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Press Release

Scaling silicon quantum photonics technology

The realisation of controllable large quantum devices is key for the development of quantum technologies.

Now a team of researchers from the University of Bristol, Peking University, Technical University of Denmark, ICFO Spain, PAS, University of Copenhagen and Dr. Jordi Tura from the Theory Division at the Max Planck Institute of Quantum Optics has developed a large-scale integrated silicon-photonics quantum circuit for the precise and general control of multidimensional entanglement.

Integrated Quantum Photonics allows the routing and control of single particles of light with intrinsically high stability and precision, however to date it has been limited to small-scale demonstrations in which only a small number of components are integrated on a chip. It is thus in high demand to scale up the integrated photonic circuits and increase the complexity and computational power of modern quantum information processing technologies that would enable many revolutionary applications.

An international team of researchers led by scientists from the University of Bristol's Quantum Engineering Technology Labs has demonstrated the first ever large-scale integrated quantum photonic circuit, which can generate, control and analyze high-dimensional entanglement with unprecedented high precision and generality. The quantum chip was realised using a scalable silicon photonics technology, similar to today's electronic circuits, which would provide a path to manufacture massive components for the realization of a optical quantum computer. The work, in collaboration with Peking University, Technical University of Denmark (DTU), Institut de Ciències Fotòniques (ICFO), Polish Academy of Sciences (PAS), University of Copenhagen and the Theory Division at the Max Planck Institute of Quantum Optics (MPQ), has been published online by the journal *Science* (8 March 2018).

Coherently and precisely controlling large quantum devices and complex multidimensional entanglement systems has been a challenging task owing to the complex interactions of correlated particles in large quantum systems. Significant progress towards large-scale quantum systems has been recently reported in a variety of platforms including photons, superconductors, ions, dots and defects. In particular, photonics represent a system able to naturally encode and process multidimensional qudit states in photon's different degrees of freedom. In this work, a programmable bipartite path-encoded multidimensional entangled system with dimension up to 15×15 is demonstrated, where each photon exists over 15 optical paths at the same time and the two photons are entangled with each other there. This multidimensional entanglement system is achieved by scaling up the silicon-photonics quantum circuits via a single chip integration of 550 optical components including 16 identical photon-pair sources, 93 optical phase-shifters, 122 beam-splitters, among other optical elements.

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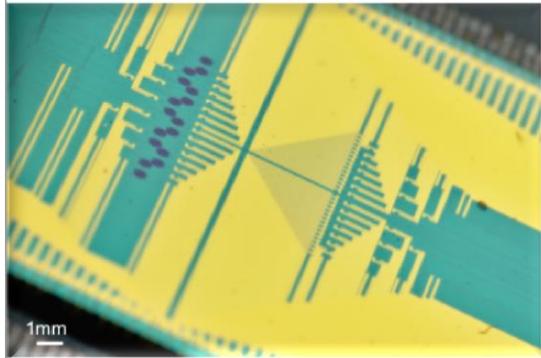
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Lead author, Dr. Jianwei Wang, said: “It is the maturity of today’s silicon-photonics that allows us to scale up the technology and reach a large-scale integration of quantum circuits. This is the most beautiful thing of quantum photonics on silicon. As a result, our quantum chip allows us to, for the first time, reach the unprecedented high precision and universality of controlling multidimensional entanglement, a key factor in many quantum information tasks of computing and communication.”

Dr. Yunhong Ding from DTU added: “New technologies always enable new applications. The capabilities of our integrated technology allow us to observe high-quality multidimensional quantum correlations including generalized Bell and EPR steering violations, and also to implement experimentally unexplored multidimensional quantum protocols: multidimensional randomness expansion and state self-testing.”



Dr. Jordi Tura from MPQ stated: “The degree of precision and control achieved with this technology has allowed us to test it against some of the most stringent quantum information protocols, such as self-testing or randomness expansion, which are possible only under very idealized experimental conditions.”

A large-scale integrated silicon-photonics quantum circuit for controlling multidimensional entanglement. (Graphic: from the original publication)

Professor Mark Thompson, the PI of the Bristol team, said: “The photonic circuits on silicon, the same material as used in our electronic circuits, allow the processing of information carried by a single particle of light. These silicon quantum photonics technologies are allowing us to scale up quantum devices and systems in an incredibly rapid speed, and in near future it would reach an integration of tens of thousands of elements on a single chip that can promise numerous quantum applications.”

Original publication:

J. Wang, S. Paesani, Y. Ding, R. Santagati, P. Skrzypczyk, A. Salavrakos, J. Tura, R. Augusiak, L. Mancinska, D. Bacco, D. Bonneau, J. W. Silverstone, Q Gong, A. Acin, K. Rottwitt, L. K. Oxenløwe, J. L. O’Brien, A. Laing, and M. G. Thompson

Multidimensional quantum entanglement with large-scale integrated optics

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