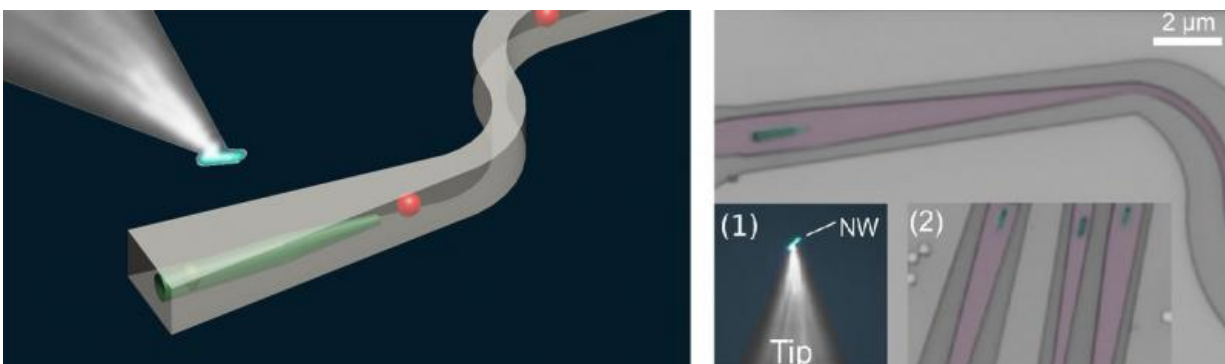


Quantum computing with single photons getting closer to reality

March 30 2016, by Lisa Zyga



(Left) Illustration and (right) color-coded microscope image of a nanowire (green) integrated in a photonic waveguide (gray on left, purple on right). In the illustration, the photons emitted from the nanowire are depicted as red spheres. Insets show a light-emitting nanowire, which in the microscope image is attached to the tip of a nanomanipulator. Credit: Zadeh, et al. ©2016 American Chemical Society

(Phys.org)—One promising approach for scalable quantum computing is to use an all-optical architecture, in which the qubits are represented by photons and manipulated by mirrors and beam splitters. So far, researchers have demonstrated this method, called Linear Optical Quantum Computing, on a very small scale by performing operations using just a few photons. In an attempt to scale up this method to larger numbers of photons, researchers in a new study have developed a way to

fully integrate single-photon sources inside optical circuits, creating integrated quantum circuits that may allow for scalable optical quantum computation.

The researchers, Iman Esmaeil Zadeh, Ali W. Elshaari, and coauthors, have published a paper on the integrated quantum circuits in a recent issue of *Nano Letters*.

As the researchers explain, one of the biggest challenges facing the realization of an efficient Linear Optical Quantum Computing system is integrating several components that are usually incompatible with each other onto a single platform. These components include a single-photon source such as quantum dots; routing devices such as waveguides; devices for manipulating [photons](#) such as cavities, filters, and quantum gates; and single-photon detectors.

In the new study, the researchers have experimentally demonstrated a method for embedding single-photon-generating quantum dots inside nanowires that, in turn, are encapsulated in a waveguide. To do this with the high precision required, they used a "nanomanipulator" consisting of a tungsten tip to transfer and align the components. Once inside the waveguide, single photons could be selected and routed to different parts of the optical circuit, where logical operations can eventually be performed.

"We proposed and demonstrated a hybrid solution for integrated quantum optics that exploits the advantages of high-quality single-photon sources with well-developed silicon-based photonics," Zadeh, at Delft University of Technology in The Netherlands, told *Phys.org*.

"Additionally, this method, unlike previous works, is fully deterministic, i.e., only quantum sources with the selected properties are integrated in photonic circuits.

"The proposed approach can serve as an infrastructure for implementing scalable integrated quantum optical circuits, which has potential for many quantum technologies. Furthermore, this platform provides new tools to physicists for studying strong light-matter interaction at nanoscales and cavity QED [quantum electrodynamics]."

One of the most important performance metrics for Linear Optical Quantum Computing is the coupling efficiency between the single-photon source and photonic channel. A low efficiency indicates photon loss, which reduces the computer's reliability. The set-up here achieves a coupling efficiency of about 24% (which is already considered good), and the researchers estimate that optimizing the waveguide design and material could improve this to 92%.

In addition to improving the coupling efficiency, in the future the researchers also plan to demonstrate on-chip entanglement, as well as increase the complexity of the photonic circuits and single-photon detectors.

"Ultimately, the goal is to realize a fully integrated quantum network on-chip," said Elshaari, at Delft University of Technology and the Royal Institute of Technology (KTH) in Stockholm. "At this moment there are a lot of opportunities, and the field is not well explored, but on-chip tuning of sources and generation of indistinguishable photons are among the challenges to be overcome."

More information: Iman Esmaeil Zadeh, et al. "Deterministic Integration of Single Photon Sources in Silicon Based Photonic Circuits." *Nano Letters*. DOI: [10.1021/acs.nanolett.5b04709](https://doi.org/10.1021/acs.nanolett.5b04709)

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