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Quantum technologies in diamond enabled by laser processing

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ABSTRACT

Integrated photonic circuits promise to be foundational for applications in quantum information and sensing technologies, through their ability to confine and manipulate light. A key role in such technologies may be played by spin-active quantum emitters, which can be used to store quantum information or as sensitive probes of the local environment. A leading candidate is the negatively charged nitrogen vacancy (NV^-) diamond color center, whose ground spin state can be optically read out, exhibiting long (≈1 ms) coherence times at room temperature. These properties have driven research toward the integration of photonic circuits in the bulk of diamond with the development of techniques allowing fabrication of optical waveguides. In particular, femtosecond laser writing has emerged as a powerful technique, capable of writing light guiding structures with 3D configurations as well as creating NV complexes. In this Perspective, the physical mechanisms behind laser fabrication in diamond will be reviewed. The properties of waveguides, single- and ensemble-NV centers, will be analyzed, together with the possibility to combine such structures in integrated photonic devices, which can find direct application in quantum information and sensing.

The existence of stable, fluorescent, and spin-active color centers has made diamond a promising platform for quantum photonics. In particular, its negatively charged nitrogen-vacancy (NV^-) color center has unveiled long spin coherence times (≈1 ms) even at room temperature,[1] making it an appealing system for quantum applications. The NV^- center, which appears intrinsically in both natural and synthetic diamond, results from the replacement of two adjacent sites of the diamond carbon lattice by a nitrogen and a vacancy. The electronic ground state of such a complex forms a spin triplet, which can be polarized under green excitation, and exhibits a zero-phonon line