September 2020

IN MEMORIAM

Arthur Ashkin (1922 - 2020)

Arthur Ashkin, IEEE Life Fellow, considered “the father of optical tweezers” for which he was awarded the Nobel Prize in Physics 2018, has passed away at the age of 98.

The IEEE Photonics Society and its members mourn this great loss of a friend, colleague and pioneer in the fields of optics and photonics.

Art, as he was known in the community, worked most of his career at AT&T Bell Laboratories, from 1952 to 1991. There he began his work on manipulation of microparticles with laser light in the late 1960s which resulted in the invention of optical tweezers in 1986. He also pioneered the optical trapping process. Such traps have found a wide range of important and unique applications. They are used to manipulate small objects down to the size of atoms.

This includes “small living things”, as Ashkin liked to say, such as viruses, bacteria, living cells, organelles within cells and macromolecules. Optical tweezers can capture microscopic living organisms with minimal harm, enabling studying them in their normal living state.

Despite his many impressive scientific achievements, Ashkin always remained a humble man and recounted frequently his modest family origin. He was born in Brooklyn, New York, in 1922, to a family of Jewish background. His father Isadore, immigrated to the United States from Odessa (then Russia and now Ukraine) while his mother, Anna, immigrated from Poland. They became U.S. citizens and started a dental laboratory, in New York.

Throughout his life, Art also never failed to mention the contributions of his colleagues at Bell Labs that helped him achieve scientific breakthroughs, especially his assistant Joseph Dziedzic.

And, the most significant support Ashkin ever received is from Aline, his wife of 66 years, who he met in college at Cornell University. She herself is well trained in chemistry and taught at Holmdel High School in New Jersey. One can find a comprehensive historical account of the scientific development of optical trapping in a book written by Ashkin with the help of Aline.

Together, he and Aline raised three children and five grandchildren.

Ashkin was a mentor, collaborator, and friend to many within the scientific community. René-Jean Essiambre, a close friend and mentee who presented the Nobel Lecture in Physics for Ashkin in 2018, expressed the profound impact he had on the optics and photonics fields.

> *“Art was a giant in optics and photonics – on topics ranging from radiation pressure to nonlinear optics. He was a lifelong learner and proud of being an inventor at heart. His scientific legacy has impacted generations of researchers and inflected the course of optical science.”*
> *- René-Jean Essiambre*

His Legacy & Fascination with Light

Ashkin was fascinated by light since he was a teenager, and in particular by the forces that light can exert on objects. He recounted that, at the age of 10, he was experimenting with a Crookes’ radiometer that operates on the thermal forces induced by light, even though young Art did not realize this at the time.

A few years later, while in high school, Ashkin learned about the thermal force, and a different force, light pressure, from the experiment of Nichols and Hull. It was his first realization that the radiation pressure of light was not too weak to do useful work.

He went on to work at the Columbia Radiation Lab from 1942 to 1945 while in the Army. He worked on developing high-power magnetrons for radars as part of the war effort. During that time, Ashkin also went on to study physics at Columbia College, where he received a B.A. in 1947. He later received his Ph.D. in nuclear physics from Cornell University in 1952.

When Ashkin joined Bell Labs in Holmdel, New Jersey, in 1952, the laser was not yet invented. It was his future colleague and friend, James P. Gordon, along with Herbert J. Zeiger and Charles H. Townes, all from Columbia University, who, in 1953, would demonstrate the first coherent amplification of radiation, the fundamental principle upon which the maser and laser are based on.

At that time, Ashkin was working on vacuum tubes. Inspired from his experience with microwaves, he would start exploring the applications of the laser soon after the first laser was demonstrated in 1960 by Theodore H. Maiman. Within a few years, Ashkin and his colleagues performed a series of experiments on laser propagation in optical fibers.

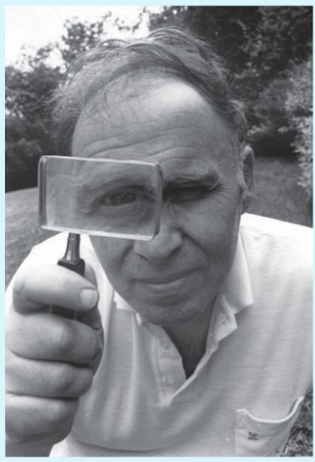
They uncovered a wealth of nonlinear phenomena that will later form the foundation of the field of nonlinear optics in fibers, a field with many applications and still widely studied to this day.

In the late 60's, Ashkin learned about "runners and bouncers" from Rawson, Hara and May. They observed the seemingly random motion of particles in the air inside a cavity illuminated by a visible laser and proved that it was due to thermal forces. Ashkin decided to try to observe light pressure forces directly by putting plastic (polystyrene) spheres, on the order of a few tens of micrometers in diameter, in water to suppress the thermal effects. Particles were pressed against the output face of the cell. Ashkin then replaced the cell wall by a counter propagating beam. That was the first all-optical trap ever built and it is referred to as a two-beam trap.

In 1971, Ashkin and his assistant Joseph (Joe) Dziedzic demonstrated levitation of small particles using a vertical laser beam, with gravity acting as the restoring force instead of the glass cell wall or the second counter propagating laser beam of previous experiments. In the next decade, the duo performed numerous experiments using levitation such as an optical version of the Millikan oil drop experiment, a precise measurement of Mie scattering, precise particle size measurements, and many other original experiments.

From the early 70's to the mid-80's, Ashkin and his colleagues spent considerable efforts trapping smaller and smaller objects, with the goal of trapping a single atom, which was ultimately achieved in 1985.

The trapping of living things came in 1987, after atom trapping, mostly by accident when a trapping experiment was left running overnight. The next morning small "bugs" were found in the optical trap. They were quickly identified as bacteria by Ashkin and Dziedzic. This serendipitous event marks the beginning of the field of optical trapping of living organisms and biological molecules such as molecular motors, DNA, RNA, and many others. Armed with this novel powerful tool, Ashkin and his colleagues went on to explore optical trapping of all kinds of new "things"—and so did the rest of the world.



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(b)

Arthur Ashkin looking through a magnifying glass (a).

Excerpts of the laboratory notebook entry describing the idea of laser trapping on September 8, 1969 (b).

Arthur Ashkin and Joseph Dziedzic, showcasing their scientific breakthrough and work with "optical tweezers".

Photo credit: AIP

The Nobel Laureate

Ashkin's pioneering work in optical trapping would result in him being awarded the Nobel Prize in Physics in 2018 at the age of 96, the oldest Nobel Laureate at the time.

Ashkin was awarded half of the prize while the other half was shared between Gérard Mourou and Donna Strickland.

He was also the author of the book "*Optical Trapping and Manipulation of Neutral Particles Using* Lasers", held 47 patents and was a Fellow of APS, AAAS, and OSA. Life Fellow of the IEEE.

In addition to the Nobel Prize, awards and honors recognizing his scientific contributions included: election to the National Academy of Engineering and the National Academy of Sciences, the IEEE Photonics Society's Quantum Electronics Award (1987), Charles Hard Townes Award (1988), the Rank Prize in Opto-Electronics (1993), OSA's Frederick Ives Medal / Jarus W. Quinn Endowment (1998), APS's Joseph F. Keithley Award for Advances in Measurement Science (2003), and the Harvey Prize for Physics (2004).

Excerpts in this "In Memoriam" came from the IEEE History Center, public obituaries and *"The 2018 Nobel Prize in Physics of Ashkin, Strickland and Mourou: Intimate Portraits of the Nobelists and Their Discoveries"* feature, in the IEEE Photonics Newsletter.
Written by René-Jean Essiambre and Theodore Sizer, of Nokia Bell Labs. [December 2018 Issue]