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OBITUARY

Nicolaas Bloembergen: a pioneer in magnetic resonance and in maser and laser physics

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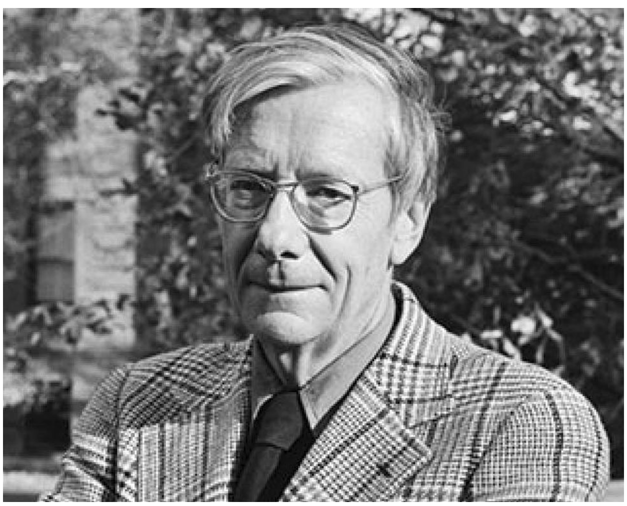
Nicolaas Bloembergen, Nobel laureate, died on September 5 at the age of 97 in Tucson, Arizona.



He was a true pioneer in two research areas: NMR spectroscopy, where he was the first to describe the fundamentals of nuclear spin relaxation, and in maser and laser physics. Historical perspectives can be found in Bloembergen (1994, 2007).

This obituary will also appear in the AMPERE bulletin (https://www.ampere-society.org).

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In particular his work on nonlinear optics earned him the Nobel Prize in Physics in 1981 (https://www.nobelprize.org/nobel_prizes/physics/laureates/1981/).

Nico Bloembergen was born in 1920 in The Netherlands. He started his study of physics in 1938 at Utrecht University mainly because Utrecht was conveniently close to Bilthoven, the town where he lived. He passed his master's exam in 1943 just a few weeks before the German army, that occupied Holland during World War II, closed the university. As conditions for his PhD research would be very poor in Holland during and just after the war, he moved in 1946 to Harvard University, where he was accepted as the first PhD student of Edward Purcell. Of course, NMR in condensed matter had just been discovered by Purcell and his co-workers Pound and Torrey (and independently by Felix Bloch at Stanford). For their discoveries Purcell and Bloch would share the Nobel Prize in Physics in 1952.

At Harvard, Bloembergen started to work at both experimental and theoretical aspects of NMR (he considered himself an experimentalist). However, his main accomplishment during the years 1946–1948 was his ground-breaking work on nuclear spin relaxation, that became known as the BPP theory (after the authors Bloembergen, Purcell, and Pound). The Phys Rev paper of 1948 is a citation classic and was for many years the most cited paper in physics (Bloembergen et al. 1948). This theory explained the "motional narrowing" effect and formed the basis for many of the subsequent important experimental and theoretical advancements in the understanding of nuclear and electron relaxation.

In 1947 Bloembergen met Prof. C.J. Gorter during a visit at Harvard. Gorter was an expert on paramagnetic relaxation at Leiden University and had made two unsuccessful attempts to discover NMR (Gorter 1936; Gorter and Broer 1942). Gorter offered him to come to Leiden and finish his PhD thesis there. This was attractive to Bloembergen also because he had already passed the Dutch qualifying exams for a doctoral thesis. So he defended his doctoral thesis, which was largely based on the research done at Harvard, in 1948 at Leiden University.

Shortly after, he accepted an offer to return to Harvard. He started as a Junior Fellow of the prestigious Society of Fellows, which served as a pool of very talented scientists from which Harvard recruited its staff. In 1951 he was appointed Professor of Applied Physics and he stayed on the faculty until his retirement in 1990. Initially he continued with magnetic resonance. To quote a few of the most significant achievements by Bloembergen in the mid-50's in this area: the treatment of the so-called Fermi contact—or scalar—relaxation between nuclei (Solomon and Bloembergen 1956), published together with Solomon, who had published on nuclear dipolar relaxation the year before; his work on nuclear relaxation in paramagnetic solutions (Bloembergen 1957); and, at the beginning of the 1960s, together with L. O. Morgan, the theory of field-dependent electron relaxation (Bloembergen and Morgan 1961).

This body of work has been highly cited, not only by physicists, but also by many experimental chemists and biochemists, and is universally known as the Solomon–Bloembergen–Morgan (SBM) model. The SBM model is at the basis of the important inter-atomic distance measurements by NOE's in biological macromolecules, and of the use of paramagnetic relaxation (PRE) as a further source of structural information when the biomolecule contains a paramagnetic metal ion or a radical center. Understanding relaxation is also very important in MRI, since the contrast in MRI scans is based on differences in relaxation times; furthermore, paramagnetic relaxation is at the basis of the development of contrast agents, paramagnetic metal complexes that are universally administered to enhance MRI contrast.

In the 1950s Bloembergen became also interested in masers, which stemmed from the search for low-noise microwave amplifiers in the upcoming fields of data communication and radio astronomy. A crucial contribution was his idea to use 3-level systems, using separate frequencies for excitation and stimulated emission. His familiarity with population inversion in NMR, either by 180° RF pulses or rapid passage methods led to this idea. The principle of 3 (or multiple) level systems led to the first practical continuous-wave masers. Bloembergen constructed a maser operating at a 21 cm wavelength, to detect the interstellar hydrogen line (Artman et al. 1957). The same type of maser was later used by Penzias and Wilson to detect the cosmic background radiation as a remnant of the Big Bang, for which they earned the Nobel Prize.

The concept of the 3-level system was later also used to develop lasers. However, Bloembergen decided not to work on the development of lasers since he felt that this could better be done in large industrial laboratories such as IBM, GE, and Bell labs, which had embarked on this.

Instead, he started to use powerful lasers to study the non-linear optical behavior of materials. That work was awarded by the Nobel Prize. He realized that common properties of light such as reflection or diffraction, which were well understood at low intensity, would change in high-intensity laser beams. He worked out the fundamentals of nonlinear optics and is often considered the father of this field. This work found important applications in fast data communication using fiber optics.

Nico Bloembergen retired from Harvard in 1990. But far from resting on his laurels he took a new position as Professor at the University of Arizona in Tucson, where he studied fast dynamical processes of materials by femto-second laser spectroscopy.

Apart from his passion for science he was also a great teacher, very much loved by his students. In honor of his pioneering work in NMR the building of the Utrecht NMR group was named after Nicolaas Bloembergen in 2001.

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