OBITUARY

Willis E. Lamb Jr (1913–2008)

Meticulous physicist and discoverer of the Lamb shift.

Willis Lamb, who died on 15 May aged 94, received his highest recognition in 1955, when he was awarded one half of the Nobel Prize in Physics for his discovery of the subtle quantum-mechanical shift in energy levels of the hydrogen atom that now bears his name. But in truth, he might have been nominated twice more. He produced a theory of the resonant absorption of γ -rays by solid-state atoms — the Mössbauer effect — 19 years before Rudolf Mössbauer himself published the observations that won him a share of the 1961 prize. And in the early 1960s, Lamb developed one of the first, semi-classical theories of how lasers work.

Lamb was born on 12 July 1913 in Los Angeles, and as an undergraduate at the University of California, Berkeley, studied chemistry. But he became increasingly fascinated with physics, and his presaging of the Mössbauer effect was part of a doctoral dissertation on the electromagnetic properties of nuclear systems, completed in 1938 under the guidance of J. Robert Oppenheimer.

Unlike many of his generation of physicists, Lamb did not follow Oppenheimer into the wartime atom-bomb project. Instead, he concentrated on his specialisms — microwaves and radar — at Columbia University in New York, performing the experiments that culminated in the observation of the Lamb shift (W. E. Lamb Jr and R. C. Retherford *Phys. Rev.* **72**, 241–243; 1947).

This shift is a tiny difference in energy between two atomic orbitals in hydrogen, denoted $2s$ and $2p$, distinguished only by their angular momenta. Quantum theories of the time predicted that these levels should have identical energies. The discovery that they did not, demanded a fundamental theoretical rethink — one that was initiated almost immediately by Hans Bethe.

The Lamb shift thus became a cornerstone of the modern edifice of quantum electrodynamics (QED). This, the quantum field theory of the electromagnetic interaction, explains the shift as resulting from energy fluctuations in the vacuum that smear out the position of the electron in a hydrogen atom. This process has a greater effect on the Coulomb energy of the electron's binding to the central proton at smaller radii (where the $2s$ state is most likely) than at

larger radii (where the $2p$ state dominates). Today, precise measurements of the Lamb shift have tested QED to an accuracy of better than one part in a million.

Lamb's disposition made him entirely suited to the difficult measurements of this tiny shift. A perfectionist, his approach to physics embodied the principle that physical intuition is a necessary, but not sufficient, condition for success. A sound conclusion demanded a solid calculation or experiment.

That perfectionism extended to Lamb's writing: he would spend considerable time revising papers, or having his students revise

them, pondering long and hard over subtle refinements such as the insertion of a comma. That honed his students' ability to write and led to unusually readable papers. But his meticulousness was never overbearing, and was always tempered by a wry, self-deprecating sense of humour. He was an outstanding supervisor, inspiring many students and postdocs with sharp insight and sure guidance. I recall trying to convince him to take me on as a graduate student, presumptuously claiming expertise in his field of interest. His response was that he was always interested in expertise, as he had so little of his own. It was the start of a long and fertile collaboration on laser theory.

In his later career, Lamb's refusal to generalize conclusions purely on intuition prevented him on occasion from publishing important work that didn't meet his own high standards. Perfection for him was a quality to be strived for, and perhaps not to be attained. He once told me that he regretted having been so close to so many great discoveries without realizing it. I replied that I wished I had that problem.

Lamb's contributions to laser physics

were a case in point. The first microwave-frequency equivalent of the laser, the maser, had been constructed by Charles Townes and collaborators at Columbia in 1953. But like others working on the extension of the maser to higher, optical frequencies, Lamb was convinced that a closed cavity, such as that in which light was amplified in a maser, would be needed to create a laser. It was left to Gordon Gould to predict that an open cavity could lase, and for Theodore Maiman to implement the idea in 1960.

Lamb's part was nevertheless substantial. His theory of laser action (W. E. Lamb Jr *Phys. Rev.* **134**, A1429–A1450; 1964) predicted the 'Lamb dip' in the output intensity of a gas laser. This spectral feature is a consequence of the Doppler effect, occurring when, owing to thermal motions of the gas, an atomic absorption line becomes smeared out in frequency. In this case, two oppositely

directed light waves will interact with atoms of the same velocity if tuned to the centre of the Doppler-broadened line, but with atoms of different velocities when tuned off-resonance. The laser gain thus saturates at a lower intensity on resonance. This Lamb dip in lasers, and its counterpart in absorptive media, enabled the creation of incredibly stable devices that redefined the way we measure time and distance.

The fact that Lamb's 1964 laser theory was semi-classical was again entirely typical: Lamb was fascinated by the

extent to which nature was necessarily quantum-mechanical. In particular, he insisted that the original photoelectric effect — the proof of whose quantum nature had garnered Albert Einstein his Nobel in 1921 — could be accounted for using a classical electromagnetic field. He had little patience for those who misused the term 'photon', particularly in situations where a classical electromagnetic wave would suffice, even once saying that he should be given responsibility for issuing licences for its use.

Tall and handsome, at first sight Willis Lamb seemed more Hollywood actor or high-flying businessman than scientist. But his dedication to physics was complete, and did not diminish in a 65-year career that encompassed Bell Labs (as a consultant on laser theory) and Stanford, Harvard, Oxford and Yale universities. He retired from the faculty of the University of Arizona only in 2002, at the age of 89.

Murray Sargent

Murray Sargent is at the Microsoft Corporation, 1 Microsoft Way, Redmond, Washington 98052, USA.

e-mail: murrays@microsoft.com

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