE Associate Director.

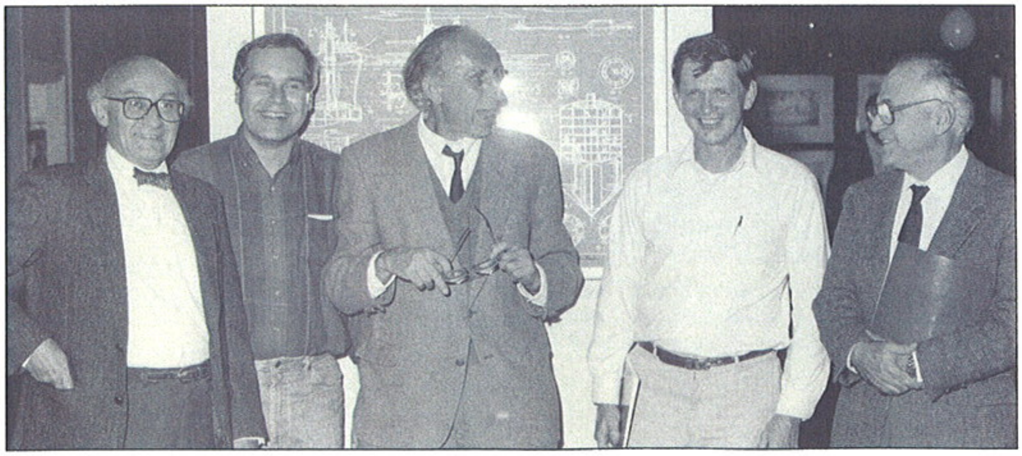


Professor Kenneth N. Stevens shares a light moment with Associate Provost Samuel J. Keyser, the Peter de Florez Professor of Humor.



It's still business as usual for two hardworking celebrants, Professors Henry I. Smith and David E. Pritchard.

Former RLE and RadLab editor Dr. Helen L. Thomas with Professor and RLE Director Emeritus Henry J. Zimmermann.



Fusion of RLE's Plasma Physics Group: Professor Abraham Bers, Research Specialist Ivan Mastovsky, Professor George Bekefi, Sponsored Research Technical Staff Edward W. Fitzgerald, and Professor Bruno Coppi.

UPDATES:

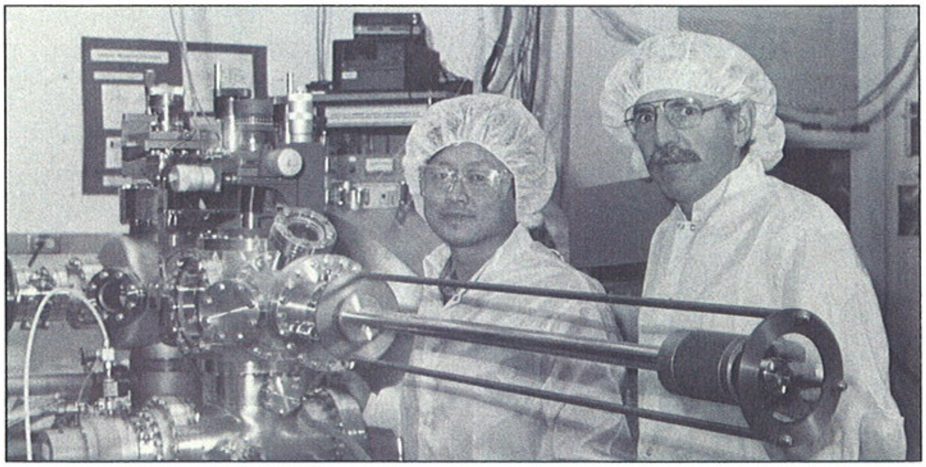
Industrial Connections

The RLE Collegium was established in 1987 to promote innovative relationships between the laboratory and business organizations through research projects and special partnerships. Its goal is to increase interaction and communication between RLE researchers and outside professionals in electronics and related fields. Collegium members have the opportunity to develop close affiliations with the laboratory's faculty, research staff, and students and can quickly access emerging results and scientific directions. This kind of professional interaction provides RLE Collegium members with the most up-to-date technical information, often in areas not fully addressed by business and industry.

Collegium benefits include access to a wide range of RLE publications, personalized seminars and laboratory visits, and other opportunities for technology transfer. RLE also hosts visiting scientists from collegium companies. Individual research projects and special partnerships may develop with mutual technical interests and the appropriate external sponsorship.

The RLE Collegium membership fee is $20,000 annually. Members of MIT's Industrial Liaison Program can elect to transfer 25% of their ILP membership fee to the RLE Collegium. Collegium fees will encourage new research initiatives within RLE.

Dr. Sang H. Kyong (PhD '66), President of the Electronics and Telecommunications Research Institute (ETRI) of Daejeon, Korea, and Professor Jonathan Allen take time out from a recent meeting at RLE. Dr. Kyong and several colleagues visited RLE in connection with Dr. Jaejin Lee, a senior engineer from ETRI who is serving as a visiting scientist in RLE.



Dr. Lee (left) is working with Professor Clifton G. Fonstad, Jr., on the epitaxial growth of III-V heterostructure devices in RLE's Materials and Fabrication Group. His appointment was made possible through ETRI's membership in the RLE Collegium. (Photos by John F. Cook)

Publications

RLE has recently published the following technical reports:

Characterization of Mechanical and Optical Properties of X-Ray Mask Membranes, by Flora S. Tsai. RLE TR No. 564. June 1991. 49 pp. $11.00.

Experimental Characteristics and Physical Modeling of Resolution Limits in Proximity Printing X-Ray Lithography, by Kathleen R. Early. RLE TR No. 565. August 1991. 164 pp. $29.00.

Synthesis, Analysis, and Processing of Fractal Signals, by Gregory W. Wornell. RLE TR No. 566. October 1991. 239 pp. $20.00.

In addition, ***RLE Progress Report No. 133***, which covers the period January through December 1990, provides extensive information about the research objectives and projects of RLE's research groups. The ***Progress Report*** also lists faculty, staff, and students who participated in each research project, identifies funding sources, and lists current RLE personnel. Also available is an up-to-date list of RLE technical reports from 1946 to the present. The 26-page list includes an author index and costs $4.00.

RLE welcomes inquiries regarding the laboratory's research. To request an RLE *Collegium Prospectus,* or for more information on RLE publications, please contact:

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