Rolf William Landauer

Rolf William Landauer, a pioneer in the physics of information processing and the individual largely responsible for making IBM Corp's research division one of the most eminent research establishments in the world, died on 27 April in Briarcliff, New York, of brain cancer.

Rolf was born on 4 February 1927 to a Jewish family in Stuttgart, Germany. Rolf's father, as he lay dying in 1934 of wounds he had received in World War I, urged his wife to raise their boys as good Germans. Fortunately, four years later, she and the family were able to flee from Germany and Nazi persecution and settle in New York City, where Rolf finished high school in 1943.

He graduated with a BA from Harvard University in 1945 and then served in the US Navy for 18 months. Returning to Harvard for graduate work, he earned his PhD in physics in 1950, under the supervision of Wendell Furry, although Léon Brillouin had been his first adviser.

After a two-year stint at the Lewis Laboratory of the National Advisory Committee for Aeronautics, Rolf joined IBM's research center (which later became the Thomas J. Watson Research Center) in Yorktown Heights, New York, in 1952. He remained there for the rest of his life.

Early on, Rolf worked on what he brought to fruition over the next two decades—namely, ferroelectrics, effective medium theory, the physics of information, and his unique approach to conductance. In 1962, he became director of a department called solid-state sciences, which included all the hardware work in the IBM research division. His task was to make his department more relevant to IBM. He did.

Two areas can be cited as outstanding examples of his forceful and effective style of management—namely, the injection laser program and large-scale integration. His drive led IBM to create an operating injection laser in 1963 in a virtual tie with a group at General Electric Corp. This breakthrough was one of the research center's first.

Large-scale integration was primarily the result of Rolf's commitment to the potential of the metal-oxide-semiconductor field-effect transistor (MOSFET) as a low-cost logic device. He pushed this program hard, and as a result there were many

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firsts. Most important was the early development, in 1965–68, of viable n-channel technology. Design automation and e-beam technology were also fostered, and the invention of the DRAM (dynamic random-access memory) resulted from this program. In physics, two-dimensional electron gases were first observed in Rolf's department.

In 1965, Rolf became assistant director of research, a post that he held until 1969, when he was appointed an IBM fellow and happily returned to full-time research. However, he was continually called upon to lead task forces, to serve as an ombudsman for personnel problems, and to be a general and trusted consultant for IBM's management.

Rolf's work clarified several fundamental issues in physics while also being inspired by questions arising from technology. An underlying theme of his work was the interface between microscopic, quantum mechanical descriptions and statistical physics. The two main topics in which his work has had major impact are the treatment of quantum transport and the basic physics of information processing.

What is now known as the Landauer approach was a fundamentally new way of considering the electrical conductance of a system by expressing it in terms of scattering. This picture is elegantly simple and has had important applications in the physics of electron localization and in almost all interesting problems in mesoscopic physics. Rolf's pioneering paper in transport theory came in 1957, followed by other contributions in 1970 and 1975. He constructed a theory for the scaling of conductance with system length and obtained for the first time the exponential decrease of the conductance with length. The important fact that elastic scattering does not break the coherence of quantum mechanical wavefunctions led to the idea of normal persistent currents. Rolf and his colleagues applied mesophysical ideas to the Aharonov–Bohm conductance oscillations, mesoscopic conductance fluctuations, and an understanding of the quantum Hall effect in terms of edge-state transport.

Rolf also contributed substantially to our understanding of classical polarization and transport in inhomogeneous systems (related to electromigration) and, more recently, our understanding of quantum shot noise. The Landauer approach stands alongside the Kubo formula as one of the two most powerful ways to understand conduction.

Rolf did more than anyone else to establish the physics of information processing as a serious subject for scientific inquiry. Because of his conviction that information is physical, Rolf continually emphasized the interdependence of mathematics and physics. It led him to pursue the thermodynamics of information processing more doggedly than any of his predecessors, who believed that each elementary information processing operation required an expenditure of work comparable to or larger than the mean thermal energy. In 1961, Rolf established that this generalization is true only for some information processing operations—those, like erasure, that cannot be undone—whereas other operations have no intrinsic, irreducible thermodynamic cost. The study of such operations led to the theory of reversible computers and communications channels, as well as to our modern understanding of Maxwell's demon, based on the thermodynamic cost of information destruction—a concept now called Landauer's principle.

For many years the theory of reversible computation and communication appeared to be interesting basic science without application, but recently it has been used in designing energy-saving circuits for laptop computers and other battery-powered computer applications. It is also fundamental to the theory of quantum computing, about which Rolf exercised his usual skepticism. But by the late 1990s, the proponents of quantum computation had addressed his criticisms of it sufficiently to win his grudging respect.

He also made important contributions to many other fields, including statistical physics, ferroelectricity, wave propagation, and tunneling time.

Rolf had very high standards for his own research and expected the same of others. He disdained ideas whose merits were exaggerated, including catastrophe theory and the recurrent notion that there is some simple criterion for identifying preferred states of systems far from equilibrium, without reference to the systems' detailed dynamics. Some of this distaste emerged in his strong attacks on those he felt were overstating such ideas. Among his special *bêtes noires* were almost all attempts to sell some new physical phenomenon as the computer technology of the future. In parallel with IBM's Robert Keyes, he developed an understanding of what sorts of devices were required to make any but the simplest computers. As a result, he took strong negative positions on optical computing. He also decried logic based on devices, such as the tunnel diode or the Josephson junction, that required extreme reproducibility and lacked gain. History has proved both men right on these issues.

Rolf received many awards, including the American Physical Society's Oliver E. Buckley Condensed Matter Physics Prize and the Edison Medal of the IEEE. He was elected to the National Academy of Sciences, the National Academy of Engineering, the American Society of Arts and Sciences, and the European Academy of Science.

Rolf touched the lives of many scientists and other people. His occasional irascibility was more than balanced by his understanding, his devotion to truth and science, his work, and his loyalty to people and to institutions. He was a rare person, who played a major role in the information revolution, both as a technical manager and as a scientist. He was the heart and soul of IBM research.

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Peter Alden Franken

PETER ALDEN FRANKEN

Peter Alden Franken, a pioneer in the field of nonlinear optics, died of liver failure on 11 March at his home in Tucson, Arizona, surrounded by his loving family.

Born in New York City on 10 November 1928, Peter earned a BA from Columbia College in 1948 and MA and PhD degrees in physics from Columbia University in 1950 and 1952, respectively. His thesis topic concerned the determination of the properties of atomic potassium in terms of the proton gyromagnetic ratio.

After spending six years at Stanford University, Peter moved in 1956 to the University of Michigan. During the late 1950s and early 1960s, he played an important role in improving the accuracy of the fundamental constants, and made trailblazing contributions to the study of optical pumping. These efforts led in particular to the design of both a magnetic-field stabilizing device and a very sensitive magnetometer.

In 1961, Peter and his coworkers at Michigan published their epochmarking paper entitled "Generation of Optical Harmonics" (*Physical Review Letters*, volume 8, page 118) on second-harmonic generation in quartz. This work gave birth to a wealth of experimental and theoretical activity in nonlinear optics, which continues to this day. Examples of its progeny include quasi-phase-matched waveguides for blue-light generation, the use of optical rectification for THz radiation, and spatial soliton propagation in second-order media. Peter's paper also formed the basis for the realization of optical experiments aimed at testing the foundations of quantum mechanics and measurement theory—in particular, in the use of parametric down-conversion to create correlated photon pairs. Furthermore, recent demonstrations of the nonlinear optics of matter waves using Bose–Einstein condensates find their direct inspiration in that seminal work.

While still at Michigan, Peter also served as the deputy director and acting director of the Advanced Research Projects Agency of the US Department of Defense (1966–68).

In 1973, he moved to the University of Arizona to become the director of its Optical Sciences Center, a position he held until 1983, after which he remained on the staff as a professor. As director, he recruited a number of world-class faculty—in particular Willis Lamb, who, with Peter's former thesis adviser Polycarp Kusch, won the Nobel Prize for Physics in 1955, and the center's current director, James C. Wyant. In addition, he expanded the sources of the center's research funding from primarily US Air Force support to include the National Science Foundation and many industrial companies.

Peter received several awards during his distinguished career. He was a Sloan Foundation fellow in 1958–62. He received an American Physical Society prize (sponsored by Hughes Aircraft Co) in 1967 and was the recipient of the Optical Society of America's Wood Prize in 1979.

Peter was famous for his bets. They were always nickel bets, except for his famous bet with the late Ed Jaynes on the calculation of the Lamb shift. After Jaynes gave a talk at the first Rochester Conference on Coherence and Quantum Optics in 1960 on his neoclassical theory of spontaneous emission, Peter claimed that this theory would not be able to compute the Lamb shift within the next ten years. He further observed that both he and Jaynes were sufficiently well off that the bet would be $100! Lamb, who held the money, paid off Peter ten years later.

Peter was a true Renaissance man. His most recent research projects included drug and explosive detection technology, precision surface measurements in seismology, the detection of asteroid impact flashes on the moon, the disposal of radioactive waste, optical methods for early detection of breast cancer, the use of high-power lasers in the treatment of extensive burns, applications of military technology for the control of locust swarms, and issues of technology transfer with the former Soviet Union. His many interests outside physics included art, greyhounds, falcons, interior design, travel, gourmet cooking, caviar, storytelling, and Russian culture.

Peter had numerous friends around the world, many of them in Eastern Europe. When the Cold War ended, he was very quick to understand that scientists in Russia faced