## Leo Kouwenhoven's Majorana Particles

If you ask Leo Kouwenhoven (1963), the overwhelming media attention for his discovery of the Majorana particle is just hype. He was invited to meet the Dutch Prime Minister Mark Rutte and almost seemed to have the Nobel Prize in Physics in the bag. A slight exaggeration, perhaps, but this nanophysicist has made a major breakthrough, and if the follow-up experiments go according to plan, he certainly has decent prospects for the prize.

Leo Kouwenhoven

It all started on 27th February 2012, at the annual meeting of the American Physical Society. Kouwenhoven presented his latest results to a packed Boston Convention Center, and became the hottest talk of the conference. The subject: strong indications of the existence of the Majorana particle, predicted by Italian theoretical physicist Ettore Majorana in 1937. The genius himself disappeared mysteriously off the face of the earth, but after a search lasting three quarters of a century his particle turned up in a physics laboratory at Delft University of Technology[1]. This was no coincidence. Kouwenhoven is a world leader in research on the electronic properties of nanostructures, particles with dimensions measurable in millionths of millimetres, which obey the laws of quantum mechanics. These laws may defy common sense (particles in two places at the same time), but they are indispensible for a fundamental understanding of the nanoworld.

Kouwenhoven was awarded a PhD *cum laude* from Delft University of Technology in 1992 and, having turned down an offer from Harvard, has been a professor at Delft since 1999. In 2007 he won the Spinoza Prize, the highest scientific award in the Netherlands. His research on quantum transport in semiconductor materials is constantly in top journals including *Nature* and *Science*. Kouwenhoven made his name constructing quantum dots, ultra tiny 'boxes' in which he managed to lock up a single electron, thereby making them potential qubits for a quantum computer. Qubits are not set to 0 or 1, like normal computer bits, they can be *0 and 1 at the same time*, exponentially increasing their computational power, so that a quantum computer can crack problems (decipher codes, search in a database) which are unthinkable for current supercomputers. There is a but: qubits must be stable and undisturbed by their environment - and there lies the rub. Even cooling them to just above absolute zero (-273 ºC) seems not to help. Quantum computers exist only on paper.

This is where Majorana particles might help. As a professor in Naples in the thirties, Ettore Majorana played with the famous Dirac equation, the heart of quantum theory. He found an unusual solution: particles which are their own antiparticles, so their properties are effectively null. These particles with null properties initially received little attention, but in the seventies a search began to prove their existence. Since then cosmology has also shown an interest. A large proportion of the universe is missing. This 'dark matter' may consist of Majorana particles. At CERN in Geneva scientists are hard at work searching for Majorana particles, so far in vain. Kouwenhoven took a different tack. In addition to elementary particles (basic building blocks) there are also complex particles, which can be useful for calculations. The effect could be comparable to a Mexican wave in a stadium, a collective phenomenon conducted by a group of individuals. With the right combinations of materials and nanowires, ultra low temperatures and strong magnetic fields, you can create conditions in which synthetic Majorana particles, combinations of thousands of electrons, can occur. Kouwenhoven was familiar with such conditions from his previous research.

Kouwenhoven's Majorana particles appear at the ends of the nanowires. The 0.003 mm-long indium antimonide nanowire lies on a superconductive surface (no electrical resistance as long as it is cooled to just above absolute zero) and is exposed to a magnetic field. The current in the nanowire is measured with electrodes. The surges detected can only be explained by the presence of Majorana particles. But strong indications are not enough to satisfy peers in the physics world or the Nobel committee. Follow-up experiments in Delft have yet to provide hard proof. These are directed at measuring the special properties of the Majorana particles, which differ from what we know about the familiar elementary particles. To be specific, Kouwenhoven would like to prove that Majorana particles conform to so-called non-Abelian statistics.

It is this property that makes Majorana particles suitable as qubits for a quantum computer. That is why Microsoft contacted Kouwenhoven in 2012, resulting in support from the US to the tune of a million dollars. Kouwenhoven now plans to build a real quantum computer based on Majorana particles, a project running into billions and requiring investors. Contact with Microsoft remains excellent. When *Science* published his Majorana article on 12th April 2012 Kouwenhoven was treated to Majorana cake at the head office in Redmond.

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*Translated by Anna Asbury*

**NOTES**

1. See www.tudelft.nl/en. Delft is about halfway between Rotterdam and The Hague.