Mapping Near-Field Coupling Effects in Infrared Gap Antennas

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The vector near-field distribution of infrared gap antennas (linear dipole antennas coupled via a nanometric gap) is mapped by scattering-type scanning near-field microscopy (s-SNOM). The images provide direct experimental evidence of strong in-plane near-field localization inside a gap as small as 50 nm. By measuring the gap fields as a function of the total antenna length (near-field spectroscopy), we observe a clear resonance shift compared to uncoupled linear dipole antennas, thus verifying strong near-field coupling via the gap. We also find significant differences between near-field and far-field spectra of the antennas and discuss their implications.

Vector near-field imaging of the infrared antennas [1, 2] was carried out with s-SNOM where s-polarized laser light is used for antenna excitation. A dielectric Si tip scatters the local near fields of the antennas. Interferometric and polarization-resolved detection of the tip-scattered light yields amplitude E and phase φ of the in- (x) and out-of-plane (z) near-field components (Ex, φx) and (Ez, φz).

Fig. 1 shows the near-field patterns obtained for a single gap antenna with a gap width of about 50 nm. The out-of-plane near-field component (Ez, φz) shows large near-field amplitudes at both sides of the gap, while a phase jump of about 180º occurs at the gap center [3]. The in-plane near-field component (Ex, φx), in contrast, is strongly enhanced exactly inside the gap and directly verifies field concentration inside the gap.

To provide experimental evidence of near-field coupling in the infrared gap antennas, we perform near-field spectroscopy. We fabricate gap antennas of different total length (but constant gap size) and measure the in-plane gap field as a function of the antenna length. A comparison with near-field spectra of single dipole antennas (continuous nanorods) shows a pronounced resonance shift, which clearly verifies near-field coupling across the antenna gap.

Our results show that vector near-field mapping is a powerful tool for measuring spectral resonance shifts in the near field of infrared antennas, in both amplitude and phase. This enables detailed studies of near-field coupling signatures, including the mapping of strongly localized field enhancement (“hot spots”) and resonance shifts of near-field spectra, which are not accessible by far-field spectroscopy.

References

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Figures

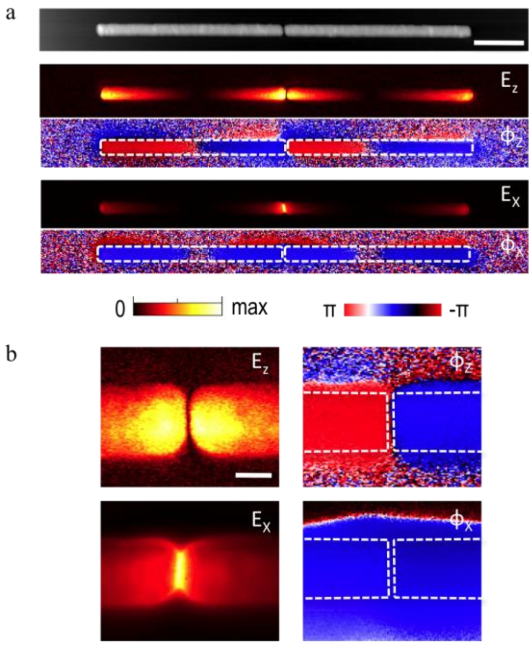

Figure 1: Near-field images of an infrared gap-antenna recorded at λ=11.06µm. (a) Out-of-plane near-field amplitude Ez and phase φz (top). In-plane near-field amplitude Ex and phase φx (bottom). Scale bar is 1 µm. (b) Enlarged near-field images of the gap region, showing amplitude and phase of the out-of-plane and in-plane near-field components. Scale bar is 100 nm.