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On-chip plasmonic cavity-enhanced quantum emitters

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Abstract: Nanofabrication of quantum cavities based on dielectric-loaded-plasmonic waveguides using Bragg gratings is presented. The cavities are deterministically positioned around the diamond-based emitters using lithographic patterning of electron-beam resist on silver. We observe a modulation of emission spectrum for the coupled emitter and a 6-fold enhancement in the total decay rate.

Keywords: Nanofabrication, quantum cavity, nitrogen-vacancy center, dielectric-loaded plasmonic waveguides, integrated quantum optics, quantum optical networks.

Strongly confined surface plasmons can be utilized to enhance the light-matter interaction for individual quantum emitters [1, 2]. Dielectric loaded surface plasmon polariton waveguide (DLSPPW) has been proposed as a waveguide which support confined modes at relatively lower loss compared with other metallic plasmonic structures [3]. Here, we employ the method of top-down fabrication [4] to make a compact cavity based on DLSPPWs which exploits filtering abilities of Bragg reflecting gratings [5] to form a cavity, which also leads to an emission rate enhancement (Fig. 1).

In the experiment, a silicon sample is coated with a silver film, on which gold coordinate markers are made, and subsequently, nanodiamonds are spin coated. The sample is then characterized by scanning in a fluorescence confocal microscope and lifetime, spectrum and autocorrelation measurements are taken for the nanodiamonds. DLSPPW-based cavities are fabricated by lithographic patterning of hydrogen silsesquioxane (HSQ) electron beam resist onto the NV-centers containing nanodiamonds (Fig.1-a (top)). Postfabrication camera image shows the coupling of the NV emitter to the cavity, and subsequent emission from the tapered gratings at the two ends of the waveguide (Fig.1-a (down)). A reduction in lifetime (from ~9 ns to ~3 ns) is observed for the coupled NV center (Fig.1-b). On average the lifetime of NV-centers decreased by a factor of 2 due to a silver plane surface, from ~18 ns on fused silica substrate to ~9 ns on silver surface. This gives a ~6-fold enhancement in total decay of the quantum emitter indicating strong mode confinement. Spectrum taken from the uncoupled NV (blue), coupled NV (red), and outcoupled ends A (dark green), and B (light green) shows an improved spectral purity (selective narrow band) for the outcoupled ends (Fig.1-c). Considering the average mode index of ~1.3, and the roundtrip length of ~13.5 µm for the cavity, the free spectral range (FSR) of the cavity is calculated to be ~25 nm at around 700 nm free space wavelength that is almost agreed with the experimental results shown in Fig1-c for the outcoupled ends A and B.

In conclusion, we have presented a DLSPPW-based cavity coupled to a diamond-based NV emitter. The integrated structure with enhanced total decay rate and improved spectral purity of the coupled NV emitter potentially can be applied for on-chip realization of quantum-optical networks.

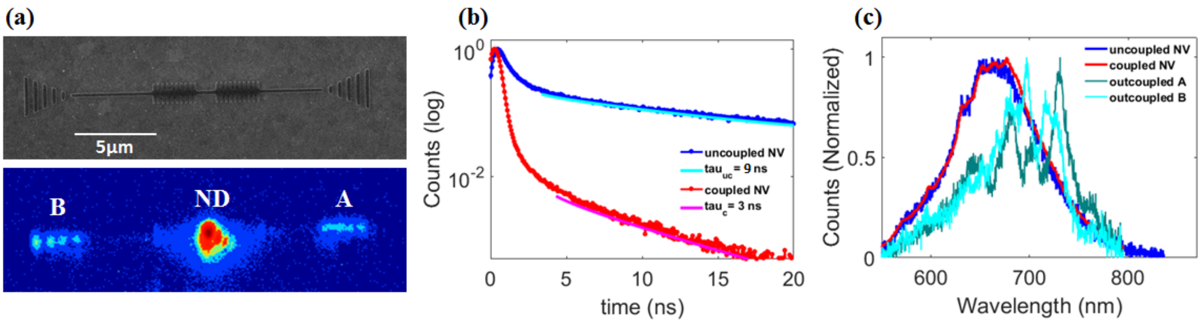

Fig. 1 (a) Scanning electron micrograph of a HSQ DLSSPW-based cavity, fabricated on silver film (top). The DLSPPW ridge has dimensions of 250 nm in width and 180 nm in height. The transverse ridges of the Bragg reflecting gratings are 1.25 µm in length, 130 nm in width and repeated with a period of Λ=275 nm. This gives an average refractive index of 1.3 for the effective DLSSPW mode. The gap distance between the two Bragg reflecting mirrors is 2.32 µm.. The periodicity of the tapered gratings at the two ends of the DLSSPW is 550 nm. Charge coupled device (CCD) camera image of the whole structure where the nanodiamond is excited at the center of the cavity and a fluorescence image of the focal plane is taken, is presented (down). (b) Lifetime of the NV center before (blue) and after coupling to the cavity. (c) Spectrum taken from the uncoupled NV (blue), coupled NV (red), and outcoupled ends A (dark green), and B (light green).

References

[1] M.S. Tame et al., Nat Phys, 9 (2013) 329-340.
[2] N.P. de Leon et. al, Physical Review Letters, 108 (2012) 226803.
[3] R.M. Briggs et al., Nano Letters, 10 (2010) 4851-4857.
[4] W. Pfaff et al., Journal of Applied Physics, 113 (2013) 024310.
[5] G. Biagi et. al, Opt. Letters, 40 (2015) 2429-2432.