A plasmonic nano-resonator refractometer in nano-structured metal-coated fiber taper

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In recent years, research in plasmonics has attracted considerable interest because of their extraordinary potentials in energy confinement and nanoantennas. Nanoscale apertures in thin noble-metal films, with dimensions comparable to the light wavelength, can form plasmonic nano-resonators and show astonishing optical properties leading to enhanced and selective light transmission and confinement. A number of different nano-structures have been considered and studied in detail for their ability to concentrate light.

In this paper, we study theoretically a strongly-coupled 3D plasmonic slot nano-resonator (PSNR) by embedding a slot nano-cavity in a plasmonic cylindrical waveguide formed by a thin-metal-film coated fiber taper. There are several dips observed in the transmission spectrum and associated peaks in the reflection spectrum, which corresponds to different type of resonances of the embedded PSNR. The resonances at λ= 1524 nm and 2050 nm correspond to first-order PSNR resonances, with only one intensity maximum along the bow-tie length. A single resonator shows enhancement factor in excess of 9×10^5, which we believe is the biggest enhancement factor calculated in all types of nano-resonators so far. Different bow-tie PSNRs with different waist and different edge width, multiple cascaded bow-tie PSNR, and rectangular PSNR were numerically investigated. Wavelength shift rates were found to be strongly dependent on the nature of the associated resonance and the plasmonic waveguide characteristics. Since the PSNR has extremely small size (less than 0.1 μm^2) and it is sensitive to the surrounding environment, the PSNR can be used as a compact refractometer in small areas. The wavelength changes linearly with the refractive index. The PSNR sensitivity resulted to be 66.7 nm/RIU, with a resolvable index change of 1.5×10^{-4} for a resolvable wavelength change of 0.01nm.

Also, for the first time, both theoretically and experimentally, the transverse excitation of a strongly-coupled 3D PSNR is investigated by embedding a rectangular slot nano-cavity in a plasmonic structure formed by a thin-metal-film coated optical fiber tip. In the experiment, a rectangular PSNR was inscribed on the surface of a gold-coated fiber tip. The fabrication process involved three main steps: manufacture of optical fiber tip, deposition of a thin gold layer and focused ion beam (FIB) nanopatterning. The strongest enhancement factor 7.24×10^3 was achieved for the resonance at the wavelength λ~1450 nm, recorded when light was polarized perpendicularly to the PSNR. The refractive index dependence of PSNR experiment is in progress.