Single-photon-single-atom quantum interfaces

Jürgen Eschner

Experimentalphysik, Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken

We are developing a comprehensive set of experimental tools, based on ion-trapping and photonic technologies, that enable controlled generation, storage, transmission, and conversion of single photonic quantum bits, thereby integrating single photons and single atoms into a quantum network. Specifically, we implemented a programmable atom-photon interface, employing the controlled quantum interaction between a single trapped $^{40}Ca^{+}$ ion and single photons [1,2]. Depending on its mode of operation, the interface serves as a bi-directional atom-photon quantum state converter (receiver and sender), as a source of entangled atom-photon states (entangler), or as a quantum frequency converter of single photons [3,4] (converter). It lends itself particularly to integrating ions with single photons or entangled photon pairs from spontaneous parametric down-conversion (SPDC) sources [5,6]. As an experimental application of the receiver mode, we demonstrate the transfer of entanglement from an SPDC photon pair to atom-photon pairs with high fidelity [7]. It is realized by heralded absorption and storage of a single photonic qubit in a single ion. We extend our quantum network toolbox into the telecom regime by quantum frequency conversion of ion-resonant single photons [9], and by implementing telecom-heralded single-photon absorption [5]. In addition, we observe signatures of entanglement between the ion and a single telecom photon. This is obtained after controlled emission of a single photon at 854 nm and its polarization-preserving frequency conversion into the telecom band, by difference-frequency generation in a nonlinear waveguide.

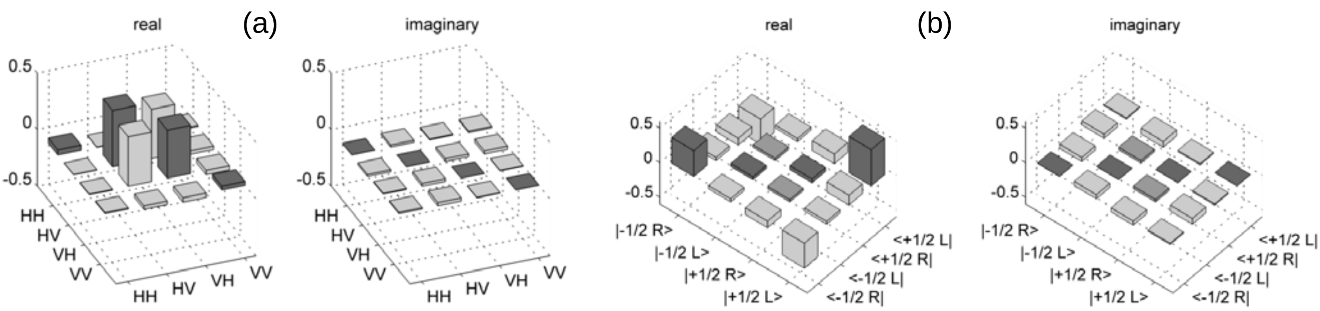

Figure 1 : Two-qubit density matrix, (a) before and (b) after heralded single-photon absorption. (a) Density matrix of the photon pair in the basis of horizontal and vertical polarisations (H,V). (b) Density matrix of the atom-photon pair after heralded absorption, in the basis of Zeeman sub-level of the atom (±1/2) and circular polarisation of the remaining photon (L,R).

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