Quantifying motion in quantum or classical terms

A new set of mathematical equations have been developed that can distinguish whether electrons in nanostructures display classical or quantum mechanical behaviour. Researchers from RIKEN, along with colleagues in Germany and Taiwan, developed the equations in an effort to overcome the problems of performing quantum measurements.

On a macroscopic scale, everyday objects like pool or billiard balls follow the classical laws of motion along exact, predictable paths. On a microscopic scale however, objects such as electrons move according to the laws of quantum mechanics, where processes occur in a probabilistic manner. At the nanoscale, determining whether electrons are transported according to the classical laws of motion or the laws of quantum mechanics is challenging because many nanostructures fall in a grey area between both regimes. Franco Nori, of RIKEN and the University of Michigan, who led the research team, explains: "Measurements on quantum mechanical systems are difficult to distinguish from invasive measurements on classical systems." He states: "It is important to be confident that experimental results are not originating from a classical effect, giving a false impression of quantum behaviour."

As a model system, the transport of electrons through vanishingly small pieces of matter known as quantum dots was chosen. To identify quantum effects, the researchers developed a set of criteria for experimental data from these quantum dots, expressed as a mathematical inequality relation, so that any excess over a critical threshold represents a clear sign of quantum behaviour. By running simulations, several regimes at low temperatures where quantum effects should occur were found without having to resort to making uncertain invasive measurements.

Since the inequality relation derived by the researchers is based on fundamental principles, it can be applied to many open, microscopic electron transport systems. Understanding the transport of electrons in nanostructures and biological molecules is crucial to understanding properties such as electrical conductivity and the biochemical behaviour of molecules.

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