Substantial plasmonic field enhancement with tunable broadband resonances from a faceted nanoparticle on a metallic mirror nanostructure

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In metallic nanostructures, near-field enhancement and localized surface plasmon resonance (LSPR) gives rise to a variety of plasmonic applications as they result in the formation of hybrid plasmonic modes with new functionalities. One such an interesting example of the plasmonic mode is, plasmonic nanogap or hot-spot, where the coupled plasmonic modes confine at the nanoscale and result in an extremely high near-field enhancement [1]. This enhanced local fields will act as a powerful building block for plasmonic nanostructures resulting in very attractive applications such as sensors, Purcell enhancement, surface enhanced spectroscopy, optoelectronics, photonics, photocatalysis, and biochemistry. In this work, we introduce a nanoparticle on a metallic mirror (NPoM) structure with flat bottom nanoparticle (NP) structural modification, so called as facet (f) (Fig. 1a). A detailed three-dimensional FDTD simulation studies were carried out where we find a variety of complex transverse cavity modes (S_{11} to S_{13}) originate due to NP faceting. It is found that the dominant cavity mode S11's resonance wavelength can be tuned widely from 600 nm to 1.5 µm, as a function of NP facet width. More importantly, despite being tuned to such broadband range, only a minimal decrease in near-field enhancement (in orders between ~ 10^9 to 10^8) were noted [2]. Additionally, we checked simulations for different NP diameter sizes and realized it is possible to achieve the near field enhancement in orders of ~ 10^9 even in case of smaller NPs with 50 nm diameter due to NP faceting effect. Alongside with cross-section electric field amplitude profiles, we used three-dimensional surface charge mappings, which identified the origin of plasmonic modes arising from either NP or cavity. From our surface charge simulations, we found that the number of radial modes was dependent upon the combination of NP faceting width and diameter [2]. These optical properties will see significant advantages in surface-enhanced spectroscopy, colour sensor applications, and device fabrication perspective. By exploring above such interesting and complex sub-wavelength optical properties of the plasmonic nanostructures, a variety of new applications can be found in fields of non-linear optics, photonics, sensors, device engineering, broadband tunable devices, surface enhanced spectroscopy and non-linear plasmonics.

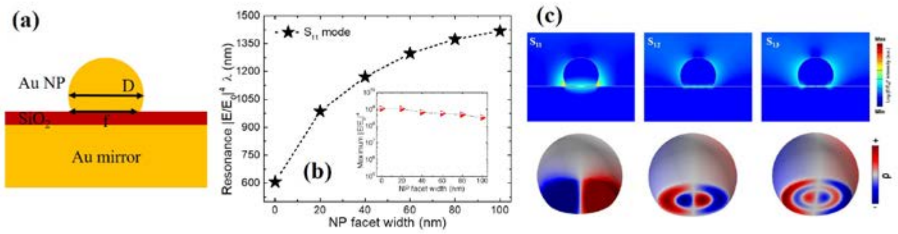

Figure 1. (a) Schematic cross-section of NPoM structure with NP facet at the bottom. **(b)** 3D FDTD simulations results show the broadband tuning of dominant S11 mode as a function of NP facet width. The inset figure shows a minimal decrease in near field enhancement (~ 10^9) despite NP faceting effect. **(c)** The plot of S11, S12 and S13 modes as observed with cross-sectional XZ electric field profiles (top) and respective 3D surface charge mappings (bottom) for an NPoM structure with NP facet width of 20 nm.

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References
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