

Designing metamaterial antennae for improving the efficiency of single centers in diamond

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In the past few years, the creation of efficient single-photon sources (SPS) for quantum communication and quantum information processing has been actively pursued. One of the possible solutions for constructing an SPS is to use atom-like centers in solids, such as nitrogen-vacancy (NV) centers in diamond nanocrystals. The main advantages of NV centers are the room-temperature operation and the potential to be integrated with other solid-state platforms.

Some of the important criteria of a good SPS are high quantum yield, emission rate, and directional emission. In order to improve these characteristics, we couple NVs to nanophotonic structures. Since NV centers have a broadband emission spectrum, it is impractical to use traditional resonance-based approaches. Instead, we place the centers on a metamaterial with hyperbolic dispersion. The metamaterial is realized as a combination of alternating ultrathin layers (epitaxially-grown superlattice) of TiN and AlScN. However, the use of hyperbolic metamaterials for this application is problematic, since it is difficult to outcouple the electromagnetic waves propagating inside the metamaterial. To couple light out of these modes into the far field, we aim at constructing a bullseye antenna around a single nanodiamond containing an NV center. The antenna will contribute momentum to the metamaterial plasmons and, as a result, enable them to scatter to free space modes more efficiently to be collected with an optical objective. We simulate the bullseye nanoantenna using a finite element method to find the optimal geometric parameters. The optimized parameters such as depth, number of rings, nanodiamond position, and grating period, will be used to perform the fabrication of the grating. Our results can enable a high-efficiency CMOS-compatible SPS operating at room temperature.