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Search in the "quantum haystack" rewarded

Innsbruck Physicists achieve breakthrough with fermionic quantum gasses

Researchers at the Institute for Quantum Optics and Quantum Information (IQOQI) at the Austrian Academy of Sciences (ÖAW) have recently ventured into uncharted physics territory. A team of Prof. Rudolf Grimm and Dr. Florian Schreck succeeded in finding so-called Feshbach resonances in a quantum gas mixture of two fermionic elements and, in cooperation with US and Dutch physicists, in characterizing them. This feat opens up a new area for researching fundamental issues of quantum physics.

Fermionic particles are individualists and only become more sociable if they are bound into pairs. A naturally occurring form are the so-called Cooper pairs, two electrons (fermions) linked by intense interaction, which are responsible for superconductivity in very cold materials. Understanding this lossless flow of an electric current is one of the big goals of modern physics. The researchers around Wittgenstein Prize-winner Rudolf Grimm had an internationally acclaimed breakthrough when they produced the first Bose-Einstein condensate from fermions back in 2003. Now the team has succeeded in creating the first ever ultra-cold fermionic gas mixture made up of two different species, Lithium-6 and Potassium-40, and in characterizing those Feshbach resonances in which the particles interact most strongly. They report their findings in the Feb 8 issue of the scientific journal Physical Review Letters.

Search for needles in a haystack

"We have shed light on the interaction of Lithium-6 and Potassium-40 atoms at extremely low temperatures," explains Florian Schreck. "This is what is fundamentally new in our experiment". Previously nothing was known about the quantum-mechanical interaction between these particles and it was impossible to predict by theory. In measurements lasting several months the researchers looked for so-called Feshbach resonances. "You can compare it to the search for very many very small needles in a haystack," Rudolf Grimm explains. In the end they found 13 such resonances. Once the Feshbach resonances of a system are known, the physicists can alter the interaction of the particles at will by altering the applied magnetic field, producing, say, molecules or Cooper pairs in a targeted manner.

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International cooperation

Before they got that far, the scientists had to properly understand the resonances they had found. “That was a big headache for us. At first none of the existing theoretical models seemed to fit,” recalls professor Grimm. “For us to crack this problem, we needed to work closely with researchers at the NIST in Gaithersburg, USA, and Dutch physicists at the University of Amsterdam and the University of Technology, Eindhoven.“ The theory groups developed a new model for interpreting the results of the measurements done in Innsbruck. “With this calculation model we can now work out all possible Feshbach resonances for lithium-potassium mixtures,” Florian Schreck emphasizes. In this way the scientists have established a major tool for exploring fermionic quantum gasses further. “In a next step we want to produce ultra-cold molecules from lithium and potassium atoms and eventually transform them into a Bose-Einstein condensate,” Schreck explains his ideas for the future.

Superconductivity in their sights

These experiments form the basis for further research on fundamental questions of physics and might improve our understanding of special forms of superfluidity, if experiments with mixed fermionic quantum gasses are successful. Today’s physics still cannot explain how high temperature superconductors work. The extremely complex solid state structures elude the grasp of current physics. “Our experiment recreates these systems in simplified form and can be controlled very exactly. In our cooperation with the theory groups we hope to gain new insights on superconductivity from these experiments and eventually end up with better superconductors,” anticipates Florian Schreck. Already superconductors are used, for instance in magnetic resonance tomographs, to produce extremely strong magnetic fields. For the future there are great hopes for controlling this physical phenomenon because currently enormous amounts of the electric energy that is produced are still lost in transport.

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Publication: Exploring an Ultracold Fermi-Fermi Mixture: Interspecies Feshbach Resonances and Scattering Properties of 6Li and 40K. E. Wille, F. M. Spiegelhalder, G. Kerner, D. Naik, A. Trenkwalder, G. Hendl, F. Schreck, R. Grimm, T. G. Tiecke, J. T. M. Walraven, S. J. J. M. F. Kokkelmans, E. Tiesinga, and P. S. Julienne. Phys. Rev. Lett. 100, 053201 (2008) [http://link.aps.org/abstract/PRL/v100/e053201]

You can find pictures on: http://www.iqoqi.at/media/download/

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