More precision from less predictability: A new quantum trade-off

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An important advance in the quantitative understanding and experimental verification of complementarity; arguably the most important foundational principle of quantum mechanics.

Researchers at Griffith University's Centre for Quantum Dynamics have demonstrated that, contrary to what the Heisenberg uncertainty relation may suggest, particle properties such as position and momentum can be measured simultaneously with high precision.

But it comes at a cost.

The findings have been published in Experimental Test of Universal Complementarity Relations in the prestigious journal *Physical Review Letters*.

Co-author Dr Michael Hall said the work represents an important advance in the quantitative understanding and experimental verification of complementarity; arguably the most important foundational principle of quantum mechanics.

"Quantum mechanics is often thought to imply that you can estimate precisely how fast an electron is moving, or exactly where it is, but not both at the same time," Dr Hall said.

"The argument is that properties such as speed and position require physically incompatible or 'complementary' devices for their precise measurement and therefore, any device used to make a simultaneous measurement will give inherently imprecise estimates," he said.

"This argument was challenged by Einstein in 1935, who gave an example where the position and speed could be measured accurately at the same time, by exploiting quantum correlations with a second particle."

Professor Geoff Pryde, co-author and leader of the experimental team, said it is important to note that this is not in direct conflict with the well-known Heisenberg uncertainty relation, which requires only that the position and speed cannot both be predicted accurately beforehand, but it does leave open the important question of whether any quantum restrictions apply to simultaneous measurements.

"We have verified experimentally that Einstein was correct by using polarisation properties of photons rather than position and speed," Professor Pryde said.

"But we have also shown that a high degree of joint precision does not come for free; it is possible only if the measurement outcomes are sufficiently unpredictable, as quantified by a new generalisation of the Heisenberg uncertainty relation.

"As the uncertainty principle underlies many aspects of quantum information technology, ranging from entanglement verification to random number generation to the security of quantum cryptography, our work could have implications in all these areas."

More information: Paper: prl.aps.org/abstract/PRL/v110/i22/e220402

Provided by Griffith University

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