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Advance in Magnetic Resonance

Erwin L. Hahn
Scientist, Mentor, Friend ☆

Photo by G. Paul Bishop Jr.

It is indeed a great privilege and pleasure for me to write some words about one of my mentors, a colleague, and dear friend, Erwin L. Hahn, one of the giants of modern physics.

A brief history—Hahn was born in Sharon, Pennsylvania, in 1921. He had several possibilities for a career, among them the navy, movie stardom, and music (many of us are aware that Hahn is an enthusiastic and gifted violinist). Well, we can be thankful that he turned toward science, in particular that he chose magnetic resonance and optics. He received his Ph.D. in physics from the University

☆ Some of the material in this editorial has been adapted from previous comments I have made about Hahn in speeches and award nominations, as well as my published comments upon his election as a Foreign Member of the Royal Society, my "Hahn Lecture" at the Gordon Conference, my "Bloch Lecture" (A. Pines, NMR in Physics, Chemistry and Biology: Illustrations of Bloch's Legacy, 1990, in: *Proceedings of the Bloch Symposium*, Editor W. Little, *International Journal of Modern Physics B* **4**, 1241–1267) and the Encyclopedia of NMR (A. Pines, Solid State NMR: Some Personal Recollections, 1996, *Encyclopedia of Nuclear Magnetic Resonance*, Editors D. Grant and R.K. Harris, Wiley).

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The guest editor cross polarizing between Sven Hartmann and Erwin Hahn, with Charles Townes looking on.

of Illinois. He was a research associate at the University of Illinois; a National Research Council fellow at Stanford University, where he worked with Felix Bloch; and a research physicist at IBM Watson Scientific Computing Laboratory before he came to Berkeley, where he has been on the faculty since 1955. Beyond his famous published works, Hahn has always been a brilliant, provocative, and entertaining lecturer, raconteur, and teacher.

With his discovery of the spin echo, a phenomenon of monumental significance, Hahn launched a major revolution in physics with numerous implications to follow in many other areas of science. The occurrence of such a time reversal has far-reaching implications in the statistical physics of processes that approach equilibrium, and echoes were the first manifestation of the infamous ''Loschmidt–Boltzmann paradox.'' Using spin echoes, Hahn also uncovered the indirect or scalar coupling of nuclear spins via hyperfine interactions. The use of spin echoes has also featured prominently in magnetic resonance imaging, one of the most important developments in diagnostic medicine in the last century.

It was Hahn who also obtained the first nuclear quadrupole resonance echoes in solids, and he is co-author of a masterful text on nuclear quadrupole resonance spectroscopy. With his students, he introduced the idea of double resonance in the rotating frame, a technique that allowed for the first time the detection of NMR for rare nuclear spins and is widely used today by solid-state physicists and chemists. In the area of coherent laser physics, Hahn and co-workers predicted and demonstrated ''self-induced transparency,'' in which coherent optical pulses of particular shapes and areas propagate unattenuated through an otherwise resonantly absorbing medium, a type of ''optical soliton.'' He provided a full theory using coupled Maxwell and Bloch equations for the phenomenon, together with experimental examples. This effect is a clear-cut manifestation of a many-particle vortex interaction, and its existence in other cooperative and statistical phenomena is the subject of much current research.

Although I wasn't one of his direct ''academic offspring,'' I do feel that perhaps I am something like an academic nephew to Hahn, himself a direct academic descendant of Felix Bloch. Indeed having Hahn as a mentor, colleague, and friend has always been part of the pleasure and privilege of being at Berkeley. My own first indirect association with Hahn involved an experiment that Won-Kyu Rhim and I did at MIT in the laboratory of the great John S. Waugh, concerning the free induction decay of coupled spins in a crystal. The question then was whether the decay of magnetization under this complex Hamiltonian was really irreversible—it turned out that you could, by applying an extended sequence of pulses called a ''magic sandwich'' after the total decay of order, bring back the magnetization. About that time, Waugh was going out to California and he planned to drop in on the father of the spin echo and tell him about our work. When he came back to the lab from the trip and we asked him what Hahn had to say, he replied that Hahn had remarked, ''With that many pulses I could bring back the Messiah!''

Taking heart from this comment of his good friend, Waugh soon asked me to speak about the magic sandwich at the ISMAR conference held in Israel in 1971. Naturally, I was nervous, not only because this was one of my first public scientific speeches but also because both Bloch and Hahn were sitting there in the front row. So when Bloch's hand went up right at the end of the talk, and he said in his deep resonant voice, ''I would like to ask a stupid question,'' I could only think to myself, ''Goodbye Pines, it's been nice knowing you.'' I don't recall what Bloch asked, but Hahn reminded me of my surprised response—''Gee, that really *is* a stupid question.'' Bloch and Hahn both laughed delightedly, and Bloch said, ''Yes, I know, but would you answer it anyway?''

As a further example of Hahn's influence, we contemplated an alternative to the multiple-pulse line narrowing of homonuclear abundant spins such as hydrogen or fluorine in solids, namely to capitalize upon the double-resonance scheme of Hartmann and Hahn, whereby two different resonant frequencies are matched in the rotating frame, allowing the exchange of magnetization between different spin species. The process which we termed "cross polarization" from abundant hydrogen to naturally dilute carbon-13, combined with spin decoupling, and subsequently magic-angle spinning, would make it possible to enhance both the sensitivity and the resolution of the directly observed carbon signal while retaining the vital anisotropic information. Indeed, this turned out to be a promising new approach to high-resolution solid-state NMR for systems from materials and chemistry to biology and medicine, again a direct beneficiary of the eternal innovations of Erwin Hahn.

My official association with Hahn began in 1972 when I was awarded a Miller Fellowship in physics to work with him at Berkeley. Shortly afterward, however, the Chemistry Department offered me a faculty position, which I accepted (despite Hahn's comment that endeared him to my chemistry colleagues—"Alex, you're too smart to be a chemist"). Since that time, one of the marvelous experiences of being at Berkeley has been the privilege of having Hahn as a colleague, scientific collaborator, and dear friend.

Some years ago, on the occasion of his 70th birthday, a symposium was organized in Hahn's honor at Berkeley. Listening to the speakers, among them many of the other luminaries and founders of NMR, as well as numerous colleagues and former students of Hahn, one could not help but be astounded by the breadth and depth of his impact as reflected on the generations of scientists whom he has educated and influenced. Telegrams and best wishes were read aloud, and the Chancellor of the University of California awarded Hahn our highest honor, the "Berkeley Citation."

The Hahn Symposium was also the occasion for what Erwin views as a compliment. Upon receipt of the symposium announcement, a colleague in Colorado called to say that he had an overseas visitor who was surprised; his response was, "My goodness, I thought that Hahn was dead!" "No," my friend explained to him, "Hahn is very much active and still working as creatively as always; in fact he is collaborating with Alex Pines, Walter Knight, and Mel Klein, the organizers of the symposium." "Pines!" the visitor exclaimed—I thought he was dead!"

Hahn's contributions to science are phenomenal. He has done so many creative and beautiful things, a fraction of any one of which could serve each of us for a lifetime. To remind us all, and to set things in perspective, let me mention again just *four* of his papers, the ones involving free precession, spin echoes, double resonance, and self-induced transparency!

Hahn has been an inspiration for generations of scientists, and we owe him a debt beyond words. For me, becoming acquainted with spin echoes and time reversal and becoming afflicted with the Hartmann–Hahn condition (from which I suffer to this very day) have been an unforgettable part of my scientific education and experience for which I am forever grateful. Certainly, Hahn is a genius, one of the greatest physicists of the last century and, moreover, he is an individual of enormous integrity in his scientific and personal life. He has been, and he remains, a shining light for all of us to follow.

Erwin, on behalf of us all in magnetic resonance, I'd like to say thank you, convey to you and your family our blessings, and hope that you will enjoy many more healthy and happy years of science, music, friendship, and humor.

Yours as always,
Alex Pines

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