Solid-state spin-photon interfaces for quantum communication networks

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Abstract :

The realization of a quantum network capable of distributing and processing entanglement across distant nodes is a major goal in quantum communications. The architecture of such a quantum network relies on connecting many optically active qubit-hosting nodes, separated by tens or hundreds of kilometers, through the exchange of quantum information carried by photons propagating in optical fibers [1]. Among the different atomic-like quantum systems investigated for implementing such a platform, the NV centers in diamond stand as promising candidates at the solid-state [2]. These point defects of diamond possess spin states with extremely long coherence time that can reach second-timescale at low temperature [3], making them appealing condensed-matter quantum memories. Thanks to a controlled spin-photon interface, NV centres are currently holding the record of the longest separation distance between atomic-like entangled systems [4]. However, these defects emit in the visible range subject to strong optical attenuation during optical fibre propagation, thus limiting the entanglement distribution to a few kilometres. This stimulates research on other point defects featuring similar spin properties, while emitting in the near-infrared (NIR) fiber-compatible spectral range.

Despite diamond, optically-active point defects similar to the NV centers do exist in other semiconductors. In particular, point defects emitting in the NIR range have been recently observed in silicon carbide (SiC) [5] and in silicon (Si) [6], that have the advantage of being adapted to industrial production processes. This PhD work aims at tackling the spin and optical properties of these new centers in SiC and Si, in order to assess their potential as spin-photon interfaces with the generation of spin-entangled single photons. We will specifically focus on vacancy-related defects in SiC, for which long-lived electron spins have been detected at the single scale [5], along with the observation of spin-conserving optical transitions [7]. In a more prospective way, we will investigate the spin properties of carbon-based centers in silicon that radiate in the O-telecom band [6]. Beyond opening perspectives for implementing quantum communication networks, these point defects have also impact in the wide range of quantum technology applications, from quantum imaging and sensors to quantum information processing.

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