ROLAND HAITZ

A Life

Pioneer of Solid-State Lighting

Creator of Haitz's Law

1935 – 2015

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History will remember Roland Haitz as the prophet of the last great revolution in lighting. Haitz's Law, the metric he formulated, is the equivalent for LEDs and lighting what Moore's Law is for transistors and integrated circuits. It correctly predicted the time-scale and degree to which light-emitting diodes (LEDs) would triumph over all other lighting technologies in efficiency and cost. Like Moore's Law, his predictions for LEDs were so accurate that they guided the investment and R&D strategies of the solid-state industry, initiating and sustaining an on-going transformation in lighting that has progressed from his personal vision to global revolution, all in just the last 15 years.

But, as well as being the prophet of what is now being called the solid-state lighting (SSL) revolution, Dr. Haitz was also its catalyst. He was the first to grasp the potential of LEDs for massively reducing energy consumption, and personally led the way in securing much-needed government support for the nascent SSL industry. An early green pioneer, Roland Haitz was one of very few visionaries who was equally fundamental in creating the technologies upon which his vision would be based. He was the recipient of many honors and awards, including (together with his former HP colleague Dr. George Craford) the prestigious Economist Innovation Award for Energy and Environment.

A productive scientist throughout his long and illustrious career, at age 76 he joined a startup – QuarkStar – in a collective mission to radically rethink the fundamental design of LED light sources and lighting fixtures. Dr. Haitz posed to QuarkStar the following challenge: The LED is to the incandescent light bulb what the transistor is to the vacuum tube. As the LED replaces filament bulbs and fluorescent tubes, what is the integrated circuit equivalent for lighting? Just as the integrated circuit unlocked the transistor's full potential, is there an integrated optics of lighting that will liberate the true potential of the LED?

Ever the seer and prophet, the answer turned out to be a resounding 'yes'. As recently stated by Dr. Haitz, "Everyone else is integrating the electronics. In QuarkStar, we have integrated the optics. Together we will create wonderful things that nobody can even imagine at this time."

Dr. Haitz played an active role in the creation of these solutions. Indeed, the last of his many patent applications was filed just three months before his death at age 80. With 10 patents filed in just the past four years, Dr. Haitz filed more than 50 patent applications over a professional lifetime of 50 years. And his last paper, in the prestigious European journal *Annalen der Physik* and published just before his passing, was an invited co-authorship presenting technical commentary and historical context on the 2014 Nobel Prize in Physics for the invention of the bright blue LED.

Roland Haitz was unique in being able to offer such insights and context. His seminal work with LEDs spans more than four decades, and his involvement with lighting and semiconductors dates back over 50 years to the very beginning of Silicon Valley and its legendary startups.

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Roland Haitz was born in Germany in 1935 and grew up in a village between Karlsruhe and Baden-Baden in the Rhine Valley. On his father's side, the family was all farmers for whom the fruits of the industrial revolution remained scarce. Their farm still depended on horses to pull logs to the sawmill in winter and to plow fields in summer. His maternal great-grandfather had been a school principal, while his grandfather started a small grocery store. It was from watching his grandmother tally items that Dr. Haitz learned basic arithmetic, well before he started school. Fascinated by numbers, he was always top of his class in mathematics.

At Munich Technical University, Roland Haitz graduated with a diploma in physics a full two years ahead of his peers. His farm-bred willingness for hard work, coupled to a grounded sense of humor, acted as a magnet for the most exacting and challenging of teachers and mentors. Dr. Haitz enjoyed the irony that, at the height of the Cold War, he could claim a Stalin Prize winner and an American Nobel Prize winner as his scientific 'fathers'. His scientific 'grandparents' were equally impressive.

His principal advisor in Munich was Nikolaus Riehl, a student of the discoverers of nuclear fission, Lise Meitner and Otto Hahn. Riehl himself worked on the German atomic bomb projects during World War II. Captured by the Russians at the end of the war to work on their atomic bomb (hence, the Stalin Prize), Riehl was repatriated to Germany just in time to become Roland Haitz's first great mentor.

But Riehl was also a world expert on luminescence and one of the inventors of the modern fluorescent lamp. Done in conjunction with Osram, Riehl's work catalyzed the early efforts of GE, eventually leading to the fluorescent tube's widespread commercialization. Through Riehl, Roland Haitz was almost certainly made aware of the idea that a new, more efficient, physics of light generation can have a global impact on lighting.

But the far greater influence was Nobel Prize winner William Shockley, co-inventor of the transistor. For his graduate work, Roland Haitz wanted to work on the most promising field, which at the time was semiconductors. But America beckoned as well. Should he do a PhD? Or go to America?

An entrepreneurial solution presented itself when he met Dr. Shockley on a visit to Munich. Shockley had just won the Nobel Prize four years before, and the young Roland Haitz had not even graduated. Neither spoke the other's language. But

communicating for hours via pencil and paper, by the end of their lunch, he was hired as Shockley's new graduate student. "Being in the right place at the right time with a little luck can have big effects," was how Dr. Haitz modestly described this meeting 50 years later.

In 1961, Shockley's newest graduate student left Germany and moved to Mountain View, California, to work at the world's first semiconductor startup, Shockley Semiconductor Lab. (Later changed to Shockley Transistor, it is from this startup that Silicon Valley's legendary semiconductor companies are descended, including Fairchild, Intel, National Semiconductor, AMD, and even the VC firm Kleiner, Perkins.) From Shockley, Dr. Haitz learned how to take a complex subject and translate it into language people could understand. "I always try to bring things down to the least complicated issue," he said, "and if you can write a formula, then great." Haitz's Law is the classic example of this ability.

Having received his PhD under Shockley, with his first patent co-invented with Shockley himself, Dr. Haitz moved to Texas Instruments in 1964. But Dallas summers were too hot for him, so after five years he moved back to Palo Alto to work for Hewlett Packard. There, Dr. Haitz found "a nearly ideal job," managing optoelectronics research and development. It was a role that allowed considerable scope for his creative abilities. One early product he was responsible for, an optocoupler (an LED-based device used to isolate electrical circuits), proved extremely profitable. In 1984, Dr. Haitz was promoted to R&D manager of HP's Semiconductor Products Group.

As an R&D manager at Hewlett Packard, he was responsible for many of HP's early LED products from printer heads to display technologies. One in particular was the alphanumeric display for HP's pocket-sized scientific calculators – it was Dr. Haitz's ideas that allowed the calculators to be hand-held in size, yet have highly legible displays. HP's calculators turned out to be a huge global hit. They were one of the earliest pioneers in what has become the portable hand-held revolution, owned by most every professional in any field involving computation. Another display innovation that Dr. Haitz set the global standard for is the ubiquitous seven-segment display still seen everywhere today, from microwaves to elevators.

Dr. Haitz was also the instigator of the high-power LED market. Initial attempts in the late 1980s to implement solid-state car brake lights lined up dozens of low-power LEDs. He took one look and snorted, "This is an unnatural act!" (a favorite expression). Better to make one big chip and then stick it in a package that could handle the heat. The resulting high-power LEDs would come to dominate the automobile signals market, now a multi-billion dollar a year industry.

"He was not one for systematic engineering management," a former co-worker recalled. "Organization and documentation systems and training did not appeal to him."

“Roland was very often wandering around, checking up with the engineers and looking to see what they were working on,” another ex-colleague remembered.

With his guttural growl and crusty, no-nonsense manner, Dr. Haitz made his presence felt. But behind the gruff exterior he proved a generous mentor, always willing to take the time to teach useful lessons and surprising people with his idiosyncratic sense of humor.

Roland Haitz’s influence and leadership ranged well beyond Silicon Valley and engineering. In 1991, in response to the threat from Japanese competitors, he co-founded the Washington-based Optoelectronic Industry Development Association (OIDA). His 1993 OIDA strategic roadmap paper on *Opportunities in Optoelectronics* clearly demonstrates a farsighted leadership and global perspective in both technology and business. For someone whose background was R&D, Dr. Haitz was very committed to business. In his last years at HP and its spin-off Agilent, he saw himself as much a financial analyst as a physicist. He would attempt to inculcate basic business principles into the young engineers he supervised, with many of his junior researchers later starting their own firms. His proud boast was that the Optoelectronics Division at HP was as influential in seeding the solid-state lighting industry as the Shockley Lab and Fairchild had been in semiconductors.

With respect to lighting, the pivotal point in Dr. Haitz’s career came in 1994. Following a tour of Philips Lighting’s laboratories in Holland, Roland Haitz’s key insight was that the future of LEDs lay in general lighting, a huge market. By 1999 he had persuaded HP’s management to establish Lumileds, a joint venture with Philips, the company quickly becoming a leading manufacturer of high-power LEDs.

Dr. Haitz had tracked the progress of LEDs since the early 1970s. In 1999 he plotted his data as a graph, from which he then derived the formula that bears his name. Haitz’s Law states that every decade, the amount of light output by an LED (measured in lumens) increases by a factor of twenty, while the price per lumen falls by a factor of ten. Extrapolating the lines, Dr. Haitz estimated that by around 2005, LEDs would begin to compete with conventional light sources.

The implications went far beyond scientific curiosity. LEDs use about eighty percent less power than incandescents. When he calculated the potential energy savings nationwide, the numbers were huge… as much as $20 billion dollars saved per year, just by replacing America’s incandescent and halogen lamps. Global savings would be much larger. This is what convinced him: “We have to do something!”

Compelling an argument as it was, a serious financial and engineering catch threatened its realization. The LED industry could not afford, by itself, to make the improvements to LED technology and increases in production capacity necessary to achieve such savings. The only solution, Dr. Haitz saw, was to devise a strategy for eliciting support and funding from the federal government.

To help make this happen, Dr. Haitz joined forces with others from Hewlett-Packard and Sandia National Laboratories (Jeff Tsao, Fred Kish, and Jeff Nelson) for the writing of a white paper, *The Case for a National Research Program on Semiconductor Lighting.* In October 1999 Dr. Haitz then presented it in Washington DC. This is considered a seminal work in the history of solid-state lighting – the gauntlet was thrown. Light emitting diodes were already displacing incandescent bulbs in colored-light applications like traffic signals. With proper funding, he predicted, rapid improvements in brightness were possible that would ultimately create the ideal light source.

Worldwide, the electricity consumed by lighting would drop by more than half, Dr. Haitz forecast: "This new light source will change the way we live, and the way we consume energy." Based on Dr. Haitz's rigorous analysis, within months of the paper's publication, calls for similar national government-industry initiatives went out overseas including Korea, Taiwan, and China.

In 2002, Dr. Haitz retired after 35 years at Hewlett Packard/Agilent Technologies, where the products developed under his leadership – the LEDs, optocouplers, and display technologies – continued to evolve. These in turn significantly contributed to the ongoing profits of the HP-derived companies Avago (originally the semiconductor division of HP at which Roland Haitz was the CTO and now a top 20 global semiconductor company) and Lumileds (a top 5 global LED company where much of Dr. Haitz's work was done in conjunction with his HP friend and colleague, former Lumileds CTO Dr. George Craford).

Dr. Haitz 'retired' in order to start the next stage of his career – overseeing, catalyzing, and lobbying for the industry he had done so much to nurture. For the next few years, Dr. Haitz was relentless in his writing and speaking engagements, taking every opportunity to communicate his vision for the lighting industry. His appeal to the US government was ultimately successful – the US Energy Policy Act of 2005 authorized funding of up to $50 million per year into the next decade, just as Dr. Haitz and his colleagues had proposed in 1999.

In 2010, Dr. Haitz paused to take stock of progress. Dramatic developments had occurred in the decade since the 1999 white paper. This resulted in another seminal paper with Jeff Tsao, *Solid-State Lighting: Why it will succeed, and why it won't be overtaken.* Unexpected new applications had popped up, like LEDs as backlights on mobile phones and flat screen televisions. Such large markets massively boosted LED production and lowered costs, continuing to follow Haitz's Law.

Yet the biggest change was the attitude of the otherwise staid lighting industry. Fixture makers had initially regarded LEDs as mere novelty. Filament and gas-filled bulbs and tubes had sufficed for over a hundred years. But fueled by Shuji Nakamura's Nobel-prize winning innovations, white light solid-state sources kept getting brighter (as Haitz's Law predicted) until they became impossible to ignore.

"Of all the green energy technologies … solid state lighting is clearly the sleeping beauty," Roland Haitz liked to say. Eventually, he felt confident, all conventional lighting technologies were headed for the history books.

But it was going to take some time. Invited to London in 2011 to participate in the *Economist*'s annual technology forum, Dr. Haitz explained, with characteristic humor, why the prophet of the solid-state lighting revolution did not yet have any LED lights in his own home:

"I know how good they can be, and they are not yet there; I know how cheap they can be, and they are not yet there; and I know they will outlast me, and I don't want to be annoyed for the rest of my life that I have bought such stupid junk!"

To solve these birthing problems of technical performance and system economics, Dr. Haitz joined forces with QuarkStar, a start-up that combined fellow luminaries in the solid-state lighting community with up-and-coming younger talent. He ended up spending four years with QuarkStar, the last quarter of the 16 years of professional efforts he dedicated to making the solid-state lighting revolution a reality. During this time Dr. Haitz synthesized and extrapolated all that he had learned and conjectured about LEDs, lighting, and solid-state optics from the previous 50 years.

His stated ambition: to help define what the "Promised Land of Lighting" should be. "We are now rapidly approaching the end of the incandescent light bulb. We are not only sending the Edison bulb into the museum – we are booting out all conventional light bulbs, including linear fluorescent and metal halides, in the transition to integrated and smart SSL components." (As befits a prophet, he signed his early communications 'Moses', walking the line between whimsy and insightful experience.)

Dr. Haitz was well aware that the electronics revolution of the 20th Century came not from the individual transistor by itself, but from the IC – the integrated circuit brought into being in large part by fellow Shockley alums, such as Robert Noyce. Bringing together his former work, interests, and still vibrant inspirations from his past, Dr. Haitz challenged QuarkStar to address what he saw as the next overarching challenge and opportunity for the entire lighting industry: making the integrated circuit equivalent for solid-state lighting.

The quest to answer this challenge became Dr. Haitz's next contribution to lighting. Focusing on "herding photons" at the LED package level, Dr. Haitz personally led a small team within QuarkStar, composed of HP veterans and Hertz Fellows. Their mission was to understand the journey of every individual photon on its outward path from the LED itself, so that not a single one would be wasted.

According to Dr. Haitz, "I've been thinking about photon herding since I've been doing optoelectronics, which started in the late sixties. I was doing photon herding

with the seven-segment display forty years ago. What I did there became the production standard for the rest of the world for this class of products. And I learned a few tricks that I never talked about because they were so subtle, and that's what I'm re-applying now." This has led Dr. Haitz and his team to new designs for real-world LED packages that approach theoretical efficiencies, and suggests previously unheard-of capabilities that integrate the functionality of modules at the package scale.

Dr. Haitz similarly inspired QuarkStar's younger engineers. Their answer to his challenge was the creation of a second, completely independent approach of integrated systems on the fixture level, one that was even more congruent to the modular and scalable nature of integrated circuits. It brings the entire light fixture closer to the scale of LEDs, elegantly solving many of the technical and economic problems of conventional LED lighting. The size and cost of light fixtures is reduced by multiples while their functional capabilities commensurately increase.

This congruency to Haitz's law for LED chips is no accident. The parallel reduction in size and cost of LED fixtures and increased performance is not only a direct consequence of the standard Haitz's Law at the LED scale, but also suggests that 'the law' can be extended to the scale of LED modules and fixtures. Considering all that has come from the original chip-scale version of Haitz's law, this is exciting indeed. Roland Haitz's Law continues to lead the future.

Dr. Haitz's last remarks on solid-state lighting underscore the progress to come. They were made just days before his passing: "Solid-state lighting is where the internet was in the 1980's. Just as we could not then have predicted what the internet is now, 30 years later -- we cannot foresee all that light and lighting will become in the next decades. We know simply that it will be wondrous and beautiful."

Dr. Haitz is survived by his wife and true partner of 49 years, Bente Haitz. He has two children, a son Lars and a daughter Kirsten, and three grandchildren.

For more information and cited papers: http://www.QuarkStar.com/Roland_Haitz

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