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M2 Quantum, Light, Matter, Nanosciences

Fundamentals of Nanophotonics - Tutorial 4

Plasmonics

1 Excitation of a surface plasmon with a grating - single photon nanoantenna

Show that the dispersion relation of a surface plasmon propagating along a metal–vacuum interface in the plane (k_x, k_y) for a given frequency is given by a circle with radius $k_{sp}(\omega)$. An incident plane wave with incident wavevector $(k_{x,inc}, k_{y,inc})$ can excite a surface plasmon in the presence of a periodic grating with period d along the x-axis.

What is the condition that needs to be satisfied by $(k_{x,inc}, k_{y,inc})$ to excite a plasmon ? Plot in the plane (k_x, k_y) the locations of the solutions. Given that light is absorbed when a surface plasmon can be excited, discuss the absorptivity map in the plane $(k_{x,inc}, k_{y,inc})$.

We want to use a metallic grating to outcouple the single photons emitted by a single photons at a pair of emergent angles in the Oxz plane (say, $\pm 15\,\mathrm{deg}$).

Discuss the position of the single dipole, its orientation, and the grating period to be used to shape the emission in order to form these two lobes, in the case of a reflective gold grating in vacuum.

What does limit the angular width of the two emission lobes ?

Surface-plasmon resonance and electrostatic reflection factor

Consider the reflection of p-polarized light on a planar interface between vacuum and a non-magnetic material with dielectric function $\varepsilon_1(\omega)$.

1. Derive the limiting form of the reflection factor r_p for p-polarization in the limit $k_x \gg \omega/c$.
2. Show that in this limit, the reflection factor becomes independent of k_x.
3. Compare this limiting form with the reflection factor $(\varepsilon_1 - 1)/(\varepsilon_1 + 1)$ used to evaluate the amplitude of the image charge in electrostatics.
4. Using the non-lossy Drude model for $\varepsilon_1(\omega)$ and the criterion that a surface resonance corresponds to a divergence of the linear response, derive the resonance frequency of the interface.
5. Show that the resonance frequency is complex for a lossy Drude model. Discuss the physical meaning of the imaginary part of the frequency.
6. Determine the quality factor of the oscillation.