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1909–1985

A Biographical Memoir by

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WALTER GORDY WAS ONE of the founding fathers of microwave spectroscopy, a man of vision, scientific taste, disarming humor, and great personal warmth. In 1948 he wrote the first comprehensive review of the field for *Reviews of Modern Physics*, envisioning much of its future. Early in the development of the field he recognized the scientific and technical importance of expanding into the millimeter and submillimeter spectral regions and devoted a significant portion of his efforts over the next 30 years toward this end. His vision of the importance of the shorter wavelengths has come to fruition in the explosion of fields as varied and vital as interstellar radio astronomy and investigations of the most fundamental atomic and molecular interactions, as well as the current enthusiasm for the terahertz spectral region. Gordy also had the foresight to see the possibilities of applying microwave techniques to the study of biological problems and in doing so became one of the pioneers in biophysics. He opened the field of study of electron spin resonance of radiation damage in both amorphous and later crystalline organic and biological materials. In the course of developing these two fields, Gordy supervised the Ph.D. theses of 75 students, mentored

57 postdocs, wrote 4 books, and published more than 250 papers.

PERSONAL HISTORY

Walter Gordy was born on April 20, 1909, the son of Walter K. and Gertrude Jones Gordy. He was reared on a farm and attended elementary and high school in rural Newton County, Mississippi. The first seven grades were in a one-teacher school, with five-month terms arranged around the busy seasons of the local farms. He did not graduate from high school until 1929, but when he did so, it was as valedictorian. Whatever the nature of his education up to that point, he did not waste any time after that. He spent one year attending Clarke Memorial Junior College, which was closely associated with small but highly respected Mississippi College. He entered Mississippi College in 1930, graduating after only two years, even while teaching during one of those years in the high school of the town of Dixon. His bachelor's degree was awarded "with special distinction" in 1932. Gordy did not forget Mississippi and Mississippi did not forget him. He was awarded an L.L.D. by Mississippi College in 1959 and a Special 50th Anniversary Award by the Mississippi Academy of Sciences in 1980.

He enrolled immediately at the University of North Carolina in 1932, received an M.A. a year later and in 1935 a Ph.D. under the direction of Earle K. Plyler. Gordy held Plyler in exceptionally high regard, and later was instrumental in working with fellow Plyler student George E. Crouch in the establishment of the Earle K. Plyler Prize for molecular spectroscopy of the American Physical Society. He himself would be awarded the prize in 1980. In Chapel Hill he met Vida Miller, an English instructor at the University of North Carolina in Greensboro (in those days, "Women's College"), whom he married in 1935. She ventured with him to Texas, where from 1935 until 1941 they both taught at a women's college, Mary Hardin-Baylor College (later university). Like Mississippi College, Mary Hardin-Baylor College was a private institution, associated with the Baptist Church, with high academic standards. During these depression years, Gordy worked with optimism, self-sacrifice, and great energy in his pursuit of physics, serving as associate professor and head of the department of mathematics and physics, while Vida taught Latin. Salaries were nominal: For the duration of the depression, faculty let the salaries be set after the enrollment for each year was known; and the vegetable garden was essential. During the summers, he traveled to the University of North Carolina and to Ohio State University, using their infrared spectroscopic facilities to pursue his interests in spectroscopic studies of hydrogen bonding. As a result of this work, he was awarded one of just two National Research Fellowships given in physics in 1941 and went to work with Linus Pauling at the California Institute of Technology.

World War II interrupted the tenure of the fellowship. In February 1942 he joined the staff of the MIT Radiation Laboratory, where he participated in the development of microwave radar. This vital work brought no personal scientific credit but had a dramatic effect on his subsequent career. Once acquainted with the new microwave technology, he immediately deduced its untapped potential for the study of molecular spectroscopy.

At the end of the war he joined the Physics Department at Duke University, rising to its highest rank, James B. Duke Professor, in 1958. His two children, Eileen and Terrell, were raised in Durham. He was elected to the National Academy of Sciences in 1964, and won the Jesse W. Beams Award of the American Physical Society in 1974. He retired from Duke in 1979 and worked intensively on a second edition of his book on microwave spectroscopy, finishing it a year before his death on October 6, 1985.

GORDY—THE MAN

Gordy's life was focused on his science, but he had a remarkable breadth of interests and a strong commitment to the well-being of others and to society. He also had strong opinions about how society could best improve itself. He never forgot the standards and values he learned in rural Mississippi, and his Mississippi speech cloaked all his lectures and conversations in a naïve but highly intelligent idiom. As his students, we were educated not only about physics but also about life, social systems, and world demography. His Saturday classes in particular, in the 1960s, were infamous for beginning their spectroscopy portion only after he had been reminded that the period was over by the closing bell.

In 1962, when faced for the first time with the prospect of a female doctoral candidate (B.P.W.), Gordy bravely proclaimed, "I've never had a girl graduate student before, but I'm willin' to try." Her introduction to the group was, "I want you to treat her like just one of the boys." Which they did, to her relief; but it was Gordy himself who reached to help her carry an oscilloscope one day.

Gordy was the epitome of a southern gentleman; even as a junior graduate student it was almost impossible to pass through a door after him. He was loyal to all his people and knew how to fight fiercely but subtly for them, without pushing them into positions they could not handle. His files are replete with letters promoting his students, counseling them about their careers, sharing the joys of their personal and professional successes, and commiserating with them in times of trouble. Both Walter and Vida Gordy took great joy in keeping up with the large "microwave family."

Many an American Physical Society meeting in Washington reached its high point for members of that family on the evening designated for the Microwave Dinner, to which a few outside guests were privileged to be included, and where Gordy addressed the assembly, sharing his pleasure in physics and his pride in the accomplishments of each of his students just finishing or after leaving Duke.

Once, as Gordy and his wife were about to depart for a weekend event, Gordy stopped first in front of the department, just to pick up his mail. Vida remained in the car, probably working on a stuffed toy for some lucky child, as we often saw her. She had to wait an unusually long time, and she was becoming unusually concerned, before Walter finally emerged from the department. In his mail he had found a letter from a young man in Germany who was asking for a postdoctoral position. After looking at his qualifications, Gordy realized there was no time to lose if he wanted to have this young physicist come, and sat down there and then to write and send a telegram to Hans Dehmelt, who indeed came, and went on to win a Nobel Prize in 1989. More than one postdoc came to Duke because Gordy answered first.

His wife, Vida, was an integral partner in his scientific life. As a former English instructor, she had a legendary role in the editing of Ph.D. theses. The Gordys were concerned not only that the science from the Duke laboratory was correct and significant but that it was conveyed to the community in a style that was clear, elegant, and syntactically correct. The teamwork was fascinating to watch and participate in at both a personal and professional level. The harshest words I ever heard from Walter Gordy came after a long struggle about a particularly difficult point to his wife, “That may be good English, but it’s damn poor physics!” Each manuscript evolved from Gordy’s energetic but illegible scrawl to Vida Gordy's coherent transcription to the secretary's clean copy, only for the cycle to begin again—often to the horror of a student or postdoc—with ruthless alterations. Several cycles were always necessary to polish a presentation to Gordy's satisfaction.

Gordy served on committees of many organizations, including the Council of the American Physical Society. The enduring image we are left with in reviewing his files is not so much the volume of this activity but the clear commitment he had toward its worthy goals. He did not collect committee assignments to expand his resume or to enjoy power over his colleagues but as a way of giving back what had been given to him. His letter declining an invitation to serve on the NASA Research Advisory Committee on Electrophysics states, "After examining the package of blanks which I am required to fill in before serving on the Committee, I have decided that it would not be advisable for me to accept the invitation. My strong interest in research and teaching conflicts, I fear, with an activity so involved as this one seems to be in red tape and security regulations." For the committees that he did serve, he worked hard and effectively. He was not a proselytizer, but rather he understood the connections and long-term effects and how to make the arguments. He wrote impassioned letters about the job crisis for physics students in the early 1970s, not just because of the impact it had on the students who had committed their lives to physics but also because he knew that it would make it difficult to recruit students in the future, that this would damage the discipline of physics, and in doing so deprive society of the best that physics could offer.

When Gordy, as a winner of the North Carolina Medal of Science, received a letter from the governor seeking his advice on the establishment of a residential high school (now the North Carolina School of Math and Science), he seriously and carefully considered the issues, consulted with knowledgeable people, and wrote a thoughtful letter. He told the governor that while the state had many talented students whose educational needs were not being met, he believed that on balance it was more important for young people to be with their families. Gordy believed that talent, hard work, family support, and character were much more important than the circumstances of secondary school education. One of us (F.C.D.) vividly recalls Gordy's bemused understanding of the political process when he received a reply from the governor announcing the establishment of the school and thanking him for his support.

Postdocs spread the expertise of the Gordy lab with lasting effect to Europe. In England, Italy, Germany, and Yugoslavia, laboratories were initiated by visitors in the 1950s and 1960s, which in the case of the latter three countries are still contributing significantly to millimeter wave spectroscopy and electron spin resonance studies.

Having built his career at Duke, Gordy was fiercely loyal to the institution, and played an important role in its development; however, he was also an academic realist. In transmitting a report on ways to further improve the university, he included a short note to his friend Markus Hobbs, the dean of the graduate school, "Enclosed is a plan for beating the Ivy League. However, I doubt that it will work. From my years of plowing in Mississippi I gleaned this wisdom. You can't make a good crop without plenty of feed for your horses and you can't have plenty of feed for your horses without making a good crop. That's why I quit farming." Clearly, Gordy's wisdom exceeded that of most academic planning committees.

PROFESSIONAL HISTORY

Gordy's early use of infrared spectroscopy to study hydrogen bonding gained him a worldwide reputation. He found the first evidence for hydrogen bonding between unlike molecules, a concept central to studies of liquids, droplets, and gaseous complexes today. Gordy determined the hydrogen bond strength, which is related to the electron-donor property, through wave number shifts in infrared bands of many organic substances. At a time when we had less data than we do today, and the concept of the chemical bond was still under discussion, his formulation of the electronegativity scale of bonded atoms, based on force constants and internuclear distances, was a guiding concept for chemical physicists, and could be correlated with the corresponding work of Pauling and Mulliken.

Gordy's most lasting legacy has been the foundations he laid for science and technology in the millimeter and submillimeter (also known as terahertz) spectral region (100 GHz-10 THz, or 3 mm-0.03 mm). Gordy went to Duke in 1946, and with great energy established one of the major centers for the new field of microwave spectroscopy. The genesis of this field was the wartime development of microwave radar, but it was greatly aided by a fortuitous (for microwave spectroscopy at least) accident. Toward the end of the war, a previously unknown rotational transition of water (6_{16}-5_{23}) immediately in the middle of the frequency band that was being developed as the next new radar band (K-band) rendered this band unusable for radar. Not only did this make vast quantities of sophisticated K-band equipment—ordinarily beyond the means of university researchers—immediately available as army surplus (K-band klystrons at a dollar a pound) but it also established the relevance of rotational spectroscopy. In his 1948 article in *Reviews of*

Modern Physics, Gordy paid homage to this juxtaposition: "So often in the past has an instrument or a body of knowledge developed by the pure scientist found use in practical affairs that it is gratifying to find an outstanding example of reciprocity."

For most of Gordy's career at Duke, his passion was the extension of microwave techniques to ever-shorter wavelengths *and* the immediate exploitation of each new technical advance for studies of the rotational spectra of small fundamental molecules. In fact, a strong argument can be made that this focus on science led Gordy down paths to enduring technological advances: the microwave harmonic generator, electronic frequency marker systems, quasi-optical propagation, and the exploitation of sensitive detectors to compliment the harmonic generation sources.

Early and often Gordy extolled the scientific reasons for his drive toward shorter wavelengths and the complimentary technical attributes of nonlinear harmonic generation as an energy source in this spectral region:

1. Molecular absorption coefficients increase very rapidly with frequency, and the generation of even small amounts of microwave power result in very sensitive experiments.

2. The very high resolution of microwave spectroscopy can only be obtained in very low-pressure gases, which are easily saturated at modest power levels.

3. Harmonic generation sources provided a natural link to the electronic frequency standards that were necessary for precision measurements.

4. Simple but scientifically powerful systems with large bandwidth can be built. (Having gone to school in the depression, he even noted in one of his reviews, "This advantage is largely a monetary one.")

5. The spectra of many of the small and most fundamental molecular species lay there.

This last attribute—combined with the widespread adoption of the harmonic generation technique—has led to a golden age in the application of submillimeter wave spectroscopy. The molecules in our atmosphere and in interstellar space are precisely those that have been or can be studied and monitored with microwave and millimeter wave techniques. Most visible have been the large and sophisticated radio astronomy and atmospheric remote sensing experiments based on this approach that are today being deployed on balloons and in aircraft and satellites. We are sure that he would be excited to see instruments such as the *Submillimeter Wave Astronomy Satellite* and *Microwave Limb Sounder* that follow in his legacy. He would be astounded at the scale and ambition of projects like the *Atacama Large Millimeter Array* that is placing sixty-four 12-meter antennas in a desert at an elevation of 16,400 feet in Llano de Chajnantor, Chile. He would be equally impressed by the European Space Agency's *Herschel*. This cryogenically cooled satellite has a 3.5-meter objective and harmonic-generation-based receiver channels up to almost 2 THz and will be located at the second Lagrange point of the Sun-Earth system, 1.5 million kilometers from Earth. These are a fitting confirmation of the importance of his original observation of millimeter wave radiation from the Sun, obtained at a rather less advantageous site atop the roof of the Duke Physics Department, using an old searchlight reflector, in 1955.

Gordy was wise in his selection of research projects. In August 1946 in his second monthly report on his new Air Force contract he reports that the first molecule that they planned to study was ozone, "because of its uncertain structure, because it should produce strong absorptions, and because of its presence in the upper atmosphere, it is obviously of importance to the Air Force." In his first report in July he had duly reported that almost all that had been accomplished had been as a result of work for gratis, because the contract had been in effect only four days. Even at the very beginning Gordy was canny in the selection of a project that combined a scientific unknown of broad general interest, an astute judgment of the requirements for the success of the project, and relevance in the real world and to the sponsor of the research. Indeed, for largely the same reasons, ozone is still of active research interest in many labs around the world today. When one of us (B.P.W.) was presenting her Duke thesis work in electron spin resonance of irradiated DNA at a seminar in Germany, her host, who also worked in this field, asked her, "How does Gordy do it? He always thinks of a new type of experiment before we have been remotely able to explore the possibilities in his last experiment."

Exploiting his laboratory's microwave expertise in 1955, Gordy pioneered the use of electron spin resonance—a brand-new technique that he had just begun to explore—for the study of radiation effects on biological substances. He led in this field with studies of amino acids, and did not shy away from proteins, DNA and RNA, and animal tissue. His laboratory also made the first measurements of a single crystal of an irradiated organic substance, allowing the full *g*-tensor to be determined. By 1965 he and his colleagues were observing the electron spin resonance spectra of single crystals of constituents of DNA, which led to the identification of a hydrogen addition radical in thymidine. Through studies of oriented radicals produced in irradiated single crystals of amino acids and simple peptides, he found the explicit structures of the stable or moderately stable free radicals preferentially produced in a number of proteins and could relate them to the protein structures. His studies helped to clarify the mechanism of the oxygen effect in radiation damage and the action of certain chemicals (cystine) in providing protection from radiation damage to biological systems. These biological studies led to the initiation of similar work by groups in medical schools studying nuclear radiation effects as well as in universities and national research laboratories in various countries. His laboratory also became infamous in the physics department at Duke because his students had to go to the local slaughterhouse for fresh bone, horn, and assorted bovine and poultry tissue.

After the surprising identification of a hydrogen addition radical in thymidine, Gordy and his coworkers explored observations of the electron spin resonance of free radicals produced in powdered samples of the nucleic acids and their constituents that had been bombarded by hydrogen atoms. Later, the method was applied to show the effects of the interaction of hydrogen atoms and of OH radicals with proteins and their constituents, as well as other substances. The identification and characterization of radiation-induced radicals through electron spin resonance has remained a cornerstone in the understanding of radiation damage of all types. Toward the end of his career Gordy wrote a major book on the methods of analysis of electron spin resonance spectra.

The scientific writing of Walter Gordy is fluent and clear, and his books have enjoyed wide readership and appreciation from students and experts alike. He published the first book on microwave spectroscopy in 1953, and then in 1970 compiled, in collaboration with Robert L. Cook, the even more significant volume *Microwave Molecular Spectroscopy*, which underwent a major revision and expansion in 1984. This was an extraordinary effort, but a labor of love and in many ways a legacy for the next generation. One of us (F.C.D.) can still recall the joy and relief in 1983 occasioned by the mailing of the final manuscript to the publisher, followed by Gordy's despair upon learning that the price of the book would be $175, clearly beyond the means of the students who he hoped he could help train. There followed a carefully crafted letter to the editor saying how disappointed he was, which elicited an equally carefully worded letter from the editor saying how he shared Gordy's disappointment. Walter would be pleased to know that this long out-of-print book has a current Internet price of $700.

More than 20 years after his death, Walter Gordy's legacy is large and expanding. In a conference devoted to the exploitation of the submillimeter spectral region, he once observed, "Thus, in 1946, the spectral region from wavelengths of 4 mm to 0.3 mm represented a rich, underdeveloped natural resource. To our newly formed microwave laboratory at Duke, it represented an exciting challenge." This "gap in the electromagnetic spectrum" that he identified early on as a worthy scientific home is now home to a diverse community going under many names: the millimeter, submillimeter, or near millimeter wave, terahertz,or far infrared region. The techniques that he pioneered and the scientific results he achieved have provided the foundations for much of this work. Similarly, he reveled in the unknown possibilities in the applications of electron spin resonance to complex biological systems, the aesthetic antithesis of the discreet millimeter wave spectroscopy of gases. Both fields are active today, 50 years later, with new technological tools and broader applications.

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