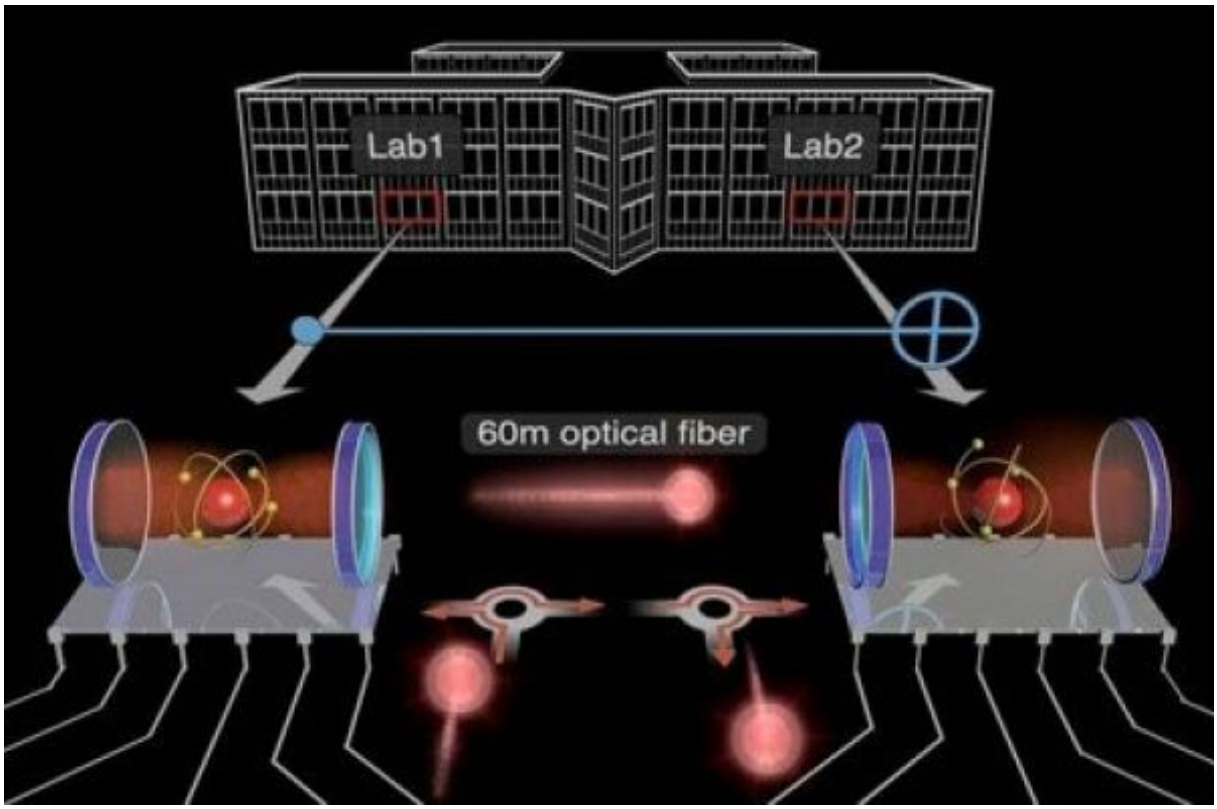


Quantum systems learn joint computing

A team of researchers realize the first quantum-logic computer operation between two separate quantum modules in different laboratories.

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Today's quantum computers contain up to several dozen memory and processing units, the so-called qubits. A international team of researchers, led by scientists at the Max Planck Institute of Quantum Optics in Garching, which include Emanuele Distante researcher from ICFO at the time of the experiment and member of the Quantum Photonics With Solids And Atoms research group, have successfully interconnected two such qubits located in different labs to a distributed quantum computer by linking the qubits with a 60-meter-long optical fiber. Over such a distance they realized a quantum-logic gate - the basic building block of a quantum computer. It makes the system the worldwide first prototype of a distributed quantum computer.

The limitations of previous qubit architectures

Quantum computers are considerably different from traditional i¿½binaryi¿½ comput
rs: Future realizations of them are expected to easily perform specific calculations for w
ich traditional computers would take months or even years - for example in the field of
ata encryption and decryption. While the performance of binary computers results from l
rge memories and fast computing cycles, the success of the quantum computer rests on the
act that one single memory unit - a quantum bit, also called i¿½qubiti¿½ - can
contain superpositions of different possible values at the same time. Therefore, a quantum
omputer does not only calculate one result at a time but instead many possible results in paral
el. The more qubits there are interconnected in a quantum computer; the more
complex calculations it can perform.

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This picture shows the two qubit modules that have been interconnected to implement a basic quantum computation over a distance of 60 meters.

The basic computing operations of a quantum computer are quantum-logic gates between two qubits. Such an operation changes - depending on the initial state of the qubits - their quantum mechanical states. For a quantum computer to be superior to a normal computer for various calculations, it would have to reliably interconnect many dozens, or even thousands of qubits for equally thousands of quantum operations.

Despite great successes, all current laboratories are still struggling to build such a large and reliable quantum computer, since every additionally required qubit makes it much harder to build a quantum computer in just one single set-up. The qubits are implemented, for instance, with single atoms, superconductive elements, or light particles, all of which need to be isolated perfectly from each other and the environment. The more qubits are arranged next to one another, the harder it is to both isolate and control them from outside at the same time.

Data line and processing unit combined

One way to overcome the technical difficulties in the construction of quantum computers is presented in a new study in the journal Science by first author Severin Daiss, Stefan Langenfeld and colleagues from the research group of Gerhard Rempe at the Max Planck Institute of Quantum Optics in Garching and the Institute of Photonic Sciences (Castelldefels, Spain). The team succeeded in connecting two-qubit modules across a 60-meter distance in such a way that they effectively form a basic quantum computer with two qubits. i¿½Acro
s this distance, we perform a quantum computing operation between two independent qub

t setups in different laboratories,i¿½ Daiss emphasizes. This enables the possibility to m rge smaller quantum computers into a joint processing unit.

Simply coupling distant qubits to generate entanglement between them has been achieved in the past, but now, the connection can additionally be used for quantum computations. For this purpose, the researchers employed modules consisting of a single atom as a qubit that is positioned amidst two mirrors. Between these modules, they send one single light quanta, a photon, that is transported in the optical fiber. This photon is then entangled with the quantum states of the qubits in the different modules. Subsequently, the state of one of the qubits is changed according to the measured state of the i¿½ancilla photoni¿½, realizi g a quantum mechanical CNOT-operation with a fidelity of 80 percent. A next step would b to connect more than two modules and to host more qubits in the individual modules.