



Credible (and Edible) Lasers: The Life of Arthur L. Schawlow

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Arthur L. Schawlow was truly a one-of-a-kind scientist and human being. Known for his gentle spirit, his sense of humor and his scientific creativity, he was the only Nobel Prize winner to have served as an OSA president. OPN examines his life and legacy on the 90th anniversary of his birth.

By tradition, Nobel laureates present a token gift to the king of Sweden when they receive their prizes. What would the laser pioneer Arthur L. Schawlow give to the monarch in 1981? A silver tray? A laser-inscribed paperweight?

Hardly. The 60-year-old professor from California presented King Carl XVI Gustaf with a measuring stick—a “ruler for a ruler.” The gift epitomized Schawlow—fun, unassuming, creative and inspired. Even when Schawlow had reached the height of his distinguished career, he never lost his sense of playfulness.

Schawlow, who passed away on 28 April 1999—just before his 78th birthday—once described himself as “the most uncompetitive person you ever saw.” He worked best as part of a team, and his most famous collaborator was his own brother-in-law, Charles Townes.

Arthur Schawlow at
an OSA meeting.



Childhood and education in Canada

Arthur Leonard Schawlow was born on 5 May 1921, in Mount Vernon, N.Y. (U.S.A.). His parents, Arthur and Helen, came from Latvia and western Canada, respectively. Neither of his parents liked to talk much about their background; young Arthur didn't learn until he was 17 that his father was Jewish. The Schawlows raised their son and his older sister, Rosemary, as Protestants.

When Arthur was three, the family moved to Toronto. His father worked for a life insurance company. Like many of the physicists of his era, the young Schawlow tinkered with radio receivers, built structures with his Meccano model set, and read lots of books, ranging from popular science to mythology to Jules Verne.

By age 16, Arthur had graduated from high school and received a scholarship to study science at the University of Toronto. Schawlow had wanted to major in engineering, but he really needed the scholarship to finance his education, and the financial aid did not extend to the engineering department. Thus, he chose physics.

As an undergraduate, Schawlow saved money by living at home and commuting to classes by streetcar. He had fond memories of his lab sessions and calculus classes.

In college, Schawlow acquired another love: jazz music, which he picked up on the radio. The Toronto of the 1930s did not have many nightclubs, but the melodies on the airwaves inspired Schawlow to start buying swing and jazz records, which he collected for the rest of his life.

During the war, Schawlow learned how to play the clarinet in homage to some of his favorite musicians, including Benny Goodman and Artie Shaw. He found a few like-minded amateurs and assembled a small music group. His Delta Jazz Band lasted until he finished his doctoral studies.

When World War II began, Schawlow was required to register for both the American and Canadian drafts. The Canadian army rejected him because he had an upset stomach on the day he

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was called on, and, by the time the U.S. military tried to draft him in 1943, he was working at Research Enterprises Ltd., a Canadian factory that built radar equipment—a crucial enough wartime technology that Schawlow was kept out of the fighting.

After the war, Schawlow finished his education at the University of Toronto by completing his Ph.D. under the guidance of Malcolm Crawford, a noted spectroscopist. He used high-resolution spectroscopy to study nuclear characteristics. During his student days, Schawlow published seven papers, most notably on electric field distribution within nuclei.

The atom beam light source project for his thesis involved vaporizing a bit of the substance under study within a vacuum chamber. The heated atoms would go out in all directions, but a baffle let only those atoms within a small angle of motion to continue their trajectory. Bombarding the atom beam with electrons would produce light. Schawlow worked to reduce or eliminate the Doppler broadening of the spectral lines.

Karl Meissner, a noted spectroscopist at Purdue University, lent Schawlow a Fabry-Pérot interferometer for his spectroscopic measurements, and he and his Toronto classmates took it apart and made a copy for themselves. Knowing the basic principles behind this device would later give Schawlow a key insight into basic laser design.

Schawlow once said: “I used to wish I could just reach out and grab those atoms and make them stand still.” Of course, many years later, laser cooling and trapping would slow atoms down to a virtual halt—and Schawlow would have a hand in that too.

Columbia, the Townes family, and what he did for love

At a meeting of the Canadian Association of Physicists, Schawlow heard Isidor I. Rabi—a Nobel laureate from Columbia University—talk about the exciting new discoveries about the nature of atoms and electrons made by his colleagues Willis Lamb and Polykarp Kusch. “I thought Columbia was really the most exciting place in the world, and I really wanted to go there,” Schawlow told an interviewer later in life. The move had broad ramifications for his future, both professionally and personally.

In 1949, Charles Hard Townes was a young faculty member in a prestigious physics department. Rabi, who had lured Townes away from Bell Telephone Laboratories, filled the department with enthusiasm, and its members met regularly for afternoon tea and discussions.

Townes had hired Schawlow for a postdoctoral project involving the application of microwave spectroscopy to organic chemistry. Schawlow didn't care much for organic chemistry, but he knew something about microwaves from his wartime work on radar. He measured nuclear quadrupole moments and, with Townes, studied the effect of nuclear charge distribution on X-ray fine structure.

“I’ve never been a real theorist,” Schawlow once said, “but strangely enough I think several of my best papers have been theoretical.” He explained that he was able to look at the subject with fresh eyes and explain it with a minimum of mathematics.

Townes and Schawlow began collaborating on a book, *Microwave Spectroscopy*. Since the two were working together so closely, Charles's wife Frances insisted that her husband invite Schawlow to dinner in the fall of 1950. Charles's younger sister Aurelia, who was living with them in their New York apartment, caught Arthur's eye. Aurelia was a singer with a master's degree; she had moved north from her South Carolina hometown to study music in the Big Apple. In May 1951, less than a



Schawlow at a news conference.

OSA Historical Archives

year after Art had laid eyes on Aurelia, the pair married in a simple ceremony back at her family home.

The happy occasion, however, meant that Schawlow had to leave the Columbia physics department. Townes was stepping up as department chairman, and strong anti-nepotism rules precluded his giving a brother-in-law a permanent faculty position. The departure also meant that Schawlow didn't have a hand in constructing the first working maser built by Townes, James P. Gordon and Herbert Zeiger in 1953. But bright horizons still awaited him. The newlywed Schawlow found a nearby place that would give him research opportunities: Bell Labs in Murray Hill, N.J.

Still, one could say that Schawlow did contribute to the maser—while he was sound asleep. During the Columbia years, Schawlow had become accustomed to the hours that theorists kept: coming in at noon and working till midnight. In 1951, the brothers-in-law traveled to a Washington, D.C., conference together and shared a hotel room. Townes, an early riser, left Schawlow to sleep late while he took a walk in nearby Franklin Park. While sitting alone on a park bench, Townes had a striking insight into the equation he needed to develop the maser.

Bell Labs, 1951-1961

Bell Labs was a well-known powerhouse of industrial research in the 1950s. Schawlow was first assigned to work on superconductivity, which did not interest him as much as his previous research. Nevertheless, he made some contributions. For instance, he was able to show that magnetic fields penetrate a tiny distance (up to a few hundred nanometers) into a superconductor and that the temperature dependence of that phenomenon was greater than originally thought. This helped to confirm the then-new Bardeen-Cooper-Schrieffer theory of superconductivity.

Bell Labs had a different culture from Columbia: Everybody worked hard from 8:15 a.m. to 5:15 p.m., with just a short break during the day. Laboratory management also restricted the purchase of capital equipment, which frustrated Schawlow for his first five years there. Then management loosened up, and big magnets and other instruments sprouted up throughout the lab. "We hadn't realized how much time we were spending working around the limitations of equipment," Schawlow said.

On weekends Schawlow got together with his brother-in-law to finish writing



Schawlow wearing an "Optics Is Light Work" T-shirt at Stanford. The slogan was one of several from an OSA competition.

their spectroscopy book, which McGraw-Hill published in 1955. Townes was the first and senior author, but the book boosted Schawlow's reputation as well.

While Townes and Schawlow were eating lunch at Bell Labs one day in October 1957, they found they had both been thinking independently about ways to make masers at shorter wavelengths, going into the infrared, so they agreed to work together.

One problem they faced was that, at higher frequencies, excited molecules release their energy more quickly—in roughly a microsecond at optical wavelengths. They considered schemes for optical pumping that would get atoms into an excited state to spur maser action.

A scientist friend suggested that any visible-maser device would have to

isolate one particular mode of oscillation. Schawlow got the idea of using two small parallel mirrors comparatively far apart. This notion had some similarity to the Fabry-Pérot interferometer he had used in graduate school, although the reflectors in that device were big and close together.

Because their equation predicted that the gain would be inversely proportional to the linewidth, Schawlow felt that solid-state materials, with their broad absorption bands and narrow emission lines, would work well. He started to investigate the properties of ruby, which not only has broad absorption bands in the middle of the visible spectrum but also two narrow lines in the red.

Schawlow cooled a ruby crystal in an old Dewar flask filled with liquid helium and then tried to stimulate emission with a weak flashlamp from a stroboscope. It didn't occur to him that he could order a more powerful lamp, probably because he had become so accustomed to doing without equipment.

Schawlow didn't see any lasing action in his experiment—which led to his one big public blooper. In September 1959, Schawlow, Townes and other scientists gathered at the first-ever International Quantum Electronics Conference to discuss possible approaches to visible masers. At the meeting, Schawlow rejected the narrow R_1 and R_2 resonance lines of ruby as good candidates for a lasing transition.

Eight months later, however, Theodore Maiman of Hughes Research Laboratories had built the first working laser out of ruby using just those resonance lines. When Schawlow saw a newspaper photo of Maiman and his small ruby rod, with the ends polished flat and parallel and the sides left open to admit the pumping radiation, he realized that it was exactly what he'd had in mind all along.

After Maiman published a short paper about the laser in *Nature*, two teams of Bell Labs scientists, with Schawlow on one of them, worked to verify the lasing action in ruby and to quantify several important properties of

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the laser, including the coherence of its light. Schawlow was one of six authors on a paper published in *Physical Review Letters* in October 1960.

The Stanford years and Nobel glory

Around that time, several universities approached Schawlow with faculty job offers. In September 1961, at age 40, Schawlow accepted a full physics professorship at Stanford University in Palo Alto, Calif., where he would work for the rest of his career.

Drawing upon his grad-school background as well as his more recent experience with his brother-in-law, Schawlow embarked on his career in laser spectroscopy. Much of his work was related to laser materials. For example, he and a student, Linn Mollenauer, applied piezoelectric stresses to ruby crystals to figure out the transitions that created a pair of Cr^{3+} lines in the material's spectrum. The lines had been known previously, but the underlying subatomic processes had not.

Other topics Schawlow and his students researched at Stanford included extremely sensitive techniques of Doppler-free spectroscopy using laser saturation, two-photon absorption, polarization labeling, optogalvanic spectroscopy and precise wavelength measurements. He served as physics department chairman from 1966 to 1970.

During his first decade at Stanford, Schawlow preferred to spend his research money on students and equipment rather than taking on postdoctoral fellows. In 1970, he rather reluctantly agreed to hire a freshly minted Ph.D. student from West Germany as a postdoc. Thus, Theodor "Ted" Hänsch arrived at Stanford and began a long, productive scientific partnership and friendship with Schawlow.

In 1975, Schawlow and Hänsch published their suggestion that laser light could cool free atoms to extremely low temperatures. At the time, both men were interested in hydrogen, which lasers cannot cool very well, so they let the cooling idea fall by the wayside.

That year, Schawlow was busy with another project: serving as OSA president. OSA executive secretary Mary Warga had persuaded Schawlow to join the society around 1960, and Schawlow and three colleagues published an article on "composite-rod optical masers" in the first issue of *Applied Optics* in 1962.

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Early one morning in October 1981, Schawlow was awakened by a long-distance phone call. He and Nicolaas Bloembergen (then of Harvard University, now an OSA honorary member) were sharing half the Nobel Prize in physics for their contributions to laser spectroscopy. The other half went to Kai Siegbahn (1918-2007), a second-generation laureate from Uppsala University in Sweden.

When reporters interviewed Schawlow about his most significant scientific accomplishments, he didn't even think to mention the laser-cooling proposal that he and Hänsch had made. He didn't discuss it in his Nobel lecture either. A few years later, though, OSA honorary members Steven Chu, then of Bell Labs, and Arthur Ashkin, along with other collaborators, demonstrated that

Courtesy of Helen Schawlow Johnson



Family and friends at the dedication of Aurelia House at the Arthur Schawlow Center, September 1992. (Left to right) Charles Townes; Carol Berger, an autism researcher; Arthur Schawlow Jr., known as Artie; Arthur Schawlow; and actor William Christopher, an autism activist best known for portraying Father Mulcahy on the television show “M*A*S*H.”



Aurelia and Arthur Schawlow visiting the Luxembourg Gardens in Paris, France, 1985.

Courtesy of Helen Schawlow Johnson

this idea actually worked. In 1987, Chu took up Schawlow’s invitation to join the Stanford faculty. A decade later, Chu would take home a Nobel for laser cooling and trapping, and just over a decade after that, he would become the U.S. Secretary of Energy.

Autism and family matters

During the Bell Labs years in New Jersey, the Schawlows had three children: Arthur (“Artie”), Helen and Edith (“Edie”). The family lived in a small, modern home in Palo Alto, and they welcomed many visiting scientists.

“It was looked on as a pleasure in our house to have these visitors and colleagues to dinner,” says Helen Schawlow Johnson. “Thanksgiving we always had a very full table of visiting physicists—we had a table and plates for 12. The talk at the table was usually about travel or music, as I recall. That was undoubtedly to include everyone.”

The Schawlows’ firstborn son did not learn how to talk on schedule, and eventually he was diagnosed with autism—an even more mysterious condition then than it is now, and one that families often did not discuss in public. Part of Schawlow’s reason for accepting the Stanford professorship in 1961 was that one of his Stanford colleagues, Robert Hofstadter, had confided to Schawlow

that he had a daughter with autism. Both sets of parents worked tirelessly to find ways to ways to communicate with their children, and they served as good support for one another.

The Schawlows studied a somewhat controversial autism therapy called “facilitated communication.” In this treatment, the autistic individual was encouraged to spell words on a machine. Jarus Quinn, OSA’s executive director during the 1970s and 1980s, recalled going with Schawlow to a Radio Shack around the corner from OSA headquarters and purchasing one of the earliest home computers. Schawlow took it back to California, set it up for his son, and Artie began typing on it—the first real father-son communication the two had ever had.

Eventually Artie moved into a group home for boys and adults in rural Paradise, Calif. When the original owner got into financial trouble in the mid-1980s, Schawlow helped to reestablish it with nonprofit status and state funding. Eventually it was renamed the Arthur Schawlow Center, and it still provides a home to adults with disabilities.

Arthur and Aurelia Schawlow spent many weekends in Paradise with their son. Tragically, Aurelia Schawlow died in a car accident one night in 1991, during the long, winding drive back to Palo

Alto. It was the year that Schawlow had formally retired from Stanford.

Humor, edible lasers and pop culture

By the mid-1960s, “the laser was new and it was bigger than big in the zeitgeist,” says Helen Schawlow Johnson. Schawlow appeared on a television game show called “I’ve Got a Secret,” and Walter Cronkite visited the Palo Alto bungalow to interview the scientist and film him while he helped his older daughter with a math problem.

Don Herbert, of “Mr. Wizard” fame, interviewed Schawlow for the “Experiment Series” of films he produced for American educational television in the mid-1960s. Schawlow also wrote three *Scientific American* articles on masers and lasers that decade.

One of the first things that Ted Hänsch noted upon his arrival at Stanford was a futuristic, tabloid-style poster of an “incredible laser” blasting away at attacking rockets. On the poster, Schawlow had appended, “For credible lasers, see inside.” When not pushing the boundaries of high-resolution spectroscopy without Doppler broadening, Hänsch and Schawlow experimented with multiple flavors of gelatin in the quest for an edible laser. That work soon led to

the development of the distributed feedback laser by Herwig Kogelnik and C.V. Shank at Bell Labs.

In another food-related experiment, Schawlow and J.L. Emmett blasted a roughly spherical object—a potato—with a high-power laser. The pair predicted that a powerful enough laser would peel the spud and cook it at near-stellar temperatures, making “fusion fries.” The results showed that the beam not only ablated the skin but also created shock waves inside the potato.

Schawlow often carried a toy laser gun that included a real ruby laser inside. Then he would inflate a double balloon—a clear outer shell with a dark blue mouse inside. Joking that “mice get into everything,” he would use the laser to dispatch the mouse balloon and leave the clear one intact. The demonstration showed that the laser could be tuned to pass through the transparent balloon without burning it.

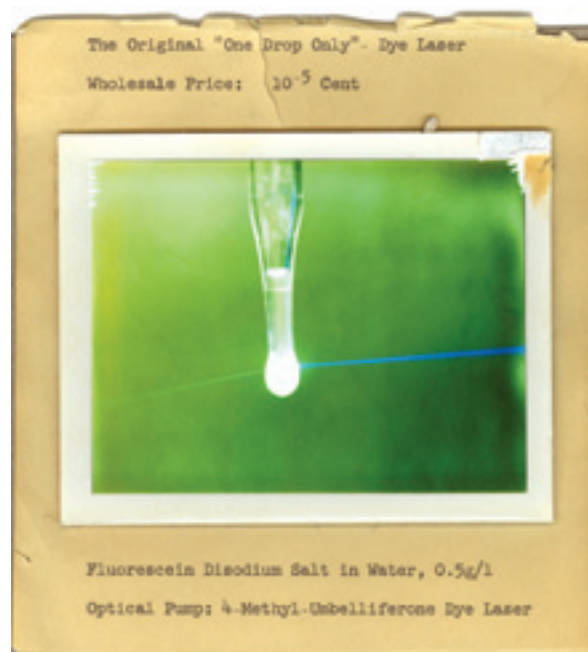
Schawlow also enjoyed demonstrating the “laser eraser.” Impishly, he would ask to borrow a \$1 bill; then he’d pull out a small Nd:glass laser and erase part of George Washington’s face.

Finally, Schawlow was famous for his quips: he joked that the “maser” acronym stood for “money acquisition scheme for expensive research.” He defined “genius” as “an infinite capacity to take planes,” and he liked to note that, if the laser’s discoverers had emphasized “light oscillation” rather than amplification, the “laser” would go down in history as the “loser.”

Lasting legacy

In retirement, Schawlow suffered from rheumatoid arthritis. He had good days and bad days. He still enjoyed his jazz collection and remained proud of his son and the Schawlow Center, as did Artie’s uncle and aunt, Charles and Frances Townes.

ONLINE EXTRA: Visit www.osa-opn.org to read some of Art Schawlow’s early contributions to *Optics News*.



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The combination of leukemia and congestive heart failure eventually put Schawlow in a wheelchair, and he died at the age of 77. To honor his love of music, a jazz band played at his memorial.

Sadly, Schawlow did not live to see his onetime postdoc, Ted Hänsch, share the Nobel Prize in physics in 2005. Nor did he witness the rise of another good friend, Steven Chu, to lead the U.S. Energy Department.

“Unlike Charlie Townes, I don’t plan my career very well,” Schawlow once said. “I just kind of take advantage of what opportunities I can see.”

Schawlow was well known for his capacity to collaborate well with others and to develop the best in other people. He never lost his humility, his creativity or his enthusiasm for the beauty of science. As he wrote to a pair of visiting Chinese scientists in 1984: “There are a lot of simple and beautiful things left for us to find.” ▲

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