

From Quantum Puzzles to Quantum Information Technology

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What are Schrödinger's cat, Einstein's "spooky action at a distance" and his comment that God does not play dice with the Universe all about? Such puzzles led to many experiments which gave rise to world-wide activities to develop quantum information technologies.

The question raised by Schrödinger's cat is how large quantum systems can be. It will be argued that this is a practical question for experimental development in the future with currently no limit in sight.

Einstein's "spooky action at a distance" epitomizes the importance of quantum entanglement. The discussion began by Einstein, Podolsky, and Rosen in 1935 has led to Bell's Theorem. Most recently, experiments have been realized closing more loopholes in such test of local realistic ("classical") views than ever before. In the most recent "Cosmic Bell Experiment", the source of randomness came from distant stars.

Likewise, the randomness of individual quantum events is now considered a fundamental constituent of our understanding of Nature. Its most recent application is the NIST randomness beacon.

A most interesting and rather visual work horse have become orbital angular momentum (OAM) states, "screws of light". These can be used to carry much more information than one bit per photon, and they can be entangled in very high dimensions. These features open up new possibilities, also relevant for fundamental questions. Realizations include 3-dimensional, 3-particle GHZ states.

To date, the fundamental concepts, demonstrated by these puzzles, became the basis for the emerging quantum information technology. It includes quantum teleportation, and quantum computation.

I expect that a future quantum internet will combine these ideas. It will consist of quantum computers connected by quantum links carrying photons. I will shortly introduce these fields. From a fundamental point of view, some of the technical realizations have helped to sharpen our basic questions about the nature of quantum systems.