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Integrated Quantum Photonics with Variable Strain

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Description

Due to their exceptional single-photon emission characteristics as well as their potential as solid-state qubits, semiconductor quantum dots are essential tools in the photonic quantum technology toolbox. Increasing efforts have been made recently to deterministically incorporate single semiconductor quantum dots into intricate photonic circuits. Despite the field's tremendous advancement, it is still difficult to control the optical characteristics of waveguide-integrated quantum emitters in a predictable, reversible, and nonintrusive way [1]. Here we present a novel class of hybrid quantum photonic circuits based on silicon nitride, III-V semiconductors, and piezoelectric crystals. We achieve the strain tuning of a chosen waveguide-integrated quantum emitter and a planar integrated optical resonator using a combination of bottom-up, top-down, and Nano manipulation techniques. The realisation of reconfigurable quantum-integrated photonics with total control over the quantum sources and the photonic circuit is made possible by our results [2].

The primary testing grounds for fundamental concepts in quantum research have been photons and quantum optical technology. This can be linked to the first quantum entanglement experiment, which used photons in an atomic cascade, and groundbreaking experiments in quantum teleportation and communication, which used parametric down conversion techniques [3]. Photons are reliable and adaptable options for flying qubits, with many coding systems based on polarisation, time domain, spatial domain, frequency domain, and even a mixture of more than one of these successfully realised. The usage of photons to communicate the results is inevitable, which makes the photonic approach even more appealing, even though there are alternate strategies now being investigated to use various quantum phenomena. However, a scalability problem is the cause of the delayed development of quantum states of light implementations for quantum information processing and sensing: The resources needed to carry out quantum optics studies above the single-photon level dramatically grow, necessitating an integrated strategy inspired by the microelectronics sector. Quantum emitters are at the core of quantum integrated photonics. Due to their near-ideal single-photon emission, the ability to generate entangled photon pairs with the potential for electrical control, as well as the prospect of using them as solid-state spin qubits, quantum dots (QDs) in particular are particularly intriguing sources for on-chip quantum technology [4].

The drawback of this flexible potential is the randomness of their position and emission characteristics, which makes it extremely challenging to scale up the quantum network. Furthermore, the quality of optical circuits built on a III-V platform is inferior to that of silicon, where waveguide losses are orders of magnitude smaller. This can be attributed in part to the highly optimised nanofabrication recipes that were taken straight from the microelectronics sector [5]. Even passive routing components can still have hundreds of undesired emitters that are arbitrarily positioned and cause absorption, which adds to the sources of loss. Particularly intriguing are hybrid integration techniques that combine selected III-V quantum emitters with silicon-based photonics since they may combine the greatest features of both platforms. Tuning the emission wavelength of circuit-integrated quantum sources is a significant difficulty in quantum integrated photonics. A fast developing field is that of controlling the emission characteristics of bulk quantum emitters. Numerous methods, including strain tuning with piezoelectric materials and MEMS devices, electric-field tuning, and thermal tuning, have been researched. Strain tuning is one of these methods that has gained popularity because it enables sophisticated control of a quantum emitter in a reversible manner without obvious deterioration of the optical characteristics [4,5]. Tuning the emission energy, removing fine structural splitting, and changing the dipole orientation of a bulk QD are recent developments in the strain tuning of QDs. It is exceedingly difficult to build large-scale planar photonic circuits with single chosen quantum emitters because the main disadvantage of strain tuning is that it requires wafer-bonding techniques to transfer the strain from a piezoelectric crystal to the circuit layer.

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Conflict of Interest

None.

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