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Multi-Wavelength Light Trapping Using Width-Graded Plasmonic Nanogratings (G)*

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Light incident on nanoscale metal-insulator-metal (MIM) plasmonic gratings generates surface plasmon polaritons (SPPs) which resonate and propagate within the grating structure. A variation in the SPP resonant wavelength is achieved by gradually increasing the width of the MIM grooves symmetrically about a central groove to create a graded grating, which leads to a gradient in the effective refractive index wherein the index increases in the direction of the central groove. The index gradient guides non-localized SPP waves towards the grating center which, in combination with localized SPP modes within the narrowest central grooves, produce multi-wavelength electric field enhancement at the center of the grating.

Central grooves with sub-50 nm widths enable enhanced localization of multiple wavelengths of light. Therefore, these structures can be used as unique substrates for surface enhanced Raman spectroscopy (SERS), having the potential to achieve unprecedented detection sensitivity, specificity and rapidity. However, large scale fabrication of such narrow gratings using standard nanofabrication techniques is not cost effective and limits the minimum groove width to approximately 50 nm. Herein we report on the development of a novel nanoplasmonic graded grating with a sub-10 nm central groove flanked by increasingly wider grooves on either side, which are fabricated economically using state-of-the-art, thin film sputter deposition.

These structures are also studied using COMSOL Multiphysics modelling where we vary the minimum groove width, groove-to-groove separation and groove depth, and thus demonstrate localization of broadband incident light with intensity enhancements of over five orders of magnitude. Additionally, we explore the effect of the number of grooves and the material composition of the structure on the near-field optical response. Experimental results from confocal fluorescence microscopy demonstrate multi-wavelength localization within the grating structures. In addition, SERS characterization of low concentration biomolecules using the gratings reveal the potential of these nanoplasmonic graded gratings as a rapid and highly sensitive platform for the detection of a variety of molecular species amenable to a wide range of applications including health, environment and security.

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