Hans Dehmelt

(1922–2017)

Nobel prizewinner who trapped electrons and demonstrated quantum jumps.

Watching a flock of birds offers little information about one bird's anatomy. Early twentieth-century physicists faced a similar problem: individual atoms and subatomic particles defied investigation. To understand a bird, you first need to catch it.

Hans Dehmelt, who died on 7 March in Seattle, Washington, was the first to trap a subatomic particle for observation and manipulation. Between 1973 and 1976, he captured and stored an electron and measured its internal magnetism — its spin moment — with unprecedented precision. This marked the height of Dehmelt's long career of experimentation with the storage and manipulation of electrons and ions, and the most delicate techniques of measurement. He shared the 1989 Nobel Prize in Physics for the work.

Dehmelt was born in Görlitz, Germany, in 1922, to a couple that struggled for economic survival in the post-war years of turmoil and hyper-inflation. He grew up in Berlin, where he attended the highly reputed Evangelisches Gymnasium zum Grauen Kloster. This high school had a strong emphasis on ancient languages, but Dehmelt spent most of his time tinkering with radio equipment and reading popular physics books. He graduated early, in 1940.

To avoid being drafted indiscriminately in the Second World War, Dehmelt volunteered for the German army's anti-aircraft artillery. He survived the horrors of both the eastern and western fronts, and spent a year in a US prisoner-of-war camp in France until 1946.

Eventually, Dehmelt found his way to the University of Göttingen in Germany, supporting himself by repairing and bartering pre-war radios. Here, he was taught by physicists including Werner Heisenberg and Wolfgang Paul (with whom he would later share the Nobel). After a doctoral thesis based on his co-discovery of the first nuclear quadrupole moment — a particular distribution of charge in an atom's nucleus — he was invited to join the prestigious microwave laboratory at Duke University in Durham, North Carolina.

In the 1950s, Dehmelt moved to the University of Washington in Seattle. His work there included cleverly aligning atoms by colliding them with other aligned vapours, to measure the atoms' resonance energies. He needed a way to keep the atoms in a small volume, so he built an electron impact tube in 1955. Refinements proved essential for the operation of atomic clocks.

EMILIO SEGRE VISUAL ARCHIVES/AMERICAN INSTITUTE OF PHYSICS/SPL

Pinning down ions or electrons for finer measurement requires either a constant quadrupole electric field overlaid with a magnetic field (a magnetron, or Penning trap), or such an electric field oscillating at a radio frequency (a Paul trap, developed by Dehmelt's former teacher in Germany).

Dehmelt's experiments with a magnetron in 1959 showed that swarms of electrons could be trapped for many seconds and he confirmed the predicted electron dynamics. He then switched his attention to the Paul trap, which seemed a simpler, more convenient technique at first glance. With this approach, the Dehmelt team recorded hyperfine spectra of trapped helium ions and molecular hydrogen ions with unprecedented resolution. But eventually, the researchers found that the magnetron trap was better suited to the electron work.

In 1973, Dehmelt and his postdoctoral researchers Dave Wineland and Phil Ekstrom isolated a single electron in a Penning trap and kept it stored for many months. It took three more years — and a little help from competing friends at the University of Mainz in Germany — to detect the minute signals of the electron's vibrational modes. Measurements of the electron and its antiparticle, the positron, showed their spin magnetic moments to be the same to within 4 parts in 10^{12}. These measurements were by far the most precise ones ever done on elementary particles, and probably in all of physics.

In the summer of 1974, Dehmelt spent two months with my research team at Heidelberg University in Germany. We came up with a proposal for trapping and cooling a barium ion, rather than a subatomic particle. This task brought new challenges. Ions have many energy states, and the excitation of the states and the manipulation of the ions require stable, continuous laser light of narrow bandwidth at the right wavelengths. Our equipment had to be home-made at that time. After three laborious years, my team laser-cooled a small cloud of barium ions in a Paul trap. Shortly after, my lab took the first snapshot of an atom — an individual barium ion — in the light of its resonance fluorescence. In Seattle, Dehmelt came up with similar experiments, opening up a friendly competition.

A highlight of this work with ion traps was the first demonstration of 'quantum jumps' — the leaping of electrons from one quantum state to another — almost simultaneously by both groups in 1986. This transformation of a metaphor into a physical phenomenon came as a surprise even to some top theoreticians.

Today, the isolation, trapping and cooling of particles, ions and neutral atoms has paved the way for the construction of atomic clocks that are accurate to within a few seconds per 10 billion years. These trapping techniques are used in searches for potential variation in fundamental natural constants, and form the core of some — still rudimentary — quantum computers.

Despite his deep immersion and accomplishments in science, Dehmelt was no hermit; he embraced all of life. He was fond of a rational health-food diet and loved dancing and yoga, which he practised occasionally at conferences, complete with headstands. He had that bit of eccentricity that is needed to make a good scientist an extraordinary one. His high art of experimentation lives on in the work of his many excellent students and associates. The memory of his ultra-precise measurements will survive forever in the annals of physics. ■

Peter Toschek *is professor of physics at Hamburg University, Germany.*
e-mail: ptoschek@physnet.uni-hamburg.de