

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 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 (EiC) 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 EiC, with the support of the IEEE Microwave Theory and Techniques (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 EiC hopes you will enjoy the short diversion of reading these articles as much as he himself enjoys the process of composing them. As a fitting subject for the first article in this series he has chosen an individual whose name is synonymous with THz time-domain spectroscopy, but whose background began with RF and microwave techniques, Dr. David Henry Auston.

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Dr. David H. Auston currently resides in Santa Barbara, CA, where he is on his fourth career as Executive Director of the University of Santa Barbara Institute for energy Efficiency. I met him in Santa Barbara for this interview after a wonderful talk he gave at the 2011 Optical THz Science and Technology Workshop (OTST) on the future and impact of energy production and the role UCSB research. The interview was conducted on March 15, 2011.

Terahertz Pioneer: David H. Auston

Working Collectively to Combine Complementary Knowledge, Perspectives and Talents

Peter H. Siegel, *Fellow, IEEE*

THE year was 1963. A bright and adventurous young radio astronomy student just out of a Masters program at University of Toronto, immediately raises his hand when asked by a visiting recruiter if anyone in the graduating class would like to move to California. David H. Auston¹ does the exact opposite of what many young American men are doing at the time. Rather than moving to Canada from the United States to avoid a very unpopular military draft that sent thousands to a war across the Pacific, he comes, with his wife and daughter, to Santa Barbara, CA, to work at the General Motors Defense Research Laboratory. With a background in physics and astronomy as well as electrical engineering, and some summer experience working at Canadair, Montreal, Canada, (now part of Bombardier Aerospace) on microwave radar domes, Auston's first projects at GM involved designing microwave resonators for applications in plasma diagnostics [1].

One of the benefits of working for GM at the time was the opportunity to pursue graduate studies, and Dr. Auston was fortunate to earn both a scholarship and a spot in UC Berkeley working with Professor John Whinnery (co-author with Simon Ramo of, *Fields and Waves in Modern Radio*, Wiley, 1953). Dr. Whinnery had a strong influence on the young Auston, in terms of his hands-on interactions with his students, background in RF, and growing interest in lasers, which were just beginning to become "the" hot new field in physics. Professor Whinnery had even spent a recent sabbatical at Bell Labs, Murray Hill, NJ, in order to help with a transition into laser science. As a consequence, Dr. Auston too began working on gas lasers and, as part of his thesis, developed a novel fast scanning HeNe system using collective transverse modes [2].

After completing his dissertation, Dr. Auston had the enviable opportunity to join a group of 120 enthusiastic research Ph.D.'s that were offered start up packages at Bell Laboratories. In 1966 he made the cross country trip to Murray Hill, NJ, where he was given a lab, an assistant, a budget, and simply asked to "do something original." At the time this mandate seemed a bit daunting to an individual just starting out on a research career path, but in



DAVID H. AUSTON

retrospect, what new graduate today would not envy the opportunity to choose a path not dictated completely by application mandates? Opportunities for basic research, at least in the US, have indeed shrunk to a very select few.

At Murray Hill, Dr. Auston quickly teamed up with materials scientist, Dr. Alastair M. Glass, in a noted partnership that resulted in pioneering work for both researchers on novel optical phenomena in electro-optic crystals [3]–[5]. Using intense picosecond duration pulses (1.06 μm) from newly available neodymium-glass lasers, they were able to create very short electrical pulses through polarization of ionic impurities in copper doped lithium tantalate crystals ($\text{LiTaO}_3\text{Cu}^{++}$). They observed the electrical pulses optically as they propagated along a LiTaO_3 transmission line by recording the electrically induced birefringence, and corresponding change in the optical transmission of a synchronized but delayed transverse 530 nm pulse derived from the same mode locked laser [4]. This work led to the more general concept of using optical excitation to generate ultra-short electronic signals. According to Dr. Auston, it was a combination of the availability of intense high speed optical sources, the use of microwave transmission line techniques, and the ability to engineer new material properties that together opened up the field of modern optoelectronics.

The idea of using photoconductors rather than ion doped crystals to generate the electrical signals came shortly afterwards when Dr. Auston began experimenting with silicon-based transmission-line structures [6], [7]. In the earliest experiments, very

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fast rise time electrical signals could be generated, but long carrier recombination times in silicon limited the bandwidth through the rather slow decay times. To terminate the electrical pulse, he deployed a second optical pulse to create a short-circuit in the transmission line. Detection of the signal was accomplished by using a second pair of optical pulses further down the transmission line to open and close the circuit in a similar fashion. This general approach for generating and detecting extremely fast electrical pulses by optical techniques became known as the “Auston Switch”.

Picking up on a suggestion by Bell colleague, Jene Golovchenko (now at Harvard University), Dr. Auston began working with laser annealed ion implanted silicon [8] and also radiation damaged silicon [9] which was known at the time to have very fast recombination times, albeit, poor mobility. During a sabbatical at Ecole Normale Supérieure, in Paris, France, he also got started on some work with thin film amorphous silicon through a collaboration with Daniel Kaplan at Thomson CSF. During his time away from Bell Labs, a treasured graduate student, Anthony Johnson (now at UMBC, MD), kept the research going and protected the equipment from “wandering off” to other programs—something many of us can relate to. The first sets of experiments on these new photoconductive materials were quite successful and yielded picosecond electrical pulses [9], [10]. Soon afterwards thin film silicon-on-sapphire photoconductors became the workhorse source and detector elements for short pulse electro-optic measurements. These included everything from millimeter wave signal generation [11] to the observation of electro-optic shock waves [12].

The first serious interest in using the generated electro-optic signals for spectroscopy came in a series of experiments conducted with colleagues K. P. (Charles) Cheung (most recently Rutgers University) and theorist David A. Kleinman, on characterizing the electrical pulses in lithium tantalite. By 1984 it was possible to observe the lattice vibrations in the material at frequencies up to 6 THz using coherent detection techniques and direct time domain observations made possible by the fast photoconductors [13], and reported in later [14]. These observations were best performed “*in situ*” in the crystal due to the very high index of refraction and the difficulty in efficiently radiating the THz power out of the media. At this time the idea of using the optical pulses not just to excite a photoconductor, but to actually generate a localized current that could be swept up and radiated by a localized RF antenna began to take shape and the coherent generation and detection of free space radiating RF fields using fast optical pulses was demonstrated [15]. This second most cited of Dr. Auston’s papers, led to additional work on optically excited photoconductive radiating antenna structures, mainly with former post-doctoral student Martin Nuss then at Bell, and resulted in the most cited of Dr. Auston’s many papers, “Subpicosecond photoconductive dipole antennas” [16].

By 1987, Bell Laboratories was well into its spectacular downsizing with the continuous dispersion and relocation of so many well known scientists and engineers it seemed at the time to this interviewer to be the greatest scientific Diaspora since the Second World War. Dr. Auston was no exception, and after referring to this time as “17 wonderful years,” he left his position as department head in Physics at Bell and accepted a

position in the Electrical Engineering School at Columbia University in NYC. Having started his career by choosing between an academic track and a professional research environment, he was now able to explore the path he had turned from in 1966.

Fortunately, at Columbia, the environment was equally conducive to collaborative research work. With the arrival of Xi-Cheng Zhang (currently at RPI, NY), who joined the department in 1987 as a research scientist, an extremely fruitful and long term partnership developed. Auston and Zhang, along with a number of students, began working on the direct generation of THz signals from a variety of semiconductor materials that could be excited optically at non-normal angles of incidence and would create a current pulse normal to the excitation direction that could launch a propagating RF wave-form outwards into free space or through the material [17]. This very effective means of generating and transmitting THz signals launched a new avenue of development for producing broad band THz pulses. At about this time Dan Grischkowsky (then at IBM Watson Research Center, Yorktown Heights, NY, now at Oklahoma State University, Tulsa) was developing alternative methods for generating, propagating and detecting THz pulses, and applications of the new techniques for a range of THz spectroscopy and imaging were beginning to emerge. The field of THz Time Domain Spectroscopy had come of age and has continued to grow ever since.

In 1990 Dr. Auston could not say no to a request that he take a position as Dean of Engineering at Columbia, and although he kept up his laboratory work and involvement with students (as well as former colleagues at Bell) for a few more years, he found himself moving further away from research. With his last Columbia graduate student, Ajay Nahata (currently at University of Utah) and Columbia colleague Tony Heinz, he worked on a free space electro-optic sampling technique, which has been widely employed [18]. By the fourth year into his Dean of Engineering post, the lab work was receding fast and new skills were being tapped. In 1994, an offer came in from Rice University, Houston Texas, with a step up to a Provost post. Another fork in the road was looming, and Dr. Auston chose to take the path that led away from individual scientific achievement and towards a challenge that involved strategic vision, superb people skills and an emphasis on political savvy. There was no regret expressed in retrospect at this decision, and Dr. Auston brought the same enthusiasm, collaborative attitude and strategic thinking to Rice that he had utilized for his entire career as a research scientist. His five years as Provost at Rice prepared him for his most trying challenge which came in 1999 when he was recruited, and ultimately accepted a position as President of Case Western Reserve University in Cleveland, Ohio. Again, his ability to develop, articulate and stand behind a strategic vision and his now expansive experience in commercial, academic and administrative work environments, made him a near perfect match for the role of University President. He undertook a campaign to build up the academic reputation and financial endowment at Case and raised more money in the two years he stayed on as University President than anyone before or since. Again, as at all the places he has worked, his personal preference to work in a collaborative way and his belief that cooperation is the key to success, shaped his vision as a leader and helped to create and sustain such an environment wherever he found himself.

After two years at Case, an impasse over the management and direction of the Medical School caused Dr. Auston to choose to leave the university and in 2001, he and his wife resettled in Santa Fe, NM. His respite was short lived, however, for soon after arriving in Santa Fe, he was courted by well known physicist and philanthropist, Fred Kavli, to head the newly founded Kavli Foundation in Oxnard California to support basic scientific research. Dr. Auston started on an enviable job, a nine year campaign to seek out and provide multi-million dollar support to each of approximately 15 academic institutions around the world, which in turn agreed to match the investment and to set up Kavli Institutes for basic research in the areas of theoretical physics, neuroscience, astrophysics and nanoscience. During this time Dr. Auston visited and evaluated more than 50 programs at universities around the globe, and true to character, he sought out for funding, those programs with a strong culture of collaboration. In fact he sums up his recipe for successful scientific research in three traits: scientific talent, the backing of the institution and a culture of collaboration and cooperation. Whether you are an individual striving for a successful career or an institution hoping to make a difference in a competitive world, I doubt that any advice could be more prescient, nor could it come from an individual with more experience than David Henry Auston.

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David H. Auston received the B.A.Sc. degree in engineering physics and the M.A.Sc. degree in electrical engineering from the University of Toronto, Toronto, ON, Canada, in 1962 and 1963, respectively, and the Ph.D. degree in electrical engineering from the University of California, Berkeley, in 1969.

He was a Research Physicist at GM Defense Research Laboratory, Santa Barbara, CA, from 1963 to 1966. From 1969 to 1987, he was a Member of Technical Staff of Physics Research, AT&T Bell Laboratories, Murray Hill, NJ, where he also served as Department Head of the Physics Research Division from 1982 to 1987. He was with Columbia University, Columbia, NY, from 1987 to 1994, wherein he served as a Professor of Electrical Engineering and Applied Physics from 1987 to 1994, Chairman of the Department of Electrical Engineering and Applied Physics in 1989; and Dean of the School of Engineering and Applied Sciences from 1990 to 1994. He was Provost, as well as Herman Brown Professor of Engineering at Rice University, Houston, TX, from 1994 to 1999. From 1999 to 2001, he was President of Case Western Reserve University, Cleveland, OH, as well as Professor of Electrical Engineering and Computer Science. He was President of the Kavli Foundation from 2002 to 2009. In 2009, he became Associate Director of the Center for Energy Efficient Materials (CEEM), University of California, Santa Barbara, where he continues to serve today. He has authored more than 100 publications in peer reviewed journals, 2 book chapters, and holds 8 patents. He has completed more than 150 conference presentations and invited talks, and to date, has 5850 citations on Web of Science.

Dr. Auston is an elected Member of the National Academy of Sciences, the National Academy of Engineering, and the American Academy of Arts and Sciences. He is a Fellow of the American Physical Society and the Optical Society of America. He was the recipient of the R. W. Wood prize of the Optical Society of America, and the IEEE JOURNAL OF QUANTUM ELECTRONICS and IEEE Morris E. Leeds Awards.