**Low loss photonic nanocavity via dark magnetic dipole resonant mode near metal**

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**Supporting Information**

1. ***Hz solution of TE mode in the dielectric-semiconductor-dielectric-metal 4-layered planar structure***

To complete the solution of the simplest TE mode in the 4 layered structure of planar geometry as given in the main texts, the Hz components are given below:

1. ***Plasmonic mode at a single dielectric-metal interface***

Starting from the central equation of electromagnetic wave theory:



Assuming the **E** has a single harmonic time dependence **E**(**r**,t)=**E**(**r**)e*-iωt*, we can then obtain Helmholtz equation:

(**S1**)

For a single dielectric-metal interface, there are only two media and one interface. We choose x as the propagation direction of the plasmonic wave and z the direction perpendicular to the infinitely large planes. The solution to Eq. (S1) can be found from ref. [[1](#_ENREF_17)]. The boundary conditions allow only TM mode to propagate at the interface of infinitely large planes, with , and (*i=d,m* and *ki* > 0). Combining these three equations, we can obtain the well known surface plasmon dispersion relation at a single interface:



(**S2**)

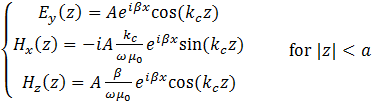
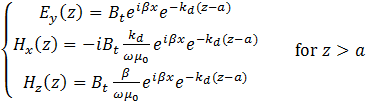


The analytical solution to Eq. (S2), assuming is:

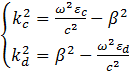
The above formula is used to calculate the plasmonic dispersion curves at a single metal-dielectric interface used in Fig. 1c. For real transition metals (Ag, Au, Cu) with *ω* < *ωp*, the permittivity is better described by [1], where γ is a damping constant. Simulation results presented in Fig. 1d, Fig. 2 and Fig. 3 are obtained using realistic material parameters.

1. ***Guided fundamental TE mode in the dielectric-semiconductor-dielectric planar structure***

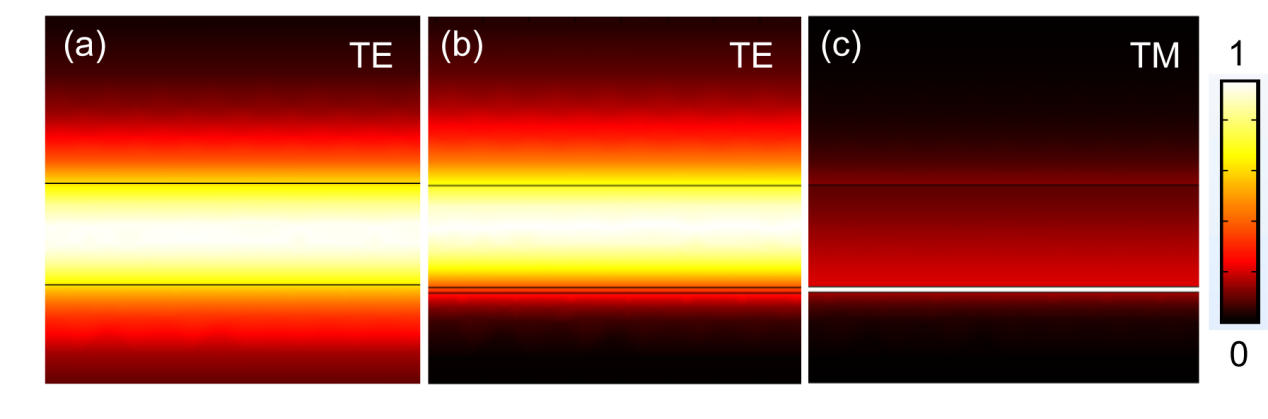
For a multilayer (> 2 layers) system, we can solve Eq. (S1) in each domain and determine their coefficients using appropriate boundary conditions. For the simplest 3 layered system, we can choose the top and bottom domains the same materials, with the core using a different material. In photonic case, both the core and cladding materials are dielectric with *ε* > 0. In this case, when *εcore > εcladding*,guided modes are supported. Both TE and TM modes can be achieved. If we choose z = 0 at the middle of the core layer and let thickness of the core be 2a. For the lowest order TE mode, the electric and magnetic fields satisfy [2,[3](#_ENREF_23)]:



Continuity of *Ey* and *Hx* at the interface leads to the conditions that and , with .

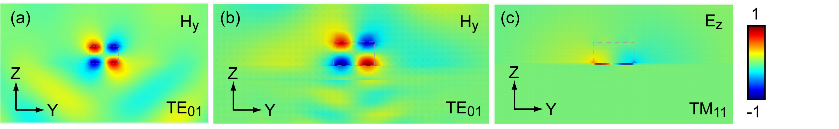


1. ***Electric field distribution of TE mode in photonic 3 layered planar structure, TE mode in 4 layered planar structure and TM mode in 4 layered planar structure***



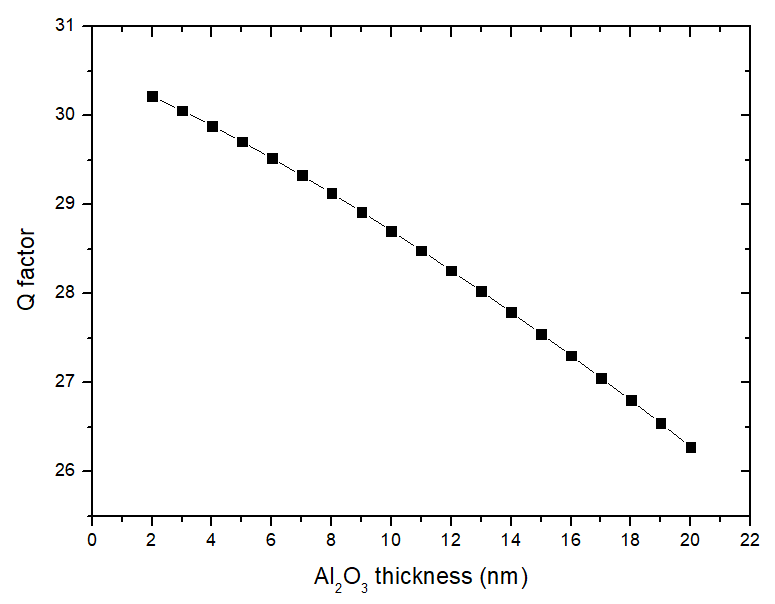
**Figure S1** (a-c) Normalized E field |E| distribution of TE mode in the dielectric-semiconductor-dielectric 3 layered structure, TE mode in the dielectric-semiconductor-dielectric-metal 4 layered structure and TM mode in the dielectric-semiconductor-dielectric-metal 4 layered structure, respectively. In this 2D simulation, d = 110 nm, h = 6 nm, εcore = 13, εd = 2.9 and wavelength is 820 nm. The metal is assumed lossless with plasma frequency at 2.27×1015 Hz.

1. ***Additional field distribution of TE01 on glass and TE01 and TM11 modes on Al2O3/Ag***



**Figure S2** (a, b) COMSOL simulations of normalized TE01 mode magnetic field Hy distribution on zy plane at x = 0, for semiconductor disk on glass and semiconductor disk on Al2O3/Ag (diameter of 200 nm for both cases). (c) Normalized TM11 mode electric field Ez distribution on zy plane at x = 0, for semiconductor disk (200 nm in diameter) on Al2O3/Ag. The dashed rectangles indicate the physical contours of the semiconductor disks.

1. ***Q of TE01 on Al2O3/Ag as a function of Al2O3 thickness***



**Figure S3** COMSOL simulated quality factor Q of TE01 mode on Al2O3//Ag vs. the thickness of

Al2O3. In this simulation, the diameter of the AlGaInP disk is fixed at 200 nm.

Reference:

1. S. A. Maier, *Plasmonics: Fundamentals and Applications* (Springer, 2007).
2. J. D. Jackson, *Classical Electrodynamics* (John Wiley&Sons, Inc., New York, 1999), 3rd edn.
3. D. K. Cheng, *Field and wave electromagnetics* (Addison – Wesley Publishing Company, Inc., 1983).