Control of local near fields in optical antennas by load engineering: bridging the gap

Martin Schnell[1], Aitzol García-Etxarri[2], Andreas Huber[1,3], Ken Crozier[4], Javier Aizpurua[2], Rainer Hillenbrand[1,3]

[1] Nanooptics Laboratory, CIC nanoGUNE, 20009 Donostia - San Sebastian, Spain
[2] Donostia International Physics Center (DIPC) and Centro Mixto de Fisica de Materiales (CSIC-UPV/EHU), 20018 Donostia – San Sebastian, Spain
[3] Max-Planck-Institut für Biochemie, 82152 Martinsried, Germany
[4] Harvard University, School of Engineering and Applied Sciences, Cambridge MA 02138, USA

m.schnell@nanogune.eu

Transmission-mode scattering-type near-field optical microscopy (s-SNOM) is applied for mapping the near-field distribution in amplitude and phase of infrared nanoantennas that are loaded with metallic bridges at their central gap. By varying the size of the bridge we trace the changes in the near-field distribution of the antennas, showing that targeted antenna loading is a promising means to engineer local near fields.

Our s-SNOM [1] is based on an atomic force microscope (AFM) where a dielectric Si tip scatters the local near fields of the antenna structures. Homogeneous antenna illumination from below through the substrate (transmission mode) avoids phase-retardation effects inherent to the backscattering geometry in typical s-SNOM experiments. In combination with a pseudoheterodyne interferometric detection scheme [2], we are able to map the near-field distribution in both amplitude and phase.

The experiments were performed with gold nanorods (1550nm x 230nm x 60nm) designed for fundamental dipolar resonance at $\lambda = 9.6$ µm [3]. By focused-ion-beam (FIB) milling at the center of the nanorods, we fabricated narrow, electrically isolating gaps. Loading the gap with metallic bridges was achieved by only partially FIB milling, leaving a small gold bridge of variable size at the gap that still electrically connects both antenna segments. With s-SNOM imaging the rods at the fixed wavelength of $\lambda = 9.6$ µm, we monitor the changes in the amplitude and phase of the near-field patterns.

The near-field images of the unmodified nanorod (Fig. 1a) show the fundamental dipolar near-field mode of a $\lambda/2$ antenna [4], yielding high amplitudes at the antenna extremities and a phase jump of 180° at the center of the antenna. By introducing an 80 nm wide isolating gap (Fig. 1c), the near-field mode splits up into two dipolar-like modes. A highly interesting near-field distribution is observed with the nanorod loaded with a tiny metal bridge (Fig. 1b). The amplitude signal on the antenna surface is always non-zero, including at the gap. Apparently, the gap is not short-circuited despite of the electrical connection made by the metal bridge. Moreover, a prominent phase gradient of 80° is observed along the antenna segments (see line plot), indicating a time delay between the near fields at the gap and the antenna extremities. Obviously, the near-field distribution depends very much on the characteristics of the gap load. Antenna loading provides an excellent means to locally control near fields which can have successful application in the development of compact and integrated nano-photonic devices.

References:

[1] F. Keilmann, and R. Hillenbrand, Philosophical Transactions of the Royal Society A 362, 787 (2004).

[2] N. Ocelic, A. Huber, and R. Hillenbrand, Applied Physics Letters 89, 101124 (2006).

[3] K. B. Crozier *et al.*, Journal of Applied Physics 94, 4632 (2003).

[4] J. Aizpurua *et al.*, Physical Review B 71, 235420 (2005).

Figures:

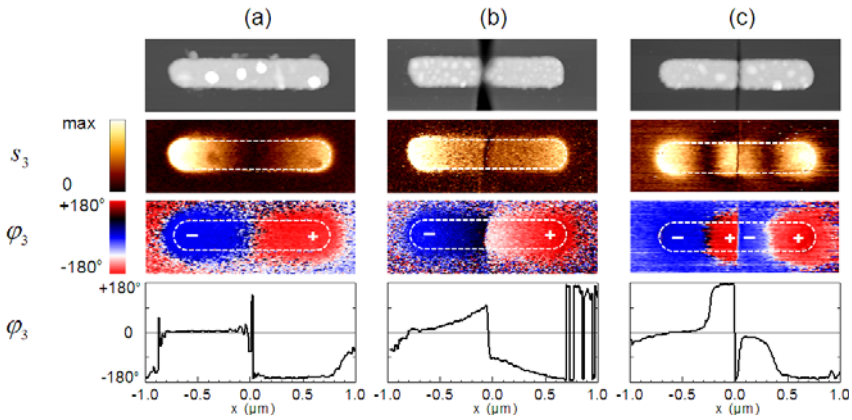

Figure 1: (from top to bottom) Topography, IR near-field amplitude s_3 and phase φ_3 images, line plot of phase φ_3 along the antenna axis.