SUPPORTING INFORMATION

Enhanced quantum dot spontaneous emission with multilayer metamaterial nanostructures

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1. Effective medium theory

The structural simplicity of periodic multilayer metamaterials makes the homogenized effective medium theory (EMT) very popular to be employed in designing hyperbolic metamaterials by predicting the epsilon-near-zero (ENZ) wavelength.[1, 2] Non-local optical effects deviate the prediction of a local EMT from that of an exact calculation.[3-6] The deviation is especially pronounced in the ENZ and hyperbolic dispersion regimes where anomalously large wave vectors leading to high spatial variations of electromagnetic field thus the local EMT is restricted. Figure S3 compares the real part of permittivity of an Ag-SiO_2 multilayer (12 nm Ag, 83 nm SiO_2,), using the local EMT and non-local EMT.[7] The ENZ wavelengths from the local EMT and the non-local EMT is 561.3 nm and 600.9 nm, respectively. The real part of the permittivity component parallel to the multilayer surface (*x*-*y* plane) deviates further between the two methods in the longer wavelength region.

2. Tunable Purcell factor

The ENZ wavelength of a multilayer structure is related to the peak of the Purcell factor spectrum. We find this relation between ENZ and Purcell factor peak is also inexplicitly presented in reference.[2] Figure S4 shows the Purcell factor of our multilayer as a function of Ag filling ratios with a fixed period of 95 nm. The Purcell factor peak position red shifts from 375 nm to 600.9 nm when the Ag filling ratio decreases from 0.5 to 0.122. This demonstrates the capability of the multilayer sample to show Purcell effect covering almost the whole visible range. All these Purcell factor peak positions are related to their individual ENZ wavelengths calculated by the non-local EMT.

3. Supplementary figures

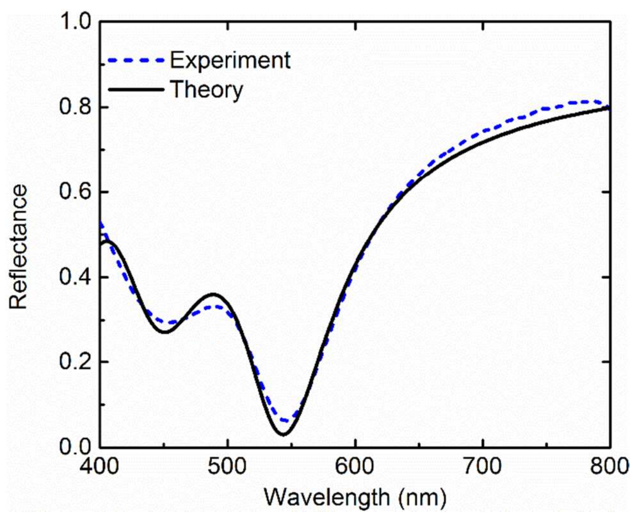

Figure S1. The measured reflectance spectrum of an Ag-SiO_2 multilayer (a_m = 12 nm, a_d = 83 nm) (blue dashed line) and the theoretical fitting using non-local EMT (black solid line).

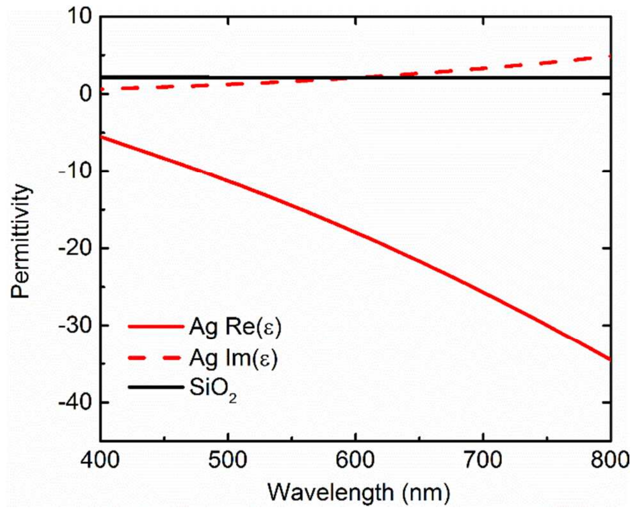

Figure S2. Experimentally characterized permittivity of Ag (red) and SiO_2 (black) used in theoretical calculation and numerical simulation. Solid and dashed lines are for real and imaginary parts of permittivity, respectively.

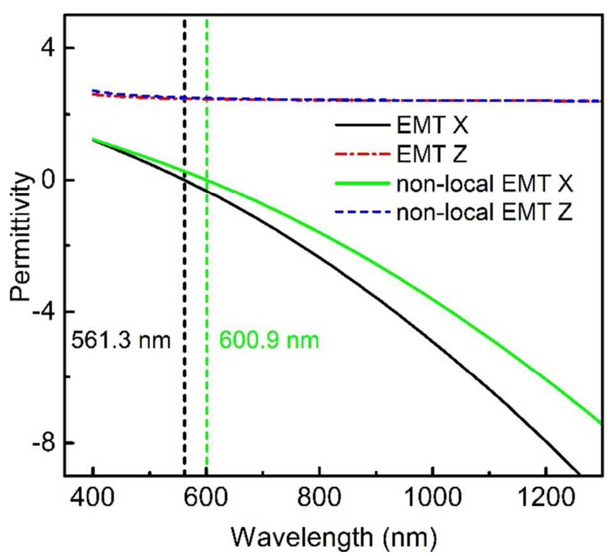

Figure S3. Predictions for ENZ wavelength of an Ag-SiO_2 multilayer (83 nm Ag, 12 nm SiO_2) with EMT (black) and non-local EMT (green).

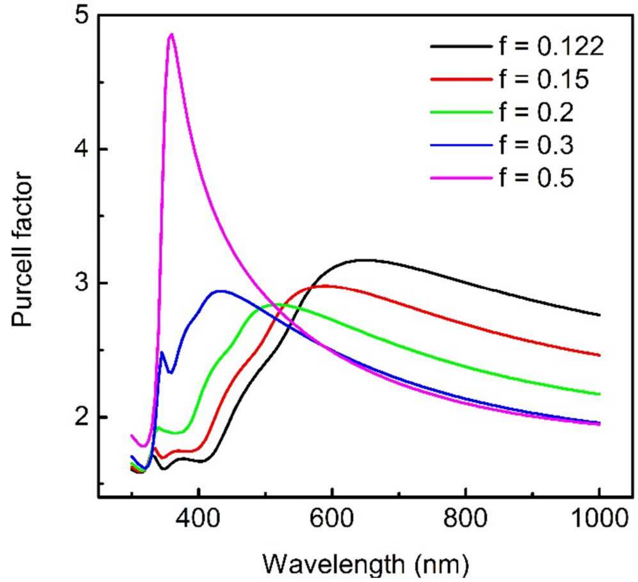

Figure S4. Purcell factor spectrum of an Ag-SiO_2 multilayer with various Ag filling ratios at a fixed period of 95 nm.

References:

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