NATIONAL ACADEMY OF SCIENCES

POLYKARP KUSCH
1911—1993

A Biographical Memoir by
NORMAN F. RAMSEY

Biographical Memoir

P. Hirsch

POLYKARP KUSCH

January 26, 1911–March 20, 1993

BY NORMAN F. RAMSEY

POLYKARP KUSCH, A GREAT physicist, teacher, and Nobel laureate, died in Dallas, Texas, at age 82 on March 20, 1993. Kusch was a pioneer in molecular beam magnetic resonance experiments; he and his associates, with unprecedented high accuracy, measured many atomic and nuclear spins, magnetic dipole moments, electric quadrupole moments, and atomic hyperfine structure separations. Kusch and his associates also made the first direct measurement of the magnetic moment of the electron, which showed that it was consistent with the previously observed anomalous hyperfine separation in atomic hydrogen and with J. Schwinger's then-new relativistic quantum electrodynamics (QED).

Polykarp Kusch was born in Blankenburg, Germany, on January 26, 1911, the son of John Mathias Kusch, a Lutheran missionary, and Henrietta van der Haas. The family emigrated to the United States in 1912, and Kusch became a naturalized U.S. citizen in 1922. He attended grade school in the Midwest, and started his college education as a chemistry major at Case Institute of Technology in Cleveland, Ohio, shifting to physics before receiving his bachelor of science degree in 1931. He then moved to the University of Illinois, where in 1933 he received an M.S. and in 1936 a Ph.D. in physics for his research on optical spectroscopy of molecules under the guidance of Professor F. Wheeler Loomis. The title of his Ph.D. thesis was "The Molecular Spectrum of Caesium and Rubidium."

On August 12, 1935, Kusch married Edith Starr Roberts, and they had three daughters. They moved to the University of Minnesota, where he was a research assistant on mass spectroscopy for two years with Professor John T. Tape.

In 1937 Kusch moved to Columbia University in New York City and began his work with Professor I. I. Rabi, measuring atomic and nuclear magnetic moments by the deflection of atomic beams. At the same time, I began with Rabi as a graduate student working for my Ph.D. Since neither Kusch nor I had any previous experience with molecular beams, we both were asked to begin as apprentices with two of Rabi's experienced postdocs, J. R. Zacharias and S. Millman, who were doing a magnetic deflection experiment to measure the spins and magnetic moments of the indium isotopes. (Since the experiment was going on in late summer, this period of time was often referred to as our "indium summer.") Although Kusch and I were equally new to the field of molecular beams, we were in a different status since Kusch had completed his Ph.D. research two years earlier and had additional research experience, whereas I was just beginning. As a result I learned much about doing research from Kusch, as well as from Zacharias and Millman.

Rabi invented the revolutionary molecular beam magnetic resonance method a few months after Kusch and I arrived in the laboratory, so we both participated in early experiments using this powerful new method. Kusch was a coauthor of the first successful magnetic resonance experiment (1948). From 1938 until 1941, when the laboratory was temporarily closed because of World War II, he and his associates further developed the magnetic resonance method and used it to measure accurately many molecular and nuclear magnetic moments and spins. During World War II, Kusch at Columbia, Westinghouse, and Bell Telephone Laboratories did research to improve radar and microwave generators, including magnetrons. Kusch returned to Columbia in 1946 as an associate professor (1946-1949) and then as a professor of physics (1949-1952) doing productive molecular beam resonance research.

In 1947, when many theorists believed that the electron magnetic moment was exactly one Bohr magneton, Kusch and Henry M. Foley (1948, 1955), by magnetic resonance experiments on different atomic states of gallium, indium, and sodium, showed that the magnetic moment of the electron was 1.00119 ± 0.00005 Bohr magnetons, in agreement with J. Schwinger's relativistic quantum electrodynamics (QED). Schwinger's theory had been stimulated by the experiment of Nafe, Nelson, and Rabi, which showed that the hyperfine interaction between the electron and the proton in atomic hydrogen was slightly different from what was expected theoretically. For his work Kusch was awarded one half of the 1955 Nobel Prize in Physics and was elected a member of the National Academy of Sciences in 1956.

Kusch's Nobel lecture (1955) demonstrated both his modesty in theoretical physics and his clear recognition of the importance of reliable and accurate measurements, such as his own, in exploring new scientific frontiers. In the first two paragraphs of his Nobel lecture he said:

I must tell you with considerable regret, that I am not a theoretical physicist. A penetrating analysis of the part that the discovery and measurement of the anomalous magnetic moment of the electron has played in the development of certain aspects of contemporary theoretical physics must be left to the group of men who have in recent years devised the theoretical structure of quantum electrodynamics. My role has been that of an experimental physicist who, by observation and measurements of the properties and operation of the physical world, supplies the data that may lead to the formulation of conceptual structures. The consistency of the consequences of a conceptual structure with the data of physical experiment determines the validity of that structure as a description of the physical universe. Our early predecessors observed Nature as she displayed herself to them. As knowledge of the world increased, however, it was not sufficient to observe only the most apparent aspects of nature to discover her more subtle properties; rather, it was necessary to interrogate nature and often to compel nature, by various devices, to yield an answer as to her functioning. It is precisely the role of the experimental physicist to arrange devices and procedures that will compel nature to make a quantitative statement of her properties and behavior. It is in this spirit that I propose to discuss my participation in a sequence of earlier experiments that made possible the precision determination of the magnetic moment of the electron. I will then discuss the experiments themselves which have yielded our present knowledge of the magnetic properties of the electron.

Research with atomic and molecular beams has had a long and fruitful record in the history of the growth of our present knowledge of matter. The experiments which I shall discuss are some in which the method of atomic and molecular beams is used essentially as a spectroscopic device for the observation of spectral lines in the range of frequencies within which power could then be generated by electronic means. The general principles of radiofrequency spectroscopy by the method of molecular beams were first described by Rabi and two groups of his co-workers[1] of which I was fortunate to be a member. It is here sufficient to say that a transition between energy levels may be observed through the circumstance that the magnetic moment of an electron or molecule may be changed in a transition. The method is characterized by a very high potential resolution, and in many observations of the frequency of a line, an accuracy of better than one part in a million has been achieved. It is of particular value as a tool in the investigation of the details of interactions within atoms and molecules because small interactions appear as first order effects rather than as small superpositions on the relatively enormous energies that characterize optical spectra.

Kusch was chair of the Columbia physics department for two terms (1949-1952, 1960-1963) and executive director of the Columbia Radiation Laboratory (1952-1960). With his students and associates he measured numerous nuclear and atomic magnetic moments as well as many atomic hyperfine interactions. Much of his research dealt with the details of the interactions of the constituent particles of atoms and molecules with one another and with externally applied fields.

Kusch's wife died in 1959, and the following year he married Betty Pezzoni; they had two daughters.

The magnetic resonance method, which Kusch pioneered, later became the forerunner of other fields of magnetic resonance research, including nuclear magnetic resonance (NMR), a highly effective and very important method for chemical analysis; and magnetic resonance imaging (MRI), a powerful tool for medical diagnosis.

Columbia University had serious student disturbances in the 1960s that eventually led to the resignation of the president of the university plus many on the administrative staff. As a result of this crisis Kusch in 1969 was appointed academic vice president and dean of the faculty (1969-1970), and finally executive vice president and provost of the university (1970-1971). In these capacities Kusch did an outstanding job of holding the university together during troubled times and solving many of its problems.

Kusch resigned his positions at Columbia in 1972 and became a professor at the University of Texas, Dallas, where he started a new atomic and molecular beam laboratory and continued precision measurements of atomic and nuclear properties. He also became interested in problems of chemical physics, which he studied with molecular beam techniques. Kusch became the Eugene McDermott Professor in 1974 and the Regental Professor at the University of Texas, Dallas, from 1980 until his retirement in 1982. Kusch and his wife continued to live in Dallas until his death in 1993.

NOTE

1. J. M. B. Kellogg, I. Rabi, N. F. Ramsey, and J. R. Zacharias. The magnetic moments of the proton and deuteron: The radio-frequency spectrum of H_2 in various magnetic fields. *Phys. Rev.* 56(1939):728.

SELECTED BIBLIOGRAPHY

1934

With F. W. Loomis. The band spectrum of caesium. *Phys. Rev.* 46:292.

1937

With A. Hustrulid and J. T. Tatem. Dissociation of HCN, C_2H_2, C_2N_2, and C_2H_4 by electron impact. *Phys. Rev.* 52:843.

1939

With I. I. Rabi, S. Millman, and J. R. Zacharias. The molecular beam magnetic resonance method of measuring nuclear magnetic moments. *Phys. Rev.* 55:526.

1940

With S. Millman and I. I. Rabi. The radio-frequency spectra of atoms; hyperfine structure and Zeeman effect in the ground state of Li^6, Li^7, K^{39}, and K^{41}. *Phys. Rev.* 57:765.

1941

With S. Millman. On the precision measurement of nuclear magnetic moments by the molecular beam magnetic resonance method. *Phys. Rev.* 60:91.

1948

With H. M. Foley. The magnetic moment of the electron. *Phys. Rev.* 74:250.

Intrinsic magnetic moment of the electron. *Phys. Rev.* 74:1203.

1949

With H. Taub. The magnetic moment of the proton. *Phys. Rev.* 75:1481.

1950

With S. A. Ochs and R. A. Logan. The hyperfine structure anomaly of the potassium isotopes. *Phys. Rev.* 78:184.

With A. G. Prodell. On the hyperfine structure of hydrogen and deuterium. *Phys Rev.* 79:1009.

1951

With S. Koenig and A. G. Prodell. The anomalous spin gyromagnetic ratio of the electron. *Phys. Rev.* 83:687.

1952

With S. H. Koenig and A. G. Prodell. The anomalous magnetic moment of the electron. *Phys. Rev.* 88:191.

1954

With T. G. Eck. Hyperfine structure of In^{115}. Evidence of a nuclear octupole moment. *Phys. Rev.* 94:1799.

1955

The magnetic moment of the electron. The Nobel Foundation Nobel lecture. December 12, 1955, p. 298. www.nobelprize.org/nobel_prizes/physics/laureates/1955/kusch-lecture.pdf (accessed Jun. 17, 2008).

With H. Reich and J. Heberle. Hyperfine structure of metastable hydrogen. *Phys. Rev.* 98:1194A.

1956

Further observations of multiple-quantum transitions. Saturation effects in radio-frequency transitions. *Phys. Rev.* 101:627.

With R. C. Miller. Molecular composition of alkali halide vapors. *J. Chem. Phys.* 25:860 (Errata 27:981, 1957).

1957

With A. G. Prodell. Hyperfine structure of tritium in the ground state. *Phys. Rev.* 106:87.

With T. G. Eck. Hyperfine structure of the $5^2\,P_{3/2}$ state of In^{115} and In^{113}: Octupole interactions in the stable isotopes of indium. *Phys. Rev.* 106:958.

With J. M. Hendrie. Radio-frequency Zeeman effect in O_2. *Phys. Rev.* 107:716.

Precision atomic beam techniques. Proceedings of the 11th Annual Frequency Control Symposium, p. 373. Ft. Monmouth, N.J.: U.S. Army Signal Engineering Laboratories, unpublished.

1958

On the polymerization of alkali halides. *J. Chem. Phys.* 28:981.

With M. Eisenstadt and G. M. Rothberg. The molecular composition of alkali fluoride vapors. *J. Chem. Phys.* 29:797.

1959

With V. Hughes. Atomic and molecular beam spectroscopy. In *Encyclopedia of Physics*, vol. 37, no. 1, p. 1. Berlin: Springer-Verlag.

1969

With D. Raskin. Interaction between a neutral atomic and molecular beam and a conducting surface. *Phys. Rev.* 179:712.