PHYS.ORG

When memory qubits and photons get entangled

March 15 2021

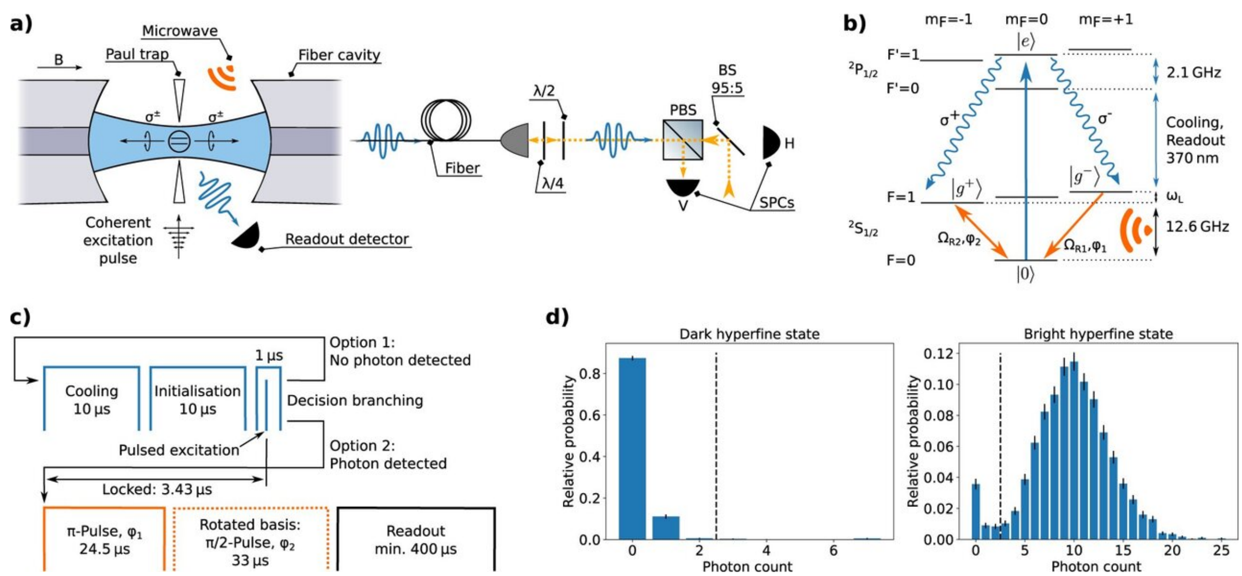
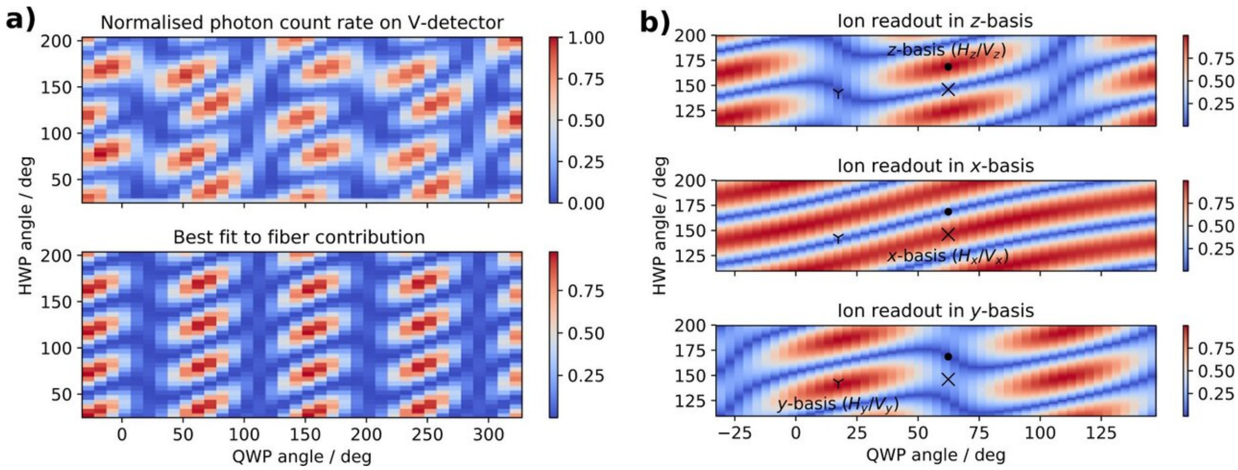


Fig. 1: Experimental setup. Credit: npj Quantum Information ISSN 2056-6387 (online)

Encrypting data in a way that ensures secure communication is an ever-growing challenge because crucial components of today's encryption systems cannot withstand future quantum computers. Researchers around the world are therefore working on technologies for novel encryption methods that are also based on quantum effects. The phenomenon of so-called quantum entanglement plays a particularly important role here. This means that in a quantum network, the stationary qubits of the network are entangled with the communication channel, which usually consists of photons (light particles). For the first time, physicists at the University of Bonn have now been able to demonstrate quantum entanglement between a stationary qubit, i.e. a two-state quantum system, and a photon with direct coupling to an optical fiber. The study has been published in the journal *npj Quantum Information*.

Quantum systems originate from the world of particles and smallest structures and may be relevant for future technologies. If different quantum information carriers (quantum nodes) are interconnected by quantum channels, researchers speak of quantum networks. Since 2009, scientists at the University of Bonn have been working on the realization of a quantum network node in which a single ion as a memory qubit is coupled to an optical resonator as a light-matter interface.

However, for the distribution of quantum information in a network, the stationary qubits of the network must be entangled with the communication channel. The physical reason is that a quantum state cannot be copied and transmitted in a classical way. Photons are typically used as the communication channel, which are difficult to store but allow for fast information transfer. "The implementation of efficient interfaces between photons and stationary qubits is therefore crucial for the rate of information transfer and the scalability of a quantum network," explains first author Pascal Kobel, a Ph.D. student in the research group Experimental Quantum Physics at the University of Bonn.



Selection of the photon readout basis. Credit: npj Quantum Information ISSN 2056-6387 (online)

Implementation of a light–matter interface

In their experimental setup, the scientists implemented a special interface between light and matter. To this end, they used an optical resonator consisting of two opposing mirrors realized on the end facets of two optical fibers. For the concave mirrors, they ablated part of the optical fiber with a laser pulse and subsequently had the optical fiber ends coated with a reflective coating. The fiber diameter of 150 micrometers was roughly on the order of a hair (approx. 60 micrometers).

"The construction and combination of such a resonator with a single ion is experimentally challenging. Fibers and ion have to be placed with a relative accuracy of about one micrometer to each other," says co-author Moritz Breyer, also physicist in the research group led by Prof. Dr. Michael Köhl at the University of Bonn. However, the small resonator volume increases the light-matter interaction, which enables high bandwidths for the distribution of quantum information in a network. Another advantage is that the fiber resonator leads to so-called intrinsic coupling of photons to optical fibers. This greatly simplifies their distribution in a network.

With their experimental setup, the scientists succeeded for the first time in demonstrating quantum entanglement between a stationary qubit and a photon out of an optical fiber resonator. They observed that even at a distance of one and a half meters, the single ion and the photon shared a common entangled quantum state. "Our presented system is well suited as a node in quantum networks," emphasizes study leader Prof. Dr. Michael Köhl, a member of the Matter and Light for Quantum Computing (ML4Q) Cluster of Excellence at the Universities of Bonn, Cologne and Aachen and Forschungszentrum Jülich and in the Transdisciplinary Research Area "Building Blocks of Matter and Fundamental Interactions." The network brings together researchers from different disciplines to work jointly on future-relevant questions at the University of Excellence Bonn.

The results of the study may be relevant for so-called distributed quantum computing or provably secure communication. In future studies, the researchers plan to further develop their system by, for example, improving the stability of the light-matter interface and using the setup for the distribution of quantum keys.

More information: Pascal Kobel et al. Deterministic spin-photon entanglement from a trapped ion in a fiber Fabry–Perot cavity, *npj Quantum Information* (2021). DOI: 10.1038/s41534-020-00338-2

Provided by University of Bonn