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, these TRANSACTIONS have included, 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 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 has taken 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. As a further means of assuring that the true flavor and circumstances of the contributions are expressed in the text, all of the articles are compiled after a face-to-face interview. The final text is shared with, and often helped considerably, by comments from the subject of the article. The Editor-in-Chief, with the support of the IEEE MTT Administrative 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.

We again ask for a bit of indulgence this month, in that our THz Pioneer, Professor Michael Bass,1 has not spent a career in the pursuit of THz science or applications. However, his thesis work on optical rectification under Peter Franken2 remains, after more than 50 years, the most relevant precursor work on THz generation through dual-source optical mixing,3 direct optical mixing with excited crystal vibrational modes,4 and via frequency component mixing in ultrafast optical pulses passing through nonlinear crystals.5 Dr. Bass was recently honored with the R. W. Wood prize for this latter development, which although it predated the technical hardware necessary to perform experimental verification, set the theoretical groundwork for what was to become an explosion of interest some 30 years later.6 7

Please join with me in reading about Dr. Bass’s career in optics, and his various interests in laser applications. I am sure we can all learn something new from this pioneer of THz generation.

Peter Siegel, Editor-in-Chief

1 I met with Michael Bass during a short lull in graduation exercises on the campus of University of Central Florida—now the second largest university by enrollment in the United States. Our discussion included many topics of general interest in addition to those contained in this short article. As it turned out, we had much that was common in our backgrounds, despite the gap of one generation. Michael grew up in the “Atoms for Peace” movement, whereas my own experience was in the heat of the Cold War. However, we both spent our youth in NYC, were the only ones in our families to have an interest in science, share an enjoyment of science history, and appreciate the twists and turns that often accompany, and in fact dictate, the choices that ultimately sum up a career.

2 Peter Franken passed away in March 1999, after a distinguished career at the University of Michigan’s Randall Laboratory, and as head of the University of Arizona’s Optical Sciences Center from 1973 to 1983. Franken served as President of the Optical Society of America in 1977, and is referred to by the Optical Society of America as a father of nonlinear optics (http://www.osa.org/en-us/history/biographies/peter-franken/).


Terahertz Pioneer: Michael Bass

“The THz Light at the End of the Tunnel”

Peter H. Siegel, Fellow, IEEE

A S A YOUNG MAN growing up in the Bronx, NY, in the 1950s, Michael Bass was able to take full advantage of the museums and other unique multi-cultural offerings of a major metropolis. The extensive New York City subway system cost a nickel a ride, and the trip from the Bronx to the American Museum of Natural History on 83rd street in Manhattan, took less than an hour. Michael found himself visiting the museum frequently and developing an early interest in science. While attending the prestigious Stuyvesant High School, a public secondary school then on 15th street in Manhattan—which boasts four Nobel laureates as alumni—Michael remembers being very impressed by an exhibit at the United Nations building in NYC in the spring of 1955. The exhibit was part of the U.S. “Atoms for Peace” initiative. There he saw a functional cloud chamber, which focused his science interests on physics. In 1956 he enrolled in Carnegie Institute of Technology (now Carnegie Mellon University) in Pittsburgh, PA, to formalize a career in science.

1I met with Michael Bass during a short lull in graduation exercises on the campus of University of Central Florida—now the second largest university by enrollment in the United States. Our discussion included many topics of general interest in addition to those contained in this short article. As it turned out, we had much that was common in our backgrounds, despite the gap of one generation. Michael grew up in the “Atoms for Peace” movement, whereas my own experience was in the heat of the Cold War. However, we both spent our youth in NYC, were the only ones in our families to have an interest in science, share an enjoyment of science history, and appreciate the twists and turns that often accompany, and in fact dictate, the choices that ultimately sum up a career.

2Established in 1904, Stuyvesant High School was open to all NYC (New York City) residents through an examination process. Originally an all-boys school, it became co-ed in 1969, and moved to its current location in Battery Park City (Chambers Street, Manhattan) in 1992 (www.stuy.edu).


4Invented in 1911 by Scottish physicist Charles Wilson, the cloud chamber was filled with saturated water vapor (later alcohol) which condenses on the ions that travel through it. Wilson received the 1927 Nobel Prize in Physics (along with Arthur Compton) for this invention. (en.wikipedia.org/wiki/Cloud_chamber).

5Peter A. Franken is referred to as the father of nonlinear optics by the Optical Society of America. He was best known for his groundbreaking work on optical harmonic generation in crystals, which of course would lead to the work on optical rectification that is the basis of our THz Pioneer article. He left the University of Michigan to head the University of Arizona’s Optical Science Center in 1973, and he passed away in 1999.

6After a long career at Phillips Laboratories, Kirkland Air Force Base, Albuquerque, NM, USA, Alan founded Plasmatronics, Inc. He maintained a close affiliation with Texas A & M University and has a nice presentation about his work with Peter Franken and Michael Bass at Michigan entitled, “Memories of the Discovery of Optical Harmonics, Peter Franken, and some thoughts about the future of nonlinear optics,” presented at the Nonlinear Optics International Conference: East–West reunion in September 2011 (available from the author).

At Carnegie, Bass happened to hear a seminar on interference (or crossover) spectroscopy [1] by renowned University of Michigan physicist, Peter A. Franken [2]. Bass had the courage to approach Franken after the lecture, and they immediately hit it off. After graduating from Carnegie, Bass was offered a graduate student stipend at University of Michigan, and he proceeded to Ann Arbor, MI, in the fall of 1960 where Franken was advisor to first year graduate students.

After acing some tough classes in his first semester at Michigan, Bass was told by Franken to start looking around for something that might serve as his thesis project. Bass bumped into one of Franken’s students, Alan Hill, then only a junior in college, who was working with the newly available optical masers. Alan was using a commercial red ruby laser (≈ 6943 Å) focused onto a quartz crystal to try and generate
the second harmonic at 3472 Å (ultraviolet) through the crystal nonlinear susceptibility $\chi^2$; the nonlinear dependence of polarization, $P$, on field strength, $E$,

$$P = \chi^2 E(1 + \alpha_1 E + \alpha_2 E^2 + \ldots).$$

When $E$ is a sinusoidal function, the polarization will contain components that are dependent on the fundamental, as well as the higher harmonics generated by the interaction of the field with the atoms in the crystal. Crystal quartz is particularly useful for this experiment because of its birefringent properties, which can be used to provide different harmonic responses depending on the orientation of the impinging electric field. In the Franken and Hill experiment, a simple prism was used to spatially separate the red and UV signals, which were then focused onto a photographic film. The first observation of second harmonic generation through this groundbreaking experiment in nonlinear electro-optics, which had to be recorded from a single pulse of the ruby laser, was published in 1961 [2]. For reference, the second harmonic conversion efficiency was approximately $10^{-8}$ [3].

It had been only a year since Ted Maiman had produced the first optical maser [4], and Bass was fascinated by a device that could put out “that much light.” He told Franken he would work on anything that utilized the lab’s ruby lasers. Franken told him that Hill, still an undergraduate, needed to return to his studies in the fall, and that he, Bass, could take over the harmonic generation project.

Bass started out his experiments by moving on to the logical next step in exploring nonlinear interactions—a mixing experiment. He took two ruby lasers with slightly different output wavelengths [5] and superimposed them through a half-silvered mirror-type beam splitter. Bass then focused the beams onto a triglycine sulfate crystal (chosen because of its superior birefringent properties, which can be used to provide different harmonic responses depending on the crystal’s orientation). The early commercial ruby lasers were not easily tunable or single mode. Bass was able to get the two lasers from the lab’s ruby lasers. He took two ruby lasers with slightly different output wavelengths [6] and multiple exposures (500 μs typical) were collected on a photographic plate that followed the spectrometer. The film recorded the second harmonic outputs of both lasers with the sum frequency exactly in the middle, as expected [6]. Similar exposures using only one or the other of the two lasers showed only a 2nd harmonic spot—no mixing signal—confirming the interpretation of the experimental results.

It is interesting to note that the difference frequency of the two Ruby lasers in Bass’s experiment would have appeared at about 620 GHz. However, in 1961, there were no off-the-shelf detectors at the Michigan lab for measuring such short wavelength RF energy, and Bass focused only on the optical sum detection. It would take another four years before Fritz Zernike and Paul Berman, working at Perkin Elmer Corporation, Danbury, CT, USA, reported difference frequency generation from closely tuned optical sources when they measured 3 THz signals from two neodymium glass lasers beating together in a quartz crystal [7].

Bass undertook the next series of experiments to look for steady induced polarization, the equivalent of the dc term in the nonlinear harmonic generation process. This “optical rectification” process, the result of an intense high frequency field interacting with the crystal lattice in a nonlinear manner, is very similar in its mathematical formulation to the linear electro-optic phenomenon known as the Pockel’s effect, wherein a dc (or very low frequency) electric field modifies the optical polarizability of the crystal. In fact, a quantitative relationship between the Pockel’s effect and the predicted results of high intensity second order field interactions in nonlinear crystals had just been published by J. A. Armstrong and Nicolaas Bloembergen [8]. This paper used a rigorous quantum mechanical approach to derive formulae that could directly predict the dc component of the polarization induced change in a sample exposed to intense coherent optical signals, from the inherent properties of the crystal itself, and the magnitude of the Pockel’s coefficients.

Bass, Franken, and colleagues John Ward and Gabriel Weinreich, tried the ruby laser on potassium dihydrogen phosphate (KDP) and potassium dideuterium phosphate (KD$_2$P) crystals, known to have a very strong linear electro-optic effect. Using a very carefully calibrated capacitively coupled mounting arrangement for the crystal, Bass was able to measure the voltage developed across the crystal as the laser beam interacted with the KDP at different polarization directions. Through the Armstrong and Bloembergen formulation, the relationship between the observed voltage and the dc polarization effect coefficients could be derived. The predicted values, based on the crystal parameters and measured dc Pockel’s effect in KDP, agreed extremely well with the measurements [9]. The very important discovery and proof of optical rectification was confirmed.

Bass and Franken went on to the investigation of several other crystalline materials, including zinc telluride, and a very rigorous mathematical formalism for quantifying the optical rectification coefficients [10]. More importantly a method was now available for predicting, measuring and understanding not only this observed second order nonlinear effect, but many other higher order phenomena that resulted from intense electro-optic field interactions [11].

From the point of view of the THz community, the optical rectification effect would have enormous positive consequences. When the electric field coupled to the crystal is...
derived from an extremely short (picosecond) pulse, rather than
the millisecond pulse available from the ruby laser in 1961, the
spectral (Fourier) content associated with the pulse falls into
the THz regime. Beating of the various components composing
the optical pulse produce a difference frequency polarization
which is nonlinearly related to the electric field produced by
the laser through the susceptibility, $\chi^e_p$. Broadband THz
energy is created at the laser field concentration point and propa
gates in all directions, but only the energy which is confined to
angles near normal incidence to the crystal boundaries gets out. It is helpful to think about the induced nonlinear
polarization as creating a localized oscillating dipole
field in the crystal that responds on a picosecond time scale
and thus radiates THz energy. The magnitude and frequency
content of the accessible THz signal is directly related to
the frequency content of the pulse, the nonlinear susceptibility
of the crystal, the phase matching conditions for the various
difference frequency components, the material index and ab-
sorption properties at both the optical and THz frequencies, the
geometry of the sample and dispersion effects [12]. The most
successful work has focused on LiNbO$_3$ crystals pumped with
Nd:YAG lasers at 1064 nm [13]. Typical conversion efficiencies
of 10$^{-4}$ are now obtained with this technique [14]. Very recent
results [15] however, report a remarkable 3.7% optical-to-THz
conversion efficiency for single cycle pulses in cryogenically
cooled lithium niobate samples excited at 1030 nm with a
680 fs pulse!

With the eventual realization of intense femtosecond laser
pulses, and the ability to understand and enhance their nonlinear
interaction with various crystals, it was possible to generate ex-
tremely broad coherent THz signals with intensity sufficient to
perform a remarkably wide range of spectroscopic and imaging
applications (see, e.g., the many up-to-date references in [16]).

From the perspective of Michael Bass in 1962 however, it
would be another 10 years before the phenomenon of optical
rectification as applied to ultra-short pulse (picosecond) lasers,
would be shown to be a potential generator for broad band THz
energy [12], [17], and more than 25 years before this tool began
to be gainfully employed for active research [18]. In both of
these later innovations, the groundbreaking work of Franken
and Bass was largely overlooked, and with the extreme excite-
ment building around the development of the laser, even Bass
himself quickly moved on to other topics.

Although lasers were still much of a scientific curiosity in
1962, there was one aspect of these early ruby-based devices
that attracted very obvious commercial application. Albeit, the
lasers only lasted for 30 or 40 pulses before the silver output
coatings began to slough off, however they produced an extra-
ordinary amount of energy, several joules, which directly trans-
lated into heat when they were focused onto absorptive samples.
They could already be used to punch small holes in metals, crys-
tals and many other materials. Maiman coined the power term
“Gillette” to describe how many stacked razor blades the fo-
cused beam would burn through.12 While at Michigan, Bass re-
calls a visit from a local manufacturer in Ann Arbor who was
interested in whether the ruby laser might make a good tool
for producing the series of clean holes needed for quality baby
bottle nipples. After a quick demo, the manufacturer was con-
vinced of the efficacy, and went out to purchase, and then de-
sign a multi-beam optical divider for drilling simultaneous holes
from a single laser pulse to replace the hot-wire piercing tech-
nique currently in use, [19] for example. The coatings became
better and this application continued though using longer lasting
lasers!

After graduating from Michigan in 1964, Bass took a post-doc appointment at University of California, Berkeley,
USA, to work with Erwin Hahn13 on spin echoes (also known
as Hahn Echo signals [20]). Hahn wanted to do the optical
equivalent of his RF spin echo experiments, and he needed a
clean coherent source. The ruby laser was just not sufficiently
narrow band at the time. Bass tried unsuccessfully for two years
to get the ruby laser up to the task required to perform Hahn’s
experiments. He eventually did find the problem (thanks to a
suggestion by Art Schawlow14) in the stimulated emission of
isotopic chromium ions in the ruby [21]. It was also a time of
great political unrest at UC Berkeley, and labs were being
closed off while student protests raged. Bass became
disenchanted with the academic lifestyle, and decided to try
his hand in a more commercial environment. Before leaving
Berkeley however, he got involved in a national education
project to help develop lab experiments that could be used for
the dissemination and teaching of laser theory and techniques
[22]. He found this activity an extremely enjoyable and pos-
tive experience, and as such, it would help pull him back to
academia a bit later in his career.

Bass and his wife Judith, moved to Watertown, Massachusetts
in 1966, where he took up a position at the Raytheon Research
Division in Waltham. Raytheon already had a strong framework
in laser research. Its staff had demonstrated the elliptical pump
cavity that made solid state lasers commercially successful, de-
veloped the first high power continuous wave CO$_2$ laser under
David Whitehouse15 and demonstrated a 100 W argon ion laser
through Roy Paananen.16

Bass took up work on solid-state lasers at Raytheon, and he is
credited as one of the co-inventors of the YAP laser (yttrium alu-
ninum perovskite–YAlO$_3$ active medium) in 1970 [23]–[26]. The
Nd:YAP laser has an advantage over the Nd:YAG laser in
that the neodymium absorption and emission lines are polariza-
tion dependent, allowing additional applications.

Along with colleagues Marvin Weber and T. F. Deutch, Bass
also developed an operational modality and pumping technique
for the dye laser [27]–[29] that ended up being crucial to the
demonstration of the first continuous wave dye laser by Pe-

12John Johnson Jr., “Theodore Maiman, 79; harness light to build the

13Erwin Hahn discovered spin echo in nuclear magnetic resonance experi-
ments in 1950. They play a critical role in modern MRI through the
t$_2$ spin–spin relaxation time constant.

141981 Nobel Laureate in Physics, and at this time a professor at nearby Stan-
ford University.

15Whitehouse started out his life as a radio broadcast actor, but changed ca-
reers to become a well-regarded physicist at MIT and then at Raytheon, where
he pioneered high power CO$_2$ laser development including a 1 kW, 40 ft long
device for the Aberdeen proving grounds in the late 1960s.

16See, for example, R. A. Paananen, “Progress in ionized-argon lasers,” IEEE
terson, Tuccio, and Snively [30] at Kodak Research Lab in 1970. Perhaps in a prescient moment, Bass was also one of the first to observe picosecond pulses in Nd:YAG lasers [31]. Towards the end of his time at Raytheon, Bass worked extensively on laser damage mechanisms [32]–[34] which would later lead to a strong interest in laser materials processing.

Towards the middle of the 1970s, many U.S. companies began reining in the scope of their research facilities to focus more on internal product development. Raytheon was one of these, and so when Larry DeShazer from the University of Southern California (USC), came to ask if Bass would like to relocate to Los Angeles in order to help head up a new Center for Laser Studies that Larry was forming, Bass did not hesitate to accept the invitation. Perhaps the hard winters in Massachusetts and the warm memories of his time at UC Berkeley in California, working on the laser education panel, played a small role in the decision to return to academia. As he had correctly anticipated, and adeptly avoided, his research group at Raytheon was dissolved three years later.

Bass arrived at USC in 1973, and immediately began to build up the laser center as Associate Director. He started bringing together personnel as well as grants and contract money. The concept was to draw in faculty from various departments with overlapping interest in laser studies and applications. Funding would come from soft money grants, but the center had a small level of startup money and some equipment inherited from an existing laser damage studies lab.

One of the first new projects to come into the center had its origins at the USC Medical Center. A resident gastroenterologist, Richard Dwyer [17] (still practicing as a laser endoscopist in Los Angeles with affiliations both at USC and at UCLA Medical Centers), came over to talk to Bass about the possibility of using lasers for wound cauterization to treat bleeding ulcers. At that time (1973), fiber-optic endoscopes were available to look at the gut, but there was no way to perform an on-the-spot clinical procedure once a problem was found. Bass off-handedly suggested the possibility of perhaps using an optical fiber to transmit the laser energy down the endoscope [35]–[37] and use it to cauterize.

Shortly after their initial discussion, Dwyer showed up in Bass’s office with six caged rats! Bass negotiated some time on one of his USC colleagues’ argon ion lasers that same day, and they tried some cauterization experiments. This soon led to canine experiments [38], [39], and eventually, to work on human subjects [40]–[42]. For the first of these experiments, Bass had to gerrymander a fiber onto the outside of the endoscope casing [35]. The technique worked however, and Dwyer at least, went on to a long, and pioneering career in laser endoscopy [43]. Eventually, better fibers became available and the Nd:YAG laser proved a better source for this type of cautery.

Bass became director of the Center for Laser Studies in 1976 and expanded into a large number of varied projects. In particular, he picked up the laser damage studies he had begun at Raytheon and broadened these out to surfaces and films, metal mirrors, and other optical elements, semiconductors and dielectrics, and infrared wavelengths [44]–[51]. Other work included new lasing media, Q-switching techniques, dye lasers, detectors and calorimetric studies, and high power interactions with metals and crystals [52]–[64]. He also became very interested in commercial laser applications (a philosophy which he maintained throughout his career with more than two dozen long term industry consulting arrangements), and worked with industrial partners on problems in laser drilling and cutting, welding, material coatings, and generalized heating effects. Overall, more than 70 papers and 12 Ph.D. dissertations came out of his work at USC.

The staff at the USC Laser Center grew to around 8 with 20–25 students in tow. They included Elsa Garmire (who followed Bass as the center director, and is noted for her work in laser art as well as her research in laser science), Eric van Stryland (OSA president in 2005), Milton Birnbaum (YAG laser expert), Susan Allen (chemical vapor deposition), Jean-Claude Diels (pulsed lasers), and Stephen Copely (materials science and laser manufacturing). During this period Bass held additional positions as chair of the USC Research Council in 1980 and 1981 (a role he would later capitalize on at University of Central Florida), and department chair in Electrical Engineering and Electrophysics from 1984 to 1987.

Of particular interest to THz researchers might be Bass’s work on flexible infrared waveguides [65]–[70] for applications including endoscopy. He, Elsa Garmire, and their students, developed a low, overmoded ribbon-like guide that could be made from sandwiched metal or metal and dielectric sheet (an early and clever form of flexible parallel plate waveguide).

In 1987, Bass’s former USC Center for Laser Studies student, M. J. Soileau, then the newly hired Director of the Center for Research in Electro-Optics and Lasers (CREOL) at the University of Central Florida (UCF), came looking for recruits. (CREOL was to become CREOL, the College of Optics and Photonics.) He sought out Bass for an open position as Dean of Engineering. Bass was intrigued by the possibility of being associated with an institute (CREOL) that had significant long-term base funding (the USC Center for Laser Studies survived only on faculty grant funding—there was no independent endowment for the center). However, he had his eye on another open administrative position at UCF, Vice President of Research—a role he had experienced and enjoyed for a short period at USC.

Bass decided to move across the country for the fourth time, and in December 1987 he relocated to central Florida. He was aided financially by his good fortune in having been one of the few to recognize the potential of a home in the Pacific Palisades region of Los Angeles on his arrival in the early 1970s, an area he chose because of the coastal climate (commuting the 35 odd kilometers to USC by car back then did not take up a significant portion of the work day!). By 1987 the commute time had more than doubled, but so had the real estate values in Pacific Palisades. Bass was able to trade his house in Los Angeles for two in central Florida!

The affiliation with CREOL turned out to be a great fit for Bass, but the position of Vice-President of Research at UCF was not quite as snug. The university changed Presidents four
times in the 5 years Bass held the post, and in 1992, he finally gave it up in frustration, and went back to full time research and teaching. During his time as an administrator at UCF, Bass undertook lots of outside commitments (perhaps as a respite from the internal politics). He served as President-Elect and President of the Laser Institute of America, General Chair of the 1989 OSA Annual meeting, Editor-in-Chief of the Handbook of Optics, and a board member for the Society Objectives and Policies committee of the Optical Society of America (OSA), during the critical period when OSA was considering a merger with SPIE.

On the technical side, Bass continued to work on solid-state lasers and laser crystals, Q-switching, nonlinear absorption mechanisms and upconversion [71]–[82]. Around 2001, he started to get interested in combinations of semiconductor lasers and upconverters for visible display technologies [83]–[87]. This later led, along with colleague Dennis Deppe, to the formation of a company, bdDisplays, LLC, to develop applications.

At age 62, Bass got very involved as an expert witness in a big patent case, and decided to take advantage of an early retirement package at UCF in order to focus more time on this and other outside activities. He became an Emeritus professor working half-time on his many grant and industry-funded research projects at CREOL, and he continued to teach at a reduced course load, but maintained a favorite: “History of Physics: Cultural Connections and Other Issues,” a widely popular class which he continues to offer today.

Bass also took on several major professional tasks, including Associate Editor for Optics Express, Editor-in-Chief for the third edition of the Handbook of Optics (which was to be a massive 5 volume series), and Associate Editor for OSA’s 100th Anniversary Commemorative Book—the OSA Centennial History Book, due to be released in 2016. He continues to publish extensively (more than 80 papers between 2001 and 2014) on a wide range of topics in lasers and optics. His most recent interests have brought him back to medical technology, where he has been exploiting his upconverter techniques to locate nanocrystals as they interact with both normal and cancerous cells by detecting the up-converted optical luminescence for bioimaging applications [88]–[90]. Ever mindful of the importance of tying academic research to commercial application, his list of patents has been growing rapidly since his semi-retirement!

In 2006, Bass attended a conference in Pisa at which he happened to hear a talk by UCF colleague to be, Konstantin Vodopyanov, on pulsed optical difference frequency generation of THz power in GaAs [91]. In this, and a later talk [92], Vodopyanov credited Bass with one of the key developments in the THz field—his pioneering work on optical rectification way back in 1962! Up to this time, Bass had not appreciated how widespread this almost forgotten concept (forgotten by him at least) had spread.

Although it has been over 50 years since his first attempt at using nonlinear crystals to generate difference frequency energy, the THz light at the end of the tunnel is now clearly visible. In 2014, Bass was finally recognized for his pioneering role in THz generation through optical rectification, as the recipient of the OSA’s R. W. Wood prize.

Michael Bass continues to teach, to do research, to consult and to work with students, staff and faculty at the University of Central Florida, while he lights the way forward for all of us who care about optical science and technology.

ACKNOWLEDGMENT

The author is grateful to Prof. X.-C. Zhang at the University of Rochester for the suggestion of the candidate for this article, and to UCF Professor Constantin Vodopyanov for some early references and some interesting historical notes.

REFERENCES

Michael Bass (M’71–SM’77–F’81–LF’06) received the B.S. degree in physics from Carnegie-Mellon University, Pittsburgh, PA, USA, in 1960, and the M.S. and Ph.D. degrees in physics from the University of Michigan, in 1962 and 1964, respectively.

He is Professor Emeritus of Optics at CREOL, the College of Optics & Photonics, University of Central Florida, Orlando, FL, USA. From December 1987 until December 1992 he served as UCF’s Vice President for Research. Until November 1987, he was Professor and Chairman of Electrical Engineering–Electrophysics at the University of Southern California, Los Angeles, CA, USA. From 1977 to 1984, he served as the Director of the Center for Laser Studies at U.S.C. Prior to coming to the university in 1973, he was a Senior Research Scientist at the Research Division of the Raytheon Company. He has been active in quantum electronics research since his thesis work on optical rectification. He was amongst the first to demonstrate homogeneous broadening in dye lasers showing why they could oscillate over so broad a spectral range. Prof. Bass is responsible for the use of the statistical approach to understanding the processes of laser induced damage. This work led to the recognition of avalanche breakdown as the principal cause of intrinsic laser induced damage to transparent media. As part of his research on the optical properties of matter, Prof. Bass developed the technique of pulsed laser calorimetry to measure small intensity dependent absorptions. He is one of the co-inventors of the YAlO₃ laser host, the flexible, hollow, metal walled infrared transmissive waveguide and the use of fiber optics to deliver laser light for the treatment of internal bleeding and tumors. Prof. Bass and colleagues were amongst the first to establish research at a U.S. university on laser materials processing where they demonstrated laser assisted machining, laser shaping of ceramics, and laser driven chemical vapor deposition. His current research interests are in the areas of optically pumped solid state lasers, design of high power solid state lasers, the use of up-conversion for displays and novel fiber lasers. In 2006, he and his colleagues were the first to demonstrate gain guided index anti guided fiber lasers that had been predicted in 2003. Subsequent work on such fiber lasers showed that lowest order mode oscillation can be achieved in fibers with core diameters as large as 400 μm and diode pumped scalable lasers were demonstrated. He has authored over 190 refereed publications, presented many invited lectures in several countries and at international conferences. He is the editor of a book entitled Laser Materials Processing (North Holland, 1983), the co-editor of the Laser Handbook (North-Holland, 1985), and the co-author with Walter Koecher, of Solid State Lasers: A Graduate Text (Springer-Verlag, 2003). In 1991, he was appointed by the Optical Society of America to be the Editor-in-Chief of the Handbook of Optics, 2nd ed. (McGraw-Hill, 1995) which sold over 11 000 copies. In 2009, he completed work as Editor-in-Chief of the Handbook of Optics, 3rd ed. (McGraw-Hill, 2010).
Prof. Bass is a Life Fellow of the Optical Society of America (OSA) and the Laser Institute of America (LIA). In 1979, he was honored as the first recipient of the U.S.C. School of Engineering Distinguished Researcher Award. He has been a guest editor of the IEEE JOURNAL OF QUANTUM ELECTRONICS and was one of the founding editors of the Journal of the Optical Society B. He has been a member of the IEEE Outside Awards Committee, both member and chairman of the OSA Adolph Lomb Award Committee and served as General Chairman of the 1989 Annual Meeting of the OSA. He served as a member of the governing board, the ADCOM of the IEEE Laser and Electro-Optics Society. During 1988, he was President of the Laser Institute of America. In 1989, he was elected to a full three-year term as a member of the Board of Directors of the OSA. He was elected a Foreign Member of the Russian National Academy of Engineering Science in 1994. He is a member of Sigma Xi, Tau Beta Pi, the American Society of the Advancement of Science, and is listed in Who’s Who in Engineering, and Who’s Who in America. In 2013, Prof. Bass was elected a Fellow of the National Academy of Inventors. He is the 2014 recipient of the R. W. Wood Prize of the Optical Society of America.