Felicidades al nuevo graduado de doctorado del ICFO

El Dr Stefano Duranti se ha graduado con una tesis titulada ?T owards efficient quantum repeater nodes based on solid-state quantum memories'

March 24, 2023

Felicitamos el Dr. Stefano Duranti que hoy ha defendido su tesis en el auditorio del ICFO. El Dr Duranti obtuvo su master en Fisica por la Universita degli Studi di Perugia en Italia. Se unio como estudiante de doctorado en el grupo de investigacion de Quantum Photonics with Solids and Atoms en ICFO dirigido por el Profesor ICREA Hugues de Riedmatten. La tesis del Dr Duranti titulada ?Towards efficient quantum repeater nodes based on solid-state quantum memories' fue supervisada por el Profesor ICREA Hugues de Riedmatten.

RESUMEN:

Quantum repeaters are the foundation of future long-distance quantum networks. In most architectures, their functional core is constituted by quantum memories, which are devices

that can store and re-emit photonic quantum information on-demand. The goal of this thesis is to progress towards efficient quantum repeater nodes enabling quantum correlations between telecom photons and matter qubits. To these ends, we performed three main experiments.

In our first work, we built a solid-state entanglement photon source with embedded storage capabilities. This emissive quantum memory was implemented in a Pr3+:Y2SiO5 crystal, by means of the atomic frequency comb (AFC) protocol. Thanks to the AFC, we were able to adapt the Duan-Lukin-Cirac-Zoller (DLCZ) protocol, initially conceived for cold atoms, to a solid-state ensemble. This experiment proved that we can produce light-matter entanglement between a heralding photon, at 606 nm, and a spin-wave excitation delocalized inside the ensemble. The matter excitation could be read on-demand at a later time with a read pulse, and mapped as a second photon, at 606 nm as well, emitted by the memory. Quantum correlations between the two photons were measured, enabling the violation of a Bell inequality, thus demonstrating the presence of entanglement. The read-out efficiency of this experiment was low, 1.6%, but solutions were identified to increase this value.

In the second experiment, we laid the groundwork for the quantum frequency conversion (QFC) of these photons to the telecom band. The long duration of these photons, up to 1 s makes their conversion with high signal-to-noise ratio (SNR) challenging. The conversio from the visible 606 nm wavelength to the telecom regime (1552 nm) was achieved b difference-frequency generation (DFG) in a PPLN waveguide using a strong pump field at 99 nm. A proof of principle with weak coherent pulses showed that we can convert s-lo g photons with the low heralding efficiency of the previous experiment with a SNR around 2. . This sets the stage for interfacing an AFC-DLCZ memory, working at 606 nm, with t e telecom network and with material systems working at a different wave length.

Finally, in the last experiment, we implemented an AFC impedance-matched cavity (IMC) storage experiment. It has been demonstrated theoretically and experimentally that the IMC enhances the storage and read-out efficiency of the AFC protocol. We harnessed this cavity to store weak coherent Gaussian pulses with up to 62% efficiency. Moreover, we stored weak coherent time-bin qubits in the same system, achieving 52% efficiency and, with an additional analysis carried out by means of an unbalanced Mach-Zehnder AFC-based interferometer, assessing a measured fidelity of 95% for the retrieved qubit, leading to a quantum memory fidelity compatible with 100%, within uncertainty. We additionally studied the influence of slow-light effects in our crystal, confirming that they lead to a reduction of cavity bandwidth by two orders of magnitude. Moreover, the AFC storage time was extended up to 50 s, to certify that the efficiency enhancement holds for different combs.

The achievements of this thesis represent the state of the art for the AFC efficiency and for qubit storage in solid-state systems, and pave the way towards efficient quantum memories. In addition, we reported the first demonstration of a solid-state photon pair source of entangled photons with embedded solid-state multimode memory. The results accomplished by this last AFC-DLCZ experiment in terms of heralding efficiency make it possible to interface it with our quantum frequency conversion experiment. Indeed, the QFC experiment, combined with the AFC-DLCZ one, enables to establish a quantum node and to interface it with different kind of nodes via conversion to the telecom band.

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