the war. We did research on ultra-high-frequency rectifiers, aiming at the development of an effective crystal mixer as a duodiode or three-electrode crystal, based on the advances that had been made in crystal rectifiers over the past two decades. Early on, the director of research, Horst Rothe, gave us the task of comparing electronic noise measurements for vacuum mixer diodes and crystal rectifiers. We also studied the compensation of the oscillator noise through the use of duodiodes in push/pull microwave mixers and the improvement of the signal/noise ratio through the use of crystal mixers with crystals such as silicon, silicon carbide, lead sulfide and germanium. And we sought ways to equalize the current/voltage characteristics of crystal duodiodes for oscillator noise compensation. In fact, I made three-electrode crystals, trying to locate both top whiskers so that the current/voltage characteristics were identical. But the crystal material was so inhomogeneous that most tests failed to result in noise compensation. In 1942, though, we published our results on noise measurements in crystal rectifiers.[2] The following year, I applied for a patent on crystal diodes with electrolytic contacts,[3] and later I sought one on crystal duodiodes for centimeter-wavelength mixers.[4]

Eventually, better crystal material became available. Karl Seiler of Breslau University evaporated silicon on graphite substrates and Heinrich Welker of the Institute of Physical Chemistry in Munich used the Bridgman technique to make germanium crystals.

After the war, I accepted an offer—as did Welker—to relocate to Paris to establish a semiconductor diode plant for Westinghouse Electric Corp under contract from France's Ministry of Post, Telegraph, and Telephone. As Welker started the buildup of a Bridgman-type crystal furnace and produced pencil-like germanium rods that were cut for use in diodes, I installed the production line for making and testing the actual devices. In those tests, I renewed my work with two whiskers with the aim of exploring the barrier layer. I noticed that in some cases I got injection and amplification when the crystal had been cut from a larger ingot, and also when certain grain boundaries were present. So I asked Welker to increase the size of his graphite boats to grow larger ingots.

Working in war-ravaged Europe, we were hampered by the problem of obtaining high-purity germanium, and no real effort was made to monocrystallize. In the US, on the other hand, companies were able to reach a high degree of purification, Gordon K. Teal at Bell Labs was starting to grow Czochralski-type monocrystals and minority carrier lifetimes had improved to the point where (under advice from Bardeen) Brattain's surface state tests had led to minority carrier injection.

Finally, early in 1948, I was able to get amplification more regularly—that is, injection into a reverse-biased point contact. Our results were duly presented to the French government, published and patented.[5] The "transistron," as the French called it, was also shown to the press and we were dubbed "les pères du transistron."[6] However, our achievement did not lead to enhanced financial support for the Paris laboratory, and so both Welker and I took up other activities. He went to Siemens to start his well-known work on III–V compounds. I started the Intermetall Corp in West Germany to produce diodes and transistors, and installed a lab for III–V compounds.

I left in 1953, when Intermetall was bought by the Clevite Transistor Corp, which—to bring this account full circle—later purchased the Shockley Semiconductor Lab from Beckman Instruments. I then emigrated to the US to continue my research project on the electrical effects of crystal defects that I had started as a young man in Düsseldorf.

References

1. See, for example, L. Hoddeson, in *Historical Studies in the Physical Sciences*, vol. 12, part 1, J. L. Heilbron, ed., Berkeley, U. of California P. (1981).
2. H. F. Mataré, Elektrische Nachrichtentechnik **19** (7), 111 (1942).
3. Swiss Patent No. 243 490 (16 November 1943).
4. French Patent No. 22 307 (23 May 1947).
5. French Patent No. 1 010 427 (13 August 1948); US Patent No. 2 673 948 (11 August 1949).
6. For a complete survey of all related patent applications and research efforts from 1925 until the final breakthrough in 1948, see B. G. Bosch, "The Multifaceted History of the Transistor" (1994) (available from the author at the University of Bochum in Germany).

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ConCERNed Scientist Says Work on Two-Beam Accelerators Goes On

I found Bertram Schwarzschild's story entitled "Stanford Wants to Build a TeV Linear Collider with Japan" (PHYSICS TODAY, November 1997, page 21) to be very well written and quite accurate with regard to the work being done both at the Stanford Linear Accelerator Center (SLAC) and Japan's High Energy Accelerator Research Organization (KEK). However, he gives the impression that the work on two-beam accelerators at CERN has stopped. On the contrary, the two-beam approach combined with high-frequency acceleration (30 GHz) is still being actively pursued at CERN. This frequency permits a high acceleration gradient and may be the ideal choice for a multi-TeV electron–positron linear collider.

I have been working on the Next Linear Collider research effort for the past ten years or so, and I have led an outstanding group of physicists and engineers to build the Next Linear Collider Test Accelerator at SLAC. The NLCTA brings together the NLC technology and accelerator physics development in a complete system test.

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Name Put Forward of Another Physicist Who Writes Sci-Fi Novels

It was pleasant to read Elisabeth M. Brown's letter (PHYSICS TODAY, October 1997, page 142) recognizing scientists who have written accurate, entertaining science fiction. However, I found one notable omission: Robert L. Forward, whose scientific work is as speculative and well-grounded as his fiction.

As a physicist, Forward has studied the design of interstellar probes, the possibility of using antimatter and laser-propelled lightsails for spacecraft propulsion and the use of space tethers for orbital maneuvers. In his novels *Dragon's Egg* and *Starquake*, he envisions life on the surface of a neutron star, based on nuclear rather than chemical reactions and proceeding vastly more rapidly than our own; in *Rocheworld* and its sequels, he explores a pair of co-orbiting planets so close together that they are distorted from spherical shape.

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