

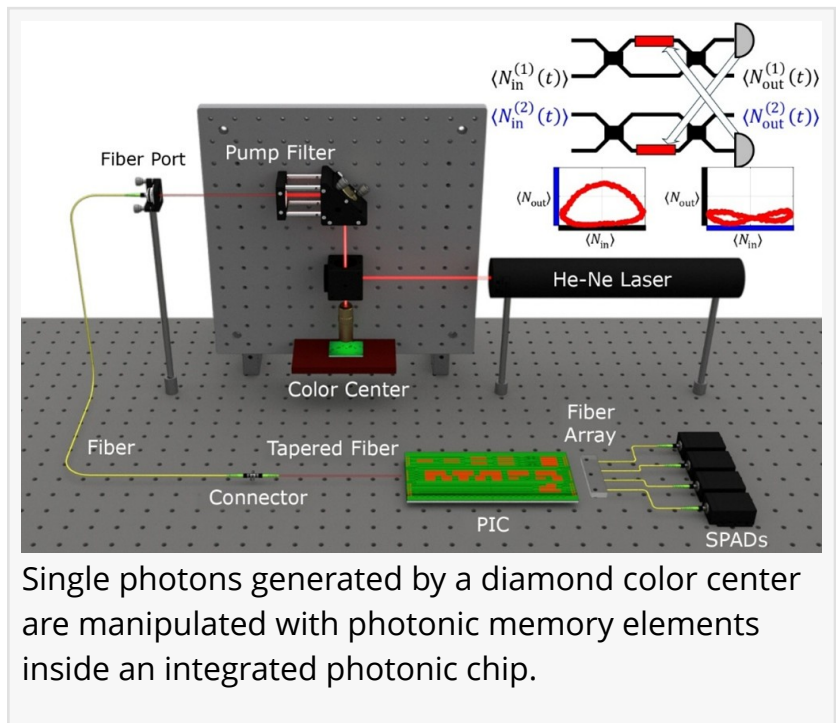
New Memory Elements to Manipulate Quanta of Light

New nonlinear and dynamical devices enable the construction of complex photonic circuits to predict temporal series

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/EINPresswire.com/ -- The study

presents a photonic integrated circuit composed of two coupled photonic quantum memristors with crossed feedback. The input is generated by a room-temperature single-photon source based on a silicon-vacancy color center in a nanodiamond. The input-output relations exhibit higher nonlinearity and memory effects compared with a single photonic quantum memristor: these new features make this network especially suited for reservoir computing. Finally, a system was used experimentally in temporal series predictions.



First section:

Photonic quantum memristors are devices that control photon fluxes: in particular, the relation between the input and output fluxes exhibits nonlinear and memory effects depending on the device settings. To achieve this, two ingredients are needed: a linear interferometer and an electrical circuit. The first element splits the input flux into two paths and recombines it to create an output flux whose value depends on the difference between the phases accumulated in the two paths. Such a phase difference can be controlled by the electrical circuit above the light paths, and its setting depends on previous values of input fluxes. The input is composed of single quanta of light generated by defects in nanodiamonds, and the outputs are measured by detectors capable of revealing the arrival of single quanta of light.

The circuit containing the photonic quantum memristors has been fabricated by an external company using standard techniques, and the method for reconfiguring the phase difference of the linear interferometers has been developed through optimization routines designed to find

the optimal settings to enhance nonlinearity and memory. This technology makes circuits for quantum light highly complex, since the final outputs are nonlinearly and dynamically related to the inputs at different instances. The combination of photonic quantum memristors and well-established devices with linear responses has the potential to make the photonic platform suitable for a new computational paradigm called reservoir computing. Contrary to a standard PC or generic von Neumann architectures, which follows a sequence of commands and alternates processing and memory instances, a reservoir-computing-based system is allowed to evolve freely with respect to inputs and its internal dynamics. Finally, the reading procedure of the output is adapted to the specific task needed to be solved. The overall computational cost of reservoir computing is usually lower than von-Neumann-architecture-based computing, and it does not require continuous communication between a processing unit and a memory unit, since the memory of the system is intrinsic.

The research is focused on the investigation of photonic reservoir computing systems based on photonic quantum memristors. These architectures provide very useful tools for temporal series prediction, i.e., grasping the future by analyzing the past.

Second section:

The research group of Prof. Lorenzo Pavesi from the University of Trento and Prof. Christophe Couteau from the University of Troyes propose a novel configuration for photonic quantum memristors. This work was made available online in the journal [Opto-Electronic Advances](#) on July 30, 2026.

This technology can be used as a fundamental component for implementing new computational paradigms that are not based on the standard von Neumann architecture. This system, equipped with a reservoir computing framework, is well-suited to process data evolving in time, since it is characterized by an intrinsic memory, nonlinearity, energetic efficiency, and low latency. Therefore, it can be applied to temporal series prediction, signal processing, and control. These tasks are central for forecasting and monitoring in finance, meteorology, industrial processes, healthcare, etc., for signal filtering, recognition, classification, and controlling complicated dynamical systems like production machines and robots. All the mentioned applications are part of people's daily lives. Thus, the development of the presented technology has a potential impact on the society, since it could allow more computational- and energetic-efficient devices able to execute those operations.

The direction of this research can be summarized by the following recipe: “build larger photonic circuits made of different photonic quantum memristors able to simultaneously manipulate multiple indistinguishable single photons.” This means the design of non-trivial combinations of the presented photonic memory elements and the creation of the initial quantum resource through suitable structures composed of many deterministic single-photon sources. Indeed, based on the findings of the study, the realization of large-scale photonic circuits fed with many single photons increases the number of computational nodes and interconnections of the resulting reservoir photonic systems. Consequently, the enhanced memory and nonlinear

capacities of the photonic network enable the encoding and processing of more demanding tasks, such as complicated temporal series prediction and real-time signal analysis. This could lead to a new generation of photonic processors that exploit the richness of non-trivial quantum interference phenomena between single photons. The overall highly dynamical and nonlinear evolution can be read and interpreted with standard electronic devices, which make the interface to the user.

Third section:

The Nanoscience Laboratory (NL) at the Department of Physics, University of Trento, focuses on cutting-edge research in areas such as neuromorphic photonics, integrated quantum photonics, non-Hermitian photonics, linear and nonlinear silicon photonics, and nanobiotechnologies. NL is dedicated to advancing understanding of the fundamental physical phenomena involving photons and their interaction with matter, particularly when structured at the nanoscale. NL's research spans the full spectrum from theoretical studies to practical device development, with a strong emphasis on photonic technologies that integrate seamlessly with modern silicon-based microelectronics.

The Quantum Nanodevice (qnD) team is part of the "Light, nanomaterials & nanotechnologies" laboratory or L2n, which is a joint research institute between the University of Technology of Troyes (UTT) and the CNRS (UMR 7076). The qnD team is an expert in quantum optics, nanophotonics, semiconductor nanomaterials, and quantum technologies where various applications of single photon sources are being investigated as well as light-matter interaction at the nanoscale. Solid-state systems are used made of semiconductor materials as well as color centers in high-band gap materials such as diamond and silicon carbide. Nonlinear optical processes and specifically spontaneous parametric down-conversion are also studied for quantum transducers.

Reference

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