# Nicolaas Bloembergen

March 11, 1920–September 5, 2017
Elected to the NAS, 1960

*A Biographical Memoir by Eric Mazur*

Figure 1 Nicolaas Bloembergen, 1981. *Dutch National Archives.*

**Nicolaas Bloembergen, a** Dutch-born American physicist, left an indelible mark on the scientific community through his groundbreaking contributions to nuclear magnetic resonance—a resonance caused by the absorption of radio-frequency radiation by atomic nuclei in the presence of a magnetic field—and to the development of masers and lasers. He was also a pioneer in the field of nonlinear optics. His work has had significant impact in society, from medicine to communications.

Nico, as he liked to be called, was born in Dordrecht, the Netherlands, on March 11, 1920, the second of six children. His father, Auke Bloembergen, was a chemical engineer and executive at a fertilizer company. Bloembergen grew up in Bilthoven, a residential suburb of Utrecht, and his curiosity about the relationship between mathematics and the physical world was evident from an early age. He attended the prestigious Utrecht municipal *gymnasium*, where he excelled in subjects like chemistry, mathematics, and Latin. But it was physics that truly captivated him.

He enrolled at the University of Utrecht to study physics in 1938 and worked for Leonard S. Ornstein, a renowned physicist whose experimental physics course sparked Bloembergen's interest. Under Ornstein's guidance, Bloembergen assisted graduate student G. A. W. Rutgers's Ph.D. research project, marking his first foray into scientific research. This work resulted in Bloembergen's first scientific publication and laid the groundwork for his future endeavors.[1]

Bloembergen's academic journey was interrupted by the outbreak of World War II and the subsequent Nazi occupation of the Netherlands. Despite the challenges posed by the war, he continued his studies under German occupation and completed his bachelor's degree in 1941. In early 1943, the Germans closed Dutch universities and shortly afterwards the Germans seized the family home, forcing Bloembergen to hide in the countryside to avoid being picked up by the Germans. Nevertheless, Bloembergen was able to continue to teach himself physics, and in April 1943 he obtained the equivalent of a master's degree in science. During the Dutch Hunger Winter of 1944–45, Bloembergen and his family endured severe food shortages, resorting to eating tulip bulbs to survive. These wartime experiences left an indelible mark on him, shaping his character and instilling in him a sense of perseverance that would define his future endeavors.

After the end of the war, driven by a desire to escape the devastation of post-war Europe, Bloembergen decided to pursue graduate studies abroad and, on the advice of his older brother, applied to three universities in the United States. His application to Harvard University was successful, and in the spring of 1946 he boarded a ship that had brought supplies to a war-ravaged Europe on its return trip to the United States. He arrived at Harvard just weeks after Edward Purcell, Robert Pound, and Henry Torrey detected a nuclear magnetic resonance (NMR) signal in solid paraffin, a discovery that would revolutionize the field of spectroscopy. Under Purcell's guidance, Bloembergen played a crucial role in developing experimental methods to probe the magnetic properties of atomic nuclei and helping understand how NMR can be used to sense the motions of water molecules through the NMR resonance of its protons. This work formed the basis of Bloembergen's seminal paper with Purcell and Pound, commonly known as the "BPP" paper, that remains one of the most referenced papers in the *Physical Review.*[2] His research in NMR led to the development of techniques for studying molecular structures and measuring magnetic fields with unprecedented precision.

In 1948, Bloembergen returned to the Netherlands to defend his PhD thesis at the University of Leiden. Titled "Nuclear Magnetic Relaxation," it explores the mechanisms governing the relaxation of nuclear spins in response to external magnetic fields and became a widely used guide to the new technology. It was ultimately published as a book that sold well for decades.[3] After defending his thesis, Bloembergen joined Cornelius Gorter's group as a postdoc at the Kamerlingh Onnes Laboratory of the University of Leiden. While there, he met Huberta Deliana Brink. Deli, as she liked to be called, was born to Dutch parents in Indonesia. When Japan occupied Indonesia during the war, the Japanese put Deli and her family in a concentration camp.

In 1949, Bloembergen returned to Harvard to join the prestigious Society of Fellows, and Deli followed soon after. They married in Amsterdam on June 26, 1950. Nico joined the Harvard faculty as an associate professor in 1951 and remained on the faculty until his retirement in 1990. Bloembergen continued his pioneering research in NMR, making significant contributions to our understanding of molecular dynamics and magnetic resonance phenomena. His discovery of motional narrowing, a counterintuitive phenomenon in which spectral lines become sharper as nuclear spins are disturbed more frequently, laid the groundwork for numerous applications in spectroscopy, including medical magnetic resonance imaging (MRI) that enabled imaging soft tissue inside the body.

In the 1950s, Bloembergen's understanding of the relaxation processes in NMR led him to the idea of the solid-state maser (microwave amplification by stimulated emission of radiation), a forerunner of the laser, in which the "l" stands for light. He devised a practical method for generating population inversion, a crucial step in the development of masers. Bloembergen's three-level pumping scheme provided a more efficient way to achieve population inversion, making masers and eventually lasers more practical and widely applicable.

His work on masers and lasers extended beyond theoretical developments to practical applications. Bloembergen's crystal maser, developed in 1956, demonstrated the feasibility of using solid-state materials to amplify microwave signals. This breakthrough paved the way for the development of solid-state lasers, which would later become indispensable in various scientific, industrial, and medical applications.

Shortly after Theodore Maiman at the Hughes Research Laboratory developed the first working laser in 1960, Peter Franken at the University of Michigan observed ultraviolet emission from a quartz crystal that was illuminated with red light from a ruby laser, a process now called second-harmonic generation. This discovery led Nico and his group to develop the theoretical basis for second-harmonic generation and many other nonlinear processes, leading to a seminal paper that came to define the field of nonlinear optics.[4] Three years later, Bloembergen published a monograph on nonlinear optics that quicky became the authoritative book on the subject.[5] Among his many contributions to nonlinear optics, Bloembergen's elucidation of the nonlinear susceptibility was particularly groundbreaking. He demonstrated that the optical response of a material could be influenced by the intensity of incident light, leading to new insights into the behavior of electromagnetic waves in nonlinear media.

His research group investigated how intense light beams interact with materials, leading to the discovery of a broad variety of nonlinear optical effects. These effects, including second-harmonic generation and changes in refractive index, occur when the properties of a material are altered by the presence of intense light. Later, Bloembergen expanded his research into tunable lasers and high-precision spectroscopy. His theoretical insights, combined with his experimental rigor, led to the development of new techniques for controlling and manipulating light at the quantum level.

Bloembergen's work in nonlinear optics had far-reaching implications, extending beyond fundamental research to practical applications in telecommunications, data storage, and optical computing. Today, the principles of nonlinear optics underpin technologies from fiber-optic communications to laser-based imaging and quantum cryptography.

In 1981, Bloembergen shared the Nobel Prize with Arthur Schawlow of the United States and Kai Siegbahn of Sweden for his work on nonlinear optics.

Throughout his distinguished career, Bloembergen remained committed to teaching, mentoring, and scientific outreach. He inspired generations of students and researchers with his infectious enthusiasm for science and his unwavering dedication to excellence. As a mentor, Bloembergen was known for his generosity, patience, and humility. He took great pride in the achievements of his students and postdoctoral fellows, fostering a collaborative and supportive research environment.

Bloembergen's influence extended far beyond the laboratory, shaping the broader scientific community, and influencing public policy. His expertise in laser technology and directed energy weapons led to his involvement in government policy matters, when U.S. president Ronald Reagan promoted his Strategic Defense Initiative, popularly called "Star Wars" because of the idea of using lasers to defeat ballistic missiles. In 1987, he and C. Kumar N. Patel of Bell Laboratories co-chaired an APS Study group titled the Science and Technology of Directed Energy Weapons. The report from this study concluded that significantly more research would be needed to determine the feasibility of directed energy weapons.[6]

In recognition of his outstanding contributions to science, Bloembergen received numerous awards and honors throughout his career. In addition to the Nobel Prize in Physics, he was awarded the Oliver E. Buckley Condensed Matter Physics Prize of the American Physical Society in 1958, the National Medal of Science from Pres. Gerald R. Ford in 1974, the Lorentz Medal in 1978, and the Institute of Electrical and Electronics Engineers Medal of Honor in 1983. He was elected to the National Academy of Sciences in 1960.

Bloembergen remained active at Harvard well into his seventies, when he decided to retire and move with Deli to Tucson. He continued to pursue his research interests at the University of Arizona in Tucson, where he held a professorship in optical sciences and where he continued to conduct research well into his nineties. Despite his many accolades and accomplishments, he remained humble and approachable, earning the respect and admiration of colleagues and students alike.

Nicolaas Bloembergen passed away in Tucson on September 5, 2017, at the age of ninety-seven. His wife Deli passed away on June 19, 2019, at the age of ninety. They are survived by their three children—Brink Bloembergen, Antonia Bloembergen, and Juliana Dalton—and two grandchildren.

Bloembergen's enduring legacy as a pioneer in physics, a dedicated educator, and a visionary leader continues to inspire future generations of scientists and engineers. His contributions to our understanding of light, matter, and the fundamental laws of nature have left an indelible mark on the scientific community and the world at large.

## References

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