

Record quantum entanglement of multiple dimensions

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An international team directed by researchers from the Austrian Academy of Sciences, with participation from the Universitat Autònoma de Barcelona, has managed to create an entanglement of 103 dimensions with only two photons. The record had been established at 11 dimensions.

The states in which [elementary particles](#), such as photons, can be found have properties which are beyond common sense. Superpositions are produced, such as the possibility of being in two places at once, which defies intuition. In addition, when two [particles](#) are entangled a connection is generated: measuring the state of one (whether they are in one place or another, or spinning one way or another, for example) affects the state of the other particle instantly, no matter how far away from each other they are.

Scientists have spent years combining both properties to construct networks of [entangled particles](#) in a state of superposition. This in turn allows constructing quantum computers capable of operating at unimaginable speeds, encrypting information with total security and conducting experiments in quantum mechanics which would be impossible to carry out otherwise.

Until now, in order to increase the "computing" capacity of these particle systems, scientists have mainly turned to increasing the number of entangled particles, each of them in a two-dimensional state of superposition: a qubit (the quantum equivalent to an information bit, but

with values which can be 1, 0 or an overlap of both values). Using this method, scientists managed to entangle up to 14 particles, an authentic multitude given its experimental difficulty.

The research team was directed by Anton Zeilinger and Mario Krenn from the Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences. It included the participation of Marcus Huber, researcher from the Group of Quantum Information and Quantum Phenomena from the UAB Department of Physics, as well as visiting researcher at the Institute of Photonic Sciences (ICFO). The team has advanced one more step towards improving entangled quantum systems.

In an article published this week in the journal *Proceedings of the National Academy of Sciences (PNAS)*, scientists described how they managed to achieve a quantum [entanglement](#) with a minimum of 103 dimensions with only two particles. "We have two Schrödinger cats which could be alive, dead, or in 101 other states simultaneously", Huber jokes, "plus, they are entangled in such a way that what happens to one immediately affects the other". The results implies a record in quantum entanglements of multiple dimensions with two particles, established until now at 11 dimensions.

Instead of entangling many particles with a qubit of information each, scientists generated one single pair of [entangled photons](#) in which each could be in more than one hundred states, or in any of the superpositions of theses states; something much easier than entangling many particles. These highly complex states correspond to different modes in which photons may find themselves in, with a distribution of their characteristic phase, angular momentum and intensity for each mode.

"This high dimension [quantum entanglement](#) offers great potential for [quantum information](#) applications. In cryptography, for example, our

method would allow us to maintain the security of the information in realistic situations, with noise and interference. In addition, the discovery could facilitate the experimental development of quantum computers, since this would be an easier way of obtaining high dimensions of entanglement with few particles", explains UAB researcher Marcus Huber.

Now that the results demonstrate that obtaining high dimension entanglements is accessible, scientists conclude in the article that the next step will be to search how they can experimentally control these hundreds of spatial modes of the photons in order to conduct quantum computer operations.

More information: Paper: arxiv.org/abs/1306.0096

Provided by Universitat Autònoma de Barcelona

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