A new class of electron interactions in quantum systems

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Physicists at the University of New South Wales have observed a new kind of interaction that can arise between electrons in a single-atom silicon transistor.

The findings, to be published this week in the journal Physical Review Letters, offer a more complete understanding of the mechanisms for electron transport in nanostructures at the atomic level.

"We have been able to study some of the most complicated transport mechanisms that can arise up to the single atom level," says lead author Dr Giuseppe C. Tettamanzi, from the School of Physics at UNSW.

The results contained in this study open the door for new quantum electronic schemes inwhich it is the orbital nature of the electrons – and not their spin or their charge – that plays a major role, he says.

The study, in collaboration with scientists from the ICMM in Madrid and the Kavli Institute in The Netherlands, describes how a single electron bound to a dopant atom in a silicon matrix can interact with many electrons throughout the transistor.

In these geometries, electron-electron interactions can be dominated by something called the Kondo effect. Conventionally, this arises from the spin degree of freedom, which represents an angular momentum intrinsic to each electron and is always in the up or in the down state.

However, researchers also observed that similar interactions could arise through the orbital degree of freedom of the electron. This describes the wave-like function of an electron and can be used to help determine an electrons' probable location around the atom's nucleus.

Importantly, by applying a strong magnetic field, the researchers were able to tune thiseffect to eliminate the spin-spin interactions while preserving the orbital-orbital interactions.

"By tuning the effect in two different symmetries of the fundamental state of the system…we have observed a symmetry crossover identical to those seen in high-energy physics," says Tettamanzi.

"In our case this crossover was observed simply by using a semiconductor device which is not too different from the transistor you use daily to send your emails."

Tettamanzi, who was recently awarded a prestigious ARC Discovery Early Career Researcher Award fellowship, will now investigate another transport mechanism that can arise in quantum dots and single atom transistors called "quantised charge pumping".

The idea here is to create a current flowing through a nanostructure without applying a voltage between the leads, but by applying varying potentials at one or more gates of the transistor, in an apparent violation of Ohm's law.

More information: The paper will be published this week in *Physical Review Letters* (online on January 26), but can be viewed online now at *arXiv*: arxiv.org/abs/1102.2977

Provided by University of New South Wales