IVAR GIAEVER: AN UNLIKELY HERO OF QUANTUM TIMES

IVAR GIAEVER: UN HÉROE IMPROBABLE DE LOS TIEMPOS CUÁNTICOS

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Giaever, who passed away in June 2025, transformed quantum physics through his experimental discovery of tunnelling in superconductors, a phenomenon predicted by BCS theory and intimately linked to the superconducting gap. Despite his modest academic beginnings, he achieved groundbreaking results at General Electric by demonstrating quasiparticle tunnelling across superconductor–insulator–superconductor junctions. His curiosity, perseverance, and collaborative environment enabled this achievement. The author, whose own research was shaped by tunnelling effects in ceramic superconductors, reflects on Giaever's profound influence during a fleeting elevator encounter.

Giaever, fallecido en junio de 2025, transformó la física cuántica mediante su descubrimiento experimental del efecto túnel en superconductores, un fenómeno predicho por la teoría BCS e íntimamente ligado al "gap" superconductor. A pesar de sus modestos comienzos académicos, logró resultados innovadores en General Electric al demostrar el efecto túnel de cuasipartículas a través de las uniones superconductor-aislante-superconductor. Su curiosidad, perseverancia y un ambiente de colaboración hicieron posible este logro. El autor, cuya propia investigación se vio influenciada por los efectos túnel en superconductores cerámicos, reflexiona sobre la profunda influencia de Giaever durante un fugaz encuentro en un ascensor.

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I guess it happened around the year 2002, when I was visiting the Physics department at the University of Oslo. One morning, I was waiting the elevator at the ground floor, when another person quietly joined me. I mechanically nodded him as he arrived but, as soon as I returned to my original position, electricity went down my body. It was Ivar Giaever.

I looked up at the elevator indicator, noticing that the doors were about to open. I desperately tried to find a dignified way to tell Ivar how much I admired him as a scientist during the 15 seconds we would ride together into the elevator. But a hesitant "bye" was the only sound coming off my mouth when he walked out at his floor. As the doors closed behind him to lock me back inside the metal box, I felt like a frustrated scientific paparazzi. Ivar has passed away by June 20, 2025, at the age of 96 years old. With Leo Esaki and Brian Josephson, he had won the Nobel Prize in Physics in 1973 "for their experimental discoveries regarding tunnelling phenomena in semiconductors and superconductors". Tunnelling, as we know, is one of the strangest signatures of the quantum world: a microscopic particle –like and electron— is eventually able to pass through an energy barrier that cannot be penetrated by a particle in the macroscopic world. Isaac Newton would have mocked this possibility; no doubt.

But let us go back to our main character. When he finished his mechanical engineering studies at the Norwegian Institute of Technology, it was very hard to predict Ivar's brilliant future as a scientist: he finished scoring 4.0 marks –which means barely passing, as the best grade in Norway was 1.0. Surprisingly, he was admitted for a position at the General Electric Research Laboratory in 1956 (Schenectady, New York), by an impressed interviewer who had no clue of the Norwegian grading system [1]. Giaever would spend decades in that place, where he performed the experiments that eventually launched him into the Nobel arena. Superconductors are materials that, for temperatures below the the so-called critical temperature (T_C), display three bizarre experimental fingerprints: zero resistivity, expulsion of magnetic flux lines from their interior (Meissner effect), and flux quantization. This collection of strange properties is the result of the fact that superconductivity is a macroscopic quantum phenomenon: all the carriers of the non-dissipative current –the Cooper pairs– can be described by a single quantum wavefunction. The microscopic theory describing it was created by Bardeen, Schrieffer and Cooper (BCS) in 1957, for which they received the Physics Nobel prize of 1972 [2]. A non-microscopic theory –perhaps even more fruitful, in my opinion—was developed by Ginzburg, Landau, Abrikosov and Gorkov (GLAG) around the same time [3]. These theories suggested that the non-dissipative current in superconductors would be carried not by electrons, but by electron couples (called Cooper pairs) that are somehow "synchronized" all over the superconductor –by means of a phonon-based interaction, if we follow the original BCS model.

Being creatures of the quantum world, Cooper pairs might be expected to tunnel through a non-superconducting barrier sandwiched between two superconductors. That would imply a hard-to-swallow quantum effect: a current could be established at zero voltage across the barrier. This effect was predicted by a 22-year-old physicist named Brian Josephson in 1962 [4] (Initially, his ideas looked so bizarre, that they were publicly –and wrongly– dismissed by Bardeen himself [5]).

But the BCS model also suggests a perhaps less bizarre kind of tunnelling. Cooper pairs can be broken into "quasi-particles" (that we can imagine as electrons "missing" their couple) if an energy equal to the "superconducting gap" is provided. One way to achieve it is applying an appropriate potential difference between two superconductors separated by an insulating barrier: in such case, Copper pairs break into quasi-particles, which tunnel through the junction from the higher voltage to the lower voltage superconducting electrode. The fingerprint of it is a current-voltage curve across the barrier where the tunnelling current only flows if the voltage difference is equal or largen than $2\Delta/e$, where e is the charge of the electron and Δ is the superconducting gap. So, if you measure a current-voltage characteristic of a superconductor-insulator-superconductor barrier, you can calculate the value of the gap of the superconducting electrodes! Ivar Giaever, partly following suggestions from colleagues, decided to test this possibility in the lab. It was not an easy task: as a mechanical engineer, he had zero experience in solid-state fabrication, low temperatures or electrical measurements, and a modest background in theoretical physics. However, with the help of extremely cooperative members of his lab at General Electric, he fabricated a tunneling barrier consisting of two lead electrodes linked by a very fine layer of lead oxide: at low enough temperatures obtained with the help of liquid helium, the lead would become superconducting but not the oxide. And in fact he found the tunneling effect: there was a range of applied voltages with basically no current passing through the device, but it would rise quite sharply when the voltage value $2\Delta/e$ was reached [6].

How is it possible that an average-performing mechanical engineer with a modest background in either theoretical or experimental physics, as well as a "non-quantum" frame of mind had made a major contribution to quantum physics? It seems that it was a combination of enormous curiosity, hard work, freedom to choose his research topic, and the help of cooperative and selfless colleagues. As Giaever himself writes in his Nobel lecture, "In particular, I can remember (Charles) Bean enthusiastically spreading the news in our laboratory and also patiently explaining to me the significance of the experiment" [7].

For decades, I worked myself in the field of superconductivity, doing inexpensive experiments at the modest temperature of liquid nitrogen, until we ran out of it due to economical debacles and the plain indolence of some decision-makers. I used to work in the most inexpensive materials: ceramic superconductors. But thank to the "dirtiness" of the samples, all my experiments were permeated by the quantum tunnelling across the "weak-links" naturally occurring between superconducting grains [8–10]. It forced me into the wonderful world of Giaever's, and critically shaped my scientific career as a mature researcher able to survive the circumstances.

These thoughts flooded my mind during the 15 second ride with Ivar Giaever in the elevator, finally condensing into a simple "bye" as the doors closed behind him to lock me back inside the metal box.

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