Terahertz Pioneers

A Series of Interviews With Significant Contributors to Terahertz Science and Technology

AS A TRIBUTE to individuals who have contributed significantly, and over many years, to the terahertz community, and as a guide and inspiration for those who are just beginning their professional association with this field of study, this TRANSACTIONS will continue to include, on a regular basis, a series of biographical interviews with technical researchers who have appreciably impacted the THz community in a positive manner. In order to go beyond a strict technical review and to take better advantage of the information and commentary only available through a direct discussion, these articles will take on a less formal style than the research articles that can be found within the remaining pages of the transactions. The Editor-in-Chief hopes that he may be given some leeway in this regard, for the benefit of communicating more fully the character, experiences, and historic circumstances that have shaped our community and set the directions for our collective research. The Editor-in-Chief, with the support of the IEEE MTT Publications Committee, has chosen to incorporate these biographical articles within the more formal technical journal because of the diversity of disciplines that make up the THz community and the prior absence of a single unifying publication with sufficient outreach to extend across the whole of the RF and optical THz disciplines. The Editor-in-Chief hopes you will enjoy the short diversion of reading these articles as much as he himself enjoys the process of composing them. As the third article in this series, he has spoken with an individual whose experience with THz sources and detectors started in 1955 at what was to become the Royal Radar Establishment in Malvern, U.K. That experience is still being tapped today. At age 79, Maurice FitzGerald Kimmitt has just put the finishing touches on a new book on *Terahertz Techniques* that he has completed with colleagues Erik Bründermann and Heinz-Wilhelm Hübers. I believe the reader can learn much from Professor Kimmitt's career path choices and his perseverance.

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Maurice FitzGerald Kimmitt lives with his wife of 51 years, Mhairi (pronounced V *ahree*) in Brightlingsea, Colchester, Essex, UK. He has been "officially" retired since 1983, but in fact has been working continuously since that time on a large number of projects with a number of well known researchers around the world, especially in Scotland, Italy, Germany and the USA. I spoke with him at his residence in Brightlingsea on October 14th, 2011, while enjoying his hospitality, his verve and his wonderful stories about the early years of THz and his unique philosophy of life.

Terahertz Pioneer: Maurice F. Kimmitt

"A Person Who Makes Things Work"

Peter H. Siegel, *Fellow, IEEE*

IN 1954, a young man who had just graduated with a degree in English Literature from Trinity College, Dublin, Ireland, decided to go into the clergy. However, his identical twin brother, Maurice, who came out with a B.A. degree in Physics in the same year, decided he could best continue his boyhood interests in crystal radio sets by joining the Radar Research Establishment (RRE), which was set up during World War II as the Telecommunications Research Establishment (TRE), in Malvern, U.K., not far from Stratford-upon-Avon. A few years later, after a 1957 visit by Queen Elizabeth II, it was rechristened as the *Royal* Radar Establishment. Thus began a career in infrared physics and devices that has spanned nearly 60 years. In the course of that time, Maurice FitzGerald Kimmitt[1] has interacted with researchers on three continents and influenced many fields of THz science, from direct detectors, to high power laser-based sources, to diagnostic and measurement instruments.

Maurice Kimmitt was generating and detecting submillimeter-waves before the field had any official designation. "Mega-megacycles" or "milli-microwaves" could be produced readily from spark gap generators, but detecting the power with sufficient sensitivity and speed to perform useful measurements was another matter. Bulk thermal detectors and crystal rectifiers were available but their sensitivity was extremely limited. The Golay cell (which had just recently been invented by Marcel Golay at the U.S. Army Signal Corp., Monmouth, NJ, USA [1]), although sensitive, was quite slow (10's of milliseconds) as well as being subject to serious background noise problems, as those of us who continue to use it today are well aware. Kimmitt started at RRE, working under David H. Parkinson, a group leader in Physics and Electronics. The plan was to study cyclotron resonance in indium antimonide, InSb, an important detector used for tracking aircraft by their engine heat. Signal power for the measurements was generated using harmonics from an 8 mm wavelength klystron that unfortunately suffered from large amplitude fluctuations. In addition, the InSb was simply not pure enough at the time to accurately measure the cyclotron resonance, but the work led to Kimmitt's first paper, published in 1956 [2]. This was on a klystron amplitude stabilization technique using an early form of ferrite modulator with permanent and adjustable coil magnets that proved very useful for this type of source fluctuation. The modulator was suggested by RRE colleague A.F. Harvey, noted for his work on microwave tubes [3], ferrites [4] and biological impacts of RF [5].

MAURICE F. KIMMITT

Cyclotron resonance research on semiconductors required the use of liquid helium, which in those days was a very precious commodity, and precooling of the semiconductor and associated equipment was often performed with more readily available liquid hydrogen—a substance one did not handle without due regard for the experiences of the passengers and crew of the Hindenburg! This early experience with low temperature techniques was to be of importance throughout Kimmitt's career.

For his next task at RRE Kimmitt was told to try and improve the sensitivity of semiconductors that might provide alternative heat sensors to InSb. One of these, lead selenide, PbSe, covers the range 1–5 μm at room temperature and out to 7 μm when cooled to 77 K. For this research he used a sophisticated two prism monochromator that had been built at RRE some years earlier [6]. This research produced very useful results and several years afterwards, when his work was declassified, Kimmitt was able to release details of this new PbSe p-n junction detector work [7].

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[1]Maurice FitzGerald Kimmitt lives with his wife of 51 years, Mhairi (pronounced *vahree* in Brightlingsea, Colchester, Essex, UK. He has been "officially" retired since 1983, but in fact has been working continuously since that time on a large number of projects with a number of well known researchers around the world, especially in Scotland, Italy, Germany, and the USA. I spoke with him at his residence in Brightlingsea on October 14th, 2011, while enjoying his hospitality, his verve and his wonderful stories about the early years of THz and his unique philosophy of life.

Having acquired valuable experience in spectroscopy, the handling of cryogenic liquids, millimeter-wave instrumentation, and infrared detector development, Kimmitt next moved over to the RRE radar group and worked on a photomultiplier tube-based track-imaging radar for a high altitude spy plane. Although the radar never actually flew, it resulted in many highly appreciated demonstrations to British Air Force personnel, who were treated to a lab demo system that scanned in a rather popular image of Marilyn Monroe and displayed it on a long duration phosphor screen!

Intercontinental Ballistic Missile guidance systems based on Doppler radar principles was Kimmitt's next project, in yet another group at RRE. His main involvement was with Joe Hewitt (of Hewitt camera fame [8]), who had designed a precision optical telescope-camera system that could pinpoint and track centimeter scale targets at 40 000 feet, using stellar astrometry. It was Kimmitt's first experience with astronomical instruments, and in 1957, was a state-of-the-art system. Unfortunately the program was cancelled when inertial guidance replaced the star tracking system. However, Hewitt and Kimmitt were able to use the system to get some of the first tracking data on Sputnik, which launched that same year.

At this time, RRE received a major contract from the Atomic Energy Research Establishment at Harwell, UK who were beginning work on a large plasma fusion reactor with the acronym *Zeta* (Zero Energy Toroidal Assembly). The *Z-pinch* design reactor went on line in 1957. The need for real-time plasma diagnostics required someone with experience in helium cooled systems, spectroscopy and IR detectors. Kimmitt was tapped for the job, and returned to the RRE physics group, where he proceeded to make some of his most successful early THz measurements. With his colleagues, he designed an evacuated grating spectrometer with very large optics to measure the plasma density and temperature via the emitted free electron-electron energy (Bremsstrahlung) of the super heated gas [9]–[11]. Initial measurements were with Golay cells and with these he was able to detect submillimeter-wave output at electron densities greater than 5×10^{16} cm^{-3}, much higher than could be monitored using microwave techniques [10]. Coincidentally, the next broadband detectors for *Zeta* used the same Boyle-developed helium cooled carbon resistive bolometers [12] that Paul Richards employed so successfully for his work on measuring bulk superconducting energy gaps [13]. Kimmitt, like Richards, also realized the severe excess current noise limitations of the carbon bolometer, and thought about cooled germanium devices, but did not convince a skeptical management at RRE to let him go off on such a tangent! To be fair to RRE management, they suspected that much faster detectors were just around the corner.

Detector speed was of course a serious issue when dealing with plasma discharges and, luckily, during the course of the *Zeta* program project, Ernest Putley, one of Malvern's many outstanding scientists, invented the sub-microsecond response time InSb bolometer, subsequently named after him [14]. The original detector operated in a magnetic field of 6 kG and had a response from about 0.3–10 mm wavelength. Ideally, response to somewhat shorter wavelengths was needed for the *Zeta* measurements. Kimmitt had noticed that, by increasing the magnetic field, the detector's response below 0.3 mm improved. Not one to do things by halves, Kimmitt constructed a 25 kG solenoid. Setting the magnet for maximum field, he found minimal signal at long wavelengths but **sw**eeping to higher frequencies, he forcibly pegged the pen recorder over a narrow wavelength range. Accidentally he had discovered a cyclotron resonance in indium antimonide that he later published with Mike Brown [15]. By a strange twist of fate, Kimmitt had returned and successfully completed his initial first assignment at RRE! Later he was to return to InSb studies yet again but at even shorter wavelengths [16].

Around this same time, Kimmitt started experimenting with stimulated emission from gases. In a classic short paper with co-authors Crocker, Mathias and noted spectroscopist Alastair Gebbie, they observed strong submillimeter wave emission from low pressure water vapor, using the spectrometer built for the *Zeta* experiments [17]. This was the first demonstration of the water vapor laser, and in fact the first far-IR gas laser. This experiment even made the popular scientific press and appeared as a New Scientist article in 1964 [18].

In 1965, on an offer from Prof. Alan Gibson, who had moved from RRE to become the first Physics Department head at the new University of Essex, Kimmitt left Malvern to take up a position in academia. Gibson was a brilliant physicist and an inspirational leader but, inevitably, much of his time was taken up in organizing the new department, and in teaching. When Kimmitt joined his research group he became largely responsible for its day-to-day operations. With a flow of excellent Ph.D. students, the next ten years were very productive, with research on CO_2 and optically pumped far-infrared lasers, many other types of infrared lasers, intensive studies of semiconductors, and the development of high power detectors. The *photon drag detector* (transfer of momentum from an optical laser to free electrons and holes in a semiconductor) invented in 1970 by Gibson, Kimmitt and Walker [19], became, and still is, a workhorse high power, high speed (nanosec), room temperature, electro-optic sensor. The first device used germanium, but later versions used a variety of different semiconductors [20]–[22]. The photon drag detector was later commercialized and has been used in a wide range of solid-state physics studies on semiconductors, as well as in high power laser monitoring.

Gibson left the university in 1975 to return to government research and Kimmitt officially took over the group at Essex. He had picked up his Ph.D. in 1973, which helped legitimize his new role. During our interview, Kimmitt waxed nostalgically about the very international make up of his university group at this time. He had one of the first students to come to the west from post-cultural revolution China, also Iran, Iraq, Egypt, India, Greece, Argentina and several other countries. This appreciation for the international nature of science stuck with Professor Kimmitt, who now began to lecture abroad widely, first with a month's visit to China through the sponsorship of the Royal Society, and later around the globe. He also assisted in starting a very popular series of specialized Masters Degree courses at Essex that brought in many new students from industry and academia, and he focused a significant amount of personal effort on organizing and teaching these classes. These courses included, for the full time students, visits to various government and industrial laboratories, often in a fourteen seat minibus driven by Kimmitt. For some of the longer visits overnight stays were required, sometimes leading to hilarious evenings. Maurice explained any liberality in funding these by

claiming that he could convert gasoline into wine, as nobody would notice the low miles to the gallon that the minibus achieved! This change of focus, with the emphasis on organization and teaching, began taking him away from his research activities, and led to a major decision point in his career path.

1983 was the turning point. As a result of both government austerity measures and falling science enrollment, long serving science faculty in many universities throughout the UK were offered early retirement in exchange for expanded benefits. Kimmitt decided he was in a good position to take advantage of the offer, and resigned his full time position at Essex. He stayed on for another seven years, but as a lecturer/researcher/administrator on very reduced hours. This turned out to be a very opportune change, as the extra time he now had available allowed him to collaborate at will with research groups around the world and not worry overly much about the full time compensation.

Kimmitt started his "retirement career" with a position at Heriot-Watt University in 1983, working with Carl Pidgeon on their free electron laser (FEL) program [23]. This relationship continued on and off for many years. In 1987 he also began working for extended periods with ENEA at Frascati near Rome, Italy (National Agency for Atomic Energy), who were also developing FELs [24]. The group at Frascati was led by Gian Piero Gallerano, now himself a very significant figure in the THz community. Kimmitt describes his visits to Italy as high spots in his life. Apart from being a productive time scientifically, with close on twenty publications over the next sixteen years, there was happiness both inside and outside the laboratory. Gian Piero became a long term collaborator and close personal friend, and Frascati later played a major role in a large European THz biological research program, THz Bridge [25].

In the early 1990's Kimmitt also became involved with a group at Oxford University, U.K., that had planned to set up an FEL facility, but was unsuccessful in getting the funding. Fortuitously, Kimmitt had by this time been introduced to Professor John Walsh, of Dartmouth College USA, by Carl Pidgeon (in an Edinburgh bar!) when Walsh was on a visit to Heriot-Watt. Walsh and Kimmitt struck up an instant friendship, which resulted in Kimmitt visiting Dartmouth, where Walsh and his students were passing electron beams across ruled metal gratings to produce Smith-Purcell (SP) radiation at millimeter wavelengths. Kimmitt advised the Oxford group to hook up with Walsh and collaborate on using the Oxford University large van de Graaff generator, and together they performed very successful, large scale far-infrared Smith-Purcell experiment at THz frequencies using a clone of Maurice's RRE spectrometer [26]. One of the leaders of the Oxford group was Dr. George Doucas, a consummate physicist, both in theory and experiment. He and Kimmitt have since collaborated on using the Smith-Purcell effect for the determination of the longitudinal bunch profiles of electron beams over many years. This has involved experiments at ENEA in Italy [27], in The Netherlands, using the electron beam of the FEL, *Felix*, and more recently at the Stanford Linear Accelerator Center in Menlo Park, CA, USA.

Kimmitt kept up the close relationship with Walsh, and was an adjunct Professor at Dartmouth until well past Walsh's death in 2000. His many papers on using the Smith-Purcell effect for generating THz radiation continued through 2009 [28] and included a notable result on the first micro-scale super-radiant Smith-Purcell emission [29].

Another of Kimmitt's major collaborations involved several colleagues and groups in Germany. Jumping back to the mid 1970's, he came into contact with Hans Peter Röser, then a Ph.D. student at the Max Planck Institute for Radio Astronomy in Bonn, Germany, and now a noted submillimeter-wave astronomer. This was at an industrial show he was attending in Munich, where Kimmitt was displaying his recently commercialized photon drag detector. Röser was working on CO_2 lasers. The two met to discuss common research problems, and the relationship blossomed. Kimmitt collaborated on and off with Röser on laser and submillimeter-wave sources and detectors for more than three decades. This included extended stays at the Max Planck Institute in Bonn and the DLR in Berlin. Significant accomplishments from this collaboration include a nice paper on early photon drag detectors [30] and more recent work on Schottky-diode detectors [31]. In the early 1990's Maurice met two of Röser's students, Heinz-Wilhelm Hübers and Erik Bründermann, both now noted THz experts, and began a collaboration with them that continues today.

If you thought at age 79, Kimmitt would be closing off his long career, you would be wrong. He has just completed a re-write and update of his early text on *Far-Infrared Techniques* [32], now *Terahertz Techniques* [33], with Hübers and Bründermann, which will appear around the time this article is printed. You can read Kimmitt's latest paper in this journal in the September 2011 Inaugural issue [34]. We hope this will not be the last. As he now claims that his time in the laboratory is ending, perhaps he will pursue his interest in the history of far-infrared research, on which he has already published and given lectures [35].

In reflecting on his long career, Kimmitt expressed that his greatest joy has been his interaction with students at Essex, Heriot-Watt, Dartmouth, Bonn, Oxford, and Berlin. He had a special involvement with those at Dartmouth after John Walsh's untimely death and was particularly touched by the tribute of Heather Andrews, one of the very last of Walsh's students to graduate, who has since being doing splendid research at Vanderbilt and now Los Alamos, New Mexico. In her thesis there is an acknowledgement to "Maurice Kimmitt, who is a good luck charm in the lab, a wealth of information about all things related to the far-infrared, and a pleasure to work with."

In a dedication to a special issue of Far-Infrared Techniques and a workshop held in his honor in Berlin in 1999, it was said of Maurice Kimmitt, he is "*a person who makes things work*." Maurice F. Kimmitt is still working, and still making things work, wherever his unique skills are sought. Although he admits he has slowed down a bit, he still keeps up with publishing, with research, and with lectures and appearances at conferences and workshops at a pace that would be the envy of much younger persons. You will find his name associated with many branches of infrared science, and you might even come across his 1985 educational book on *Lasers* [36] with co-author Lynn Myring, if you engage in science reading with your children!

Perhaps two lessons to take away from this interview, are that a career does not necessarily end after retirement, and that the buffeting about that accompanies many career paths often has consequences that are not quite as predictable as a good experimentalist might anticipate, but are nonetheless rewarding.

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Maurice F. Kimmitt received the B.A. degree from Trinity College, Dublin, in 1954 and the Ph.D. degree from the University of Essex in 1973. He joined the Telecommunications Research Establishment (later the Royal Radar Establishment) in Malvern, U.K., in 1955, where he remained until 1965. At RRE, he worked in various departments, including Physics, Radar Systems, and astronomical cameras related to missile guidance. He joined the staff at the University of Essex in 1965 where he first concentrated on research, and later taught in the Physics Department until 1986. From 1976 to 1987 he helped to develop and run a series of highly popular specialist 'Masters Degree Courses' at the University of Essex. In 1983, Dr. Kimmitt retired to a part time post at the University, that he held through 1990. He was then able to focus more fully on collaborative research, holding visiting positions at Heriot-Watt University in Edinburgh, U.K., Dartmouth College in the USA, ENEA Frascati outside Rome, Italy, the Max Planck Institute of Radio Astronomy and the DLR in Germany. His publications include two technical books *Far-Infrared Techniques* and *Terahertz Techniques* (with Heinz-Wilhelm Hübers and Erik Bründermann), joint authorship of two book chapters, editor of two volumes on 'Lasers in Manufacturing', a book for 'young persons' on Lasers, well over 100 (author or joint author) papers in refereed journals, and several Royal Radar Establishment internal reports.

Dr. Kimmitt has lectured widely around the globe and given many invited talks at major conferences and workshops. In 1999 a special issue of the journal Infrared Physics and Technology was dedicated to 'Professor Maurice Kimmitt' following a meeting in his honor in Berlin. Amongst other awards he received the 2004 Kenneth J. Button medal for contributions to the field of electromagnetics. Most recently he was Honorary Chair of the 2010 International Conference on Infrared, Millimeter, and Terahertz Waves in Rome, Italy.