

Electromagnetic Energy Transport in Nanoparticle Chains via Dark Plasmon Modes

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Abstract

Using light to exchange information offers large bandwidths and high speeds, but the miniaturization of optical components is limited by diffraction. Converting light into electron waves in metals allows one to overcome this problem. However, metals are lossy at optical frequencies and large-area fabrication of nanometer-sized structures by conventional top-down methods can be cost-prohibitive. We show electromagnetic energy transport with gold nanoparticles that were assembled into close-packed linear chains. The small inter-particle distances enabled strong electromagnetic coupling causing the formation of low-loss sub-radiant plasmons, which facilitated energy propagation over many micrometers. Using a novel imaging method, Bleach Imaged Plasmon Propagation (BIIPP), we determined a plasmon propagation distance of $L_0 = 3.9 \pm 0.6 \mu\text{m}$ for these gold nanoparticle chains when exciting into the dark modes, in contrast to no measurable propagation when exciting into the bright single nanoparticle mode. Electrodynamic calculations furthermore showed that disorder in the nanoparticle arrangement enhances energy transport, demonstrating the viability of using bottom-up nanoparticle assemblies for ultra-compact opto-electronic devices.

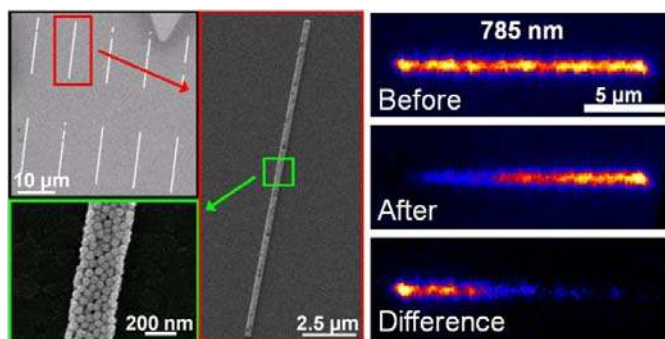


Figure 1: Left: SEM images at different magnifications of an array of chains made from 50 nm gold nanoparticles. The chains measured 300 nm x 15 μm, are 5 – 6 nanoparticles wide, and approximately 2 – 3 layers high. Right: BIIPP of a nanoparticle chain for 785 nm excitation. Fluorescence images of a dye coated chain taken before (top) and after (middle) exposure of the left end of the chain to 785 nm laser light for 20 minutes. Photo-bleaching due to plasmon propagation is apparent in the difference image (bottom).

Analysis of the BIIPP data for this nanoparticle chain yielded a plasmon propagation distance of $L_0 = 4.2 \mu\text{m}$.