A new label-free plasmonic imaging technique for quantitative analysis of transparent nanoscale objects approaching molecular size

Label-free observation of transparent nanoparticles by far-field optical microscopy faces fundamental challenges in resolution and detection. They are difficult to detect because their ability to scatter light dramatically diminishes with decreasing size. Among various imaging techniques, those based on propagating surface plasmon resonance (SPR) and localized surface plasmon resonance (LSPR) have shown promises and respective limitations.

In this paper, we demonstrate ultra near-field index modulated PlAsmonic NanO-apeRture lAbel-free iMAging (PANORAMA) that addresses existing issues for both SPR and LSPR imaging techniques [1]. This technique has been implemented on a high-density gold nanodisk array exhibiting strong radiative coupling among the individual units [2]. The array has been patterned by nanosphere lithography on a glass substrate [3]. Individual nanodisks have been undercut to remove any substrate effect and are called arrayed gold nanodisks on invisible substrate (AGNIS). Unlike most scattering-based imaging techniques, PANORAMA relies on *unscattered* light to detect nanoobjects smaller than 100 nm. On one hand, PANORAMA can produce diffraction-limited lateral resolution free of the smearing effect in SPR imaging. PANORAMA also has higher surface sensitivity. PANORAMA addresses the sparse sampling issue in LSPR imaging by achieving dense sampling with a large imaging fill factor. The bright-field approach also provides much higher light throughput compared to dark-field microscopy, empowering higher imaging speed. Its system configuration is identical to a standard bright-field microscope using a trans-illumination tungsten-halogen lamp and a camera without the need for laser, LED, or interferometric detection. Therefore, PANORAMA is readily implementable on any existing commercial microscopes.

We have experimentally demonstrated that PANORAMA can image and size single polystyrene nanoparticle in water down to 25 nm, count individual nanoparticles within a sub-diffraction limit cluster, and dynamically monitor single nanoparticle approaching the plasmonic surface down to the millisecond timescale. The extrapolated size limit of detection is expected to reach sub-10 nm, which is approaching the size of a single molecule. The imaging speed is expected to be much higher with high-speed cameras. PANORAMA would provide new capabilities in label-free imaging and single nanoparticle analysis. Molecular imaging can be envisioned with surface functionalized plasmonic substrates for single biological nanoparticle analysis including extracellular vesicles (e.g., exosomes) and pathogens (e.g., viruses) [4].

References:

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