Near-field Intensity Correlations in Semicontinuous Metal-dielectric Films

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Spatial correlations of field and intensity are indicative of the nature of wave transport in random media and have been widely investigated in the context of electromagnetic wave propagation in disordered dielectric systems However, less is known of near-field intensity correlations in metallic random systems, which can exhibit rich phenomena due the involvement of intrinsic resonance effects-surface plasmons. Neither is clear the difference between correlation functions in metallic and dielectric systems.

This paper presents the first experimental study of near-field intensity correlations in metal-dielectric systems in regimes where localization and delocalization are expected. Significant differences are observed between the spatial intensity correlations functions in metal-dielectric systems and those of purely dielectric random media.

In disordered metallic nanostructures, surface plasmon modes are governed by the structural properties of the system and may be strongly localized. Recent theoretical studies of metallic nanoparticle aggregates suggest that the eigenmodes of such systems may have properties of both localized and delocalized states. However, it is not clear how such eigenmodes impact the propagation or localization of surface plasmon polaritons excited by impinging light, an issue addressed in this study. In the current experiment, the concentration of metal particles on a dielectric surface p was varied over a wide range to control the amount of scattering. Spatial intensity correlations obtained from near-field optical microscopy (NSOM) images show a transition from propagation to localization and back to propagation of optical excitations in planar random metal-dielectric systems with increase in metal filling fraction.

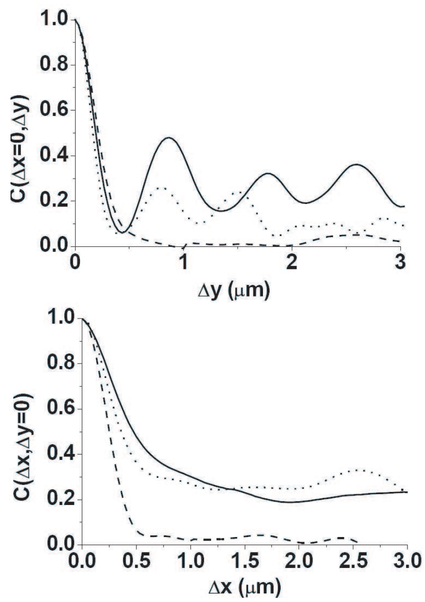

Figure 1: $C(0, \Delta y)$ and $C(\Delta x, 0)$ at $p = 0.36$ solid line), 0.65 (dashed line) and 0.83 (dotted line). For comparison, all curves are normalized to a value of unity.

Semicontinuous silver films on glass substrates were synthesized by pulsed laser deposition. Samples were illuminated by the evanescent field (in the total internal reflection geometry) of He-Ne lasers, and the local optical signal was collected by a fiber tip. From the near-field images, we computed the 2D correlation functions for near-field intensities. Fig. 1 shows the intensity correlation functions in the directions parallel and perpendicular to the incident wave vector $k_{\parallel}$, i. e., $C(0, \Delta y)$ and $C(\Delta x, 0)$. Along $k_{\parallel}$, $C(0, \Delta y)$ exhibits oscillatory behavior at $p = 0.36$ with a period of 870 nm. This oscillation is replaced by a monotonic decay at $p = 0.65$. At $p = 0.83$, the oscillations reappear with a smaller period of 690 nm. The presence of oscillations in $C(0, \Delta y)$ is an indication of wave propagation along the y-axis. This propagation is suppressed at $p = 0.65$, suggesting localization of near-field energy. Therefore, the existence, suppression and reappearance of the oscillations in the near-field intensity correlation function with increasing p correspond to a gradual transition from propagation to localization and back to propagation of optical excitations in the samples. Note that the oscillation periods observed above are always larger than λ, in contrast with purely dielectric media, which exhibit damped oscillations with a period of $\lambda/2$.