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Tunable two-photon quantum interference of structured light

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Abstract

Structured photons are an interesting resource for quantum optics due to the richness of properties they show under propagation and in their interaction with matter. One of the key ingredients needed to exploit the full potential of structured light in quantum domain is the control of quantum interference. We recently demonstrated how to tune quantum interference between vectorial modes of light by simply adjusting the parameters of a spin-orbit coupler device. Besides providing a new tool for structured light manipulation, our technique is intrinsically compact and stable and can be a useful resource for quantum information processing in complex networks.

Photon-photon interference is a key ingredient in quantum optics as it is exploited in a number of tasks ranging from quantum metrology applications to entanglement swapping and quantum simulations. In the original Hong Ou Mandel experiment, the time delay between two photons entering a beam splitter is tuned in order to observe quantum interference [1]. However, photon-photon interference is not restricted to beam splitters, moreover other parameters (like polarization or spatial modes), besides time delay, can be controlled to make indistinguishable the contributions of the two photons to the final state.

Polarization in particular is usually considered to be uniform across the beam profile, however it is possible to build vectorial beams where the polarization varies across the beam profile according to specific geometries. These modes have interesting applications in a plethora of fields, both in classical and quantum regime, ranging from optical trapping to quantum information [2]. In quantum communication in particular, vectorial modes allow to encode qubits in rotational-invariant single photon states and thus, to overcome the need of a reference frame shared by the users [3, 4, 5].

Despite the large development of vector beams applications in the quantum domain, fully controlled quantum interference has been observed only very recently [6]. By exploiting a q-plate, a liquid crystal device that allows to couple polarization and orbital angular momentum of a light beam, we demonstrated how to tune quantum interference between vectorial modes of light by simply adjusting the device parameters and with no need of any interferometric setup. Being based on a single, thin device, our technique is intrinsically compact and stable and can be a useful resource for quantum information processing in complex networks. More in general, we believe this result provides a new tool for fundamental research and quantum technologies based on structured light.

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