Purcell Enhancement of Quantum Emitters Based on NV-centres in Nanodiamonds with Si-based Metasurfaces

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Improving the properties of quantum emitters plays a considerable role in the rapid development and deployment of quantum information, communication and sensing technologies [1]. The main approach is based upon integration of quantum emitters with either individual nanostructures or their arrays (metasurfaces), which provide an increased electromagnetic local density of states. This approach allows significant enhancement of the emission for quantum emitters, together with directivity and polarization control [2].

In this work, we develop dielectric metasurfaces based on silicon (Si) for integration with quantum emitters. Si offers the advantage of CMOS-compatibility, low ohmic losses in comparison with plasmonic counterpart, and, correspondingly, high radiation efficiency [3]. We demonstrate the applicability of our metasurfaces by interfacing them with quantum emitters based on NV-centres in nanodiamonds (NDs) [4].

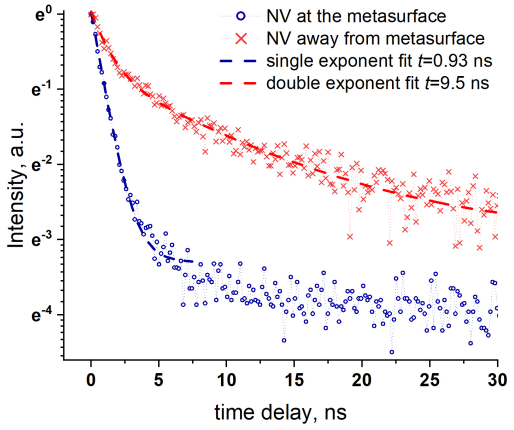

Figure 1: Lifetime measurements and exponential fit (dashed lines) for NVs in nanodiamonds at metasurface (blue), and away from it (red)

First, we characterized the fabricated metasurfaces by reflectance measurements using micro-spectro photometer. Then, the NDs with NVs of average size 40 nm from Adamas Nano were deposited at the metasurfaces using dip-coating. The sample was then placed at the home-built confocal microscope setup, where the excitation of NVs was performed by 515 nm laser through 100x objective lens with NA=0.9. The laser was able to operate both in CW and pulsed mode with 110 ps pulse width. We performed room temperature studies of NDs at the metasurfaces and away from them within the spectral bands, which corresponded to the resonances of the metasurfaces.

We confirmed the presence of quantum emitters by measuring $g^{(2)}(t)$ function for NDs with NVs ($g^{(2)}(0) < 1$ for quantum and $g^{(2)}(0) < 0.5$ for single photon emitters). Both for NDs with quantum emitters and without them we observed significant lifetime reduction in case of NDs located at the metasurfaces, see Fig. 1. We detected the lifetime below 1 ns (0.93 ns), while for the NDs away from metasurfaces it fell within the range of 8-10 ns. It constitutes almost the order of magnitude lifetime reduction. The comparison of the emission rates for quantum emitters at the metasurface and away from it also confirms almost order of magnitude enhancement (8 times). These measurements confirm that our developed system has the Purcell effect close to 10. This is one of the best results achieved so far for dielectric metasurfaces. We believe that our results will contribute to the development of integrated systems for quantum computing, communications and sensing.

References

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