QUANTUM SCIENCE CENTER

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Enhancing quantum emission by optical modification of plasmonic cavity-antenna nanostructures

Simeon Bogdanov[1], Oksana Makarova[2], **Xiaohui Xu**[3], Zachariah Martin[3], Alexei Lagutchev[3], Deesha Shah[3], Sarah Chowdhury[3], Aidar Gabidullin[4], Ilya Ryzhikov[4], Ilya Rodionov[4], Alexander Kildishev[3], Sergey Bozhevolnyi[5], Alexandra Boltasseva[3], Vladimir Shalaev[3], Jacob Khurgin[6]

[1]University of Illinois at Urbana-Champaign, USA. [2]Harvard University, USA. [3]Purdue University, USA. [4]Bauman Moscow State Technical University, Russia. [5]University of Southern Denmark, Denmark. [6]Johns Hopkins University, USA

Background

Ideal solid-state quantum emitters (QEs): emit indistinguishable single photons that enable future quantum communication, information processing, etc.

Challenge: Decoherence rate >> photon emission rate at non-cryogenic temperature.

How plasmonics could help:

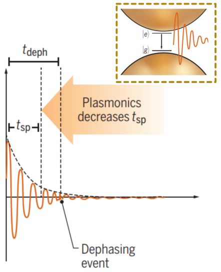
Sub-diffraction mode confinement

⇩

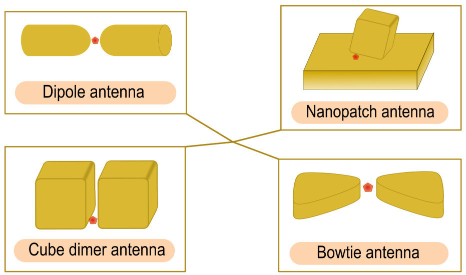
Large Purcell enhancement

⇩

$\gamma_{sp} > \gamma_{dec}$



Plasmonic cavity-antenna nanostructures



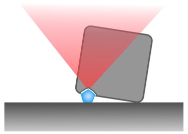
! Most reported cavity-antenna structures operate far from their fundamental limits

Goal

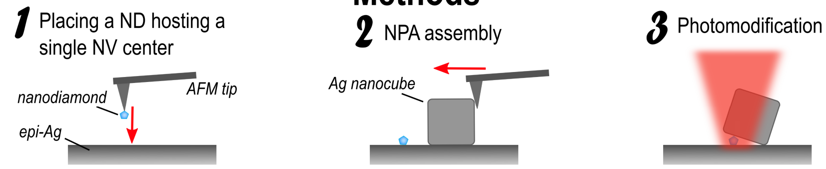
★ Improve the emission enhancement in nanopatch antenna (NPA) with photomodification

★ Analytically explain the observed enhancement

★ Estimate the maximum enhancement when optimizing NPA parameters

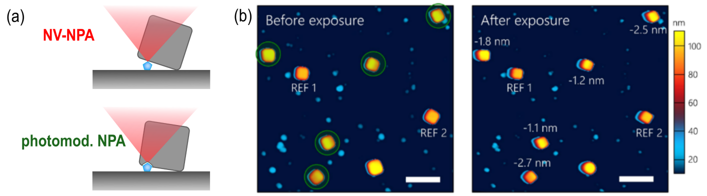


Methods

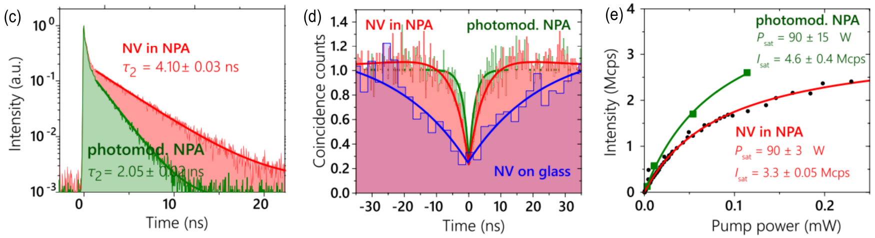


Results

Characterization of photomodification

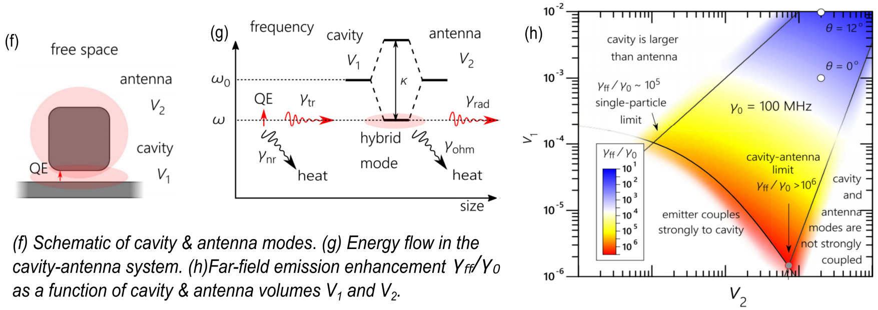


(a) schematic and (b) AFM maps showing NPA structures before & after photomofication.



(c) Fluoresence lifetime, (d) photon antibunching and (e) saturation curves of the NV center in a NPA before and after photomodification.

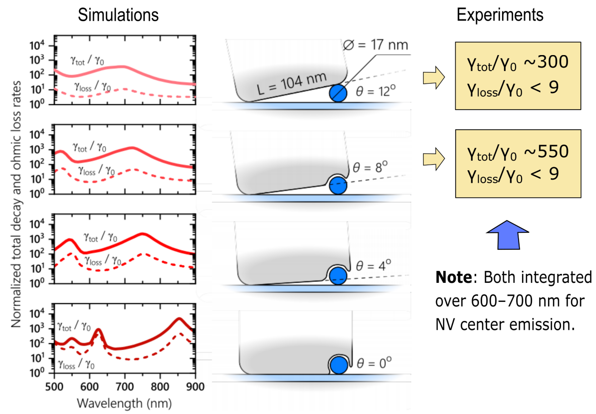
Analytical model of photomodification-induced enhancement



(f) Schematic of cavity & antenna modes. (g) Energy flow in the cavity-antenna system. (h)Far-field emission enhancement γ_{ff}/γ_0 as a function of cavity & antenna volumes V_1 and V_2.

Simulations

Total decay rate & loss rate



Note: Both integrated over 600–700 nm for NV center emission.

Discrepancy between experiments and simulations

- Finite intrinsic quantum yield of NV centers
- random NV dipole orientation
- suboptimal positioning of ND in NPA
- …

Conclusion

- Photomodification of NPAs is capable of enhancing the radiative emission of quantum emitters.
- An analytical model is proposed to explain observed enhancement and predict structures with optimum enhancement
- The analysis is readily extendable to other cavity-antenna structures
- The study provides a practical route to achieve ulrafast single photon emission at non-cryogenic temperatures.

References

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