Simulation of arrays of metal nanowires using a monochromatic recursive convolution finite-difference time-domain method

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Abstract

Arrays of metal nanowires can support localized surface plasmon resonance (LSPR) modes, making them suitable for various applications. In this paper we compute the extinction spectra of arrays of silver nanowires in order to study the LSPR properties of such arrays.

The extinction spectra of an infinitely long, nanowire with circular cross-section can be computed analytically using Mie theory. However, no analytical methods are available for simulation of arrays of such nanowires. Numerical methods, e.g., discrete dipole approximation, finite-difference time-domain (FDTD) method are used [1, 2].

Here, we use a monochromatic version of recursive convolution (RC) FDTD method [3] for simulation. Conventionally, RC-FDTD is used with pulsed, broadband, light sources [4]. In contrast with the conventional approach, the monochromatic version of RC-FDTD allows us to use the handbook values of material refractive indices at all the simulation wavelengths.

The simulations indicate that the position and size of the peaks of the extinction spectra depend on the separation (d) between two contiguous nanowires, the polarization direction of the incident light and the diameter of the cross-sections (D) of individual nanowires constituting the array.

Figure 1 shows the intensity distribution of the scattered field around a pair of silver nanowires and the extinction spectra for the pair with d ; 20nm, 16nm, 12nm, 6nm and 2nm.The extinction spectra show two peaks, one of which is close to the dipole peak of a single nanowire and shifts from 350nm to 365nm as d is reduced. The second peak is in relatively longer wavelength side and shifts from 385nm to 395nm. The two peaks result from the resonance related to coupling between the plasmonic modes of the individual nanowires. The two peaks are indicated respectively as peak 1 and peak 2 in Fig. 1b. The relative heights of the two peaks change as d becomes small. At larger values of d , the coupled oscillation mode corresponding to shorter wavelength (peak 1) is more prominent and the coupled modes only exist for narrow band of wavelengths. For smaller values of d (~2nm), the coupled modes exist over a broadband of wavelengths and the coupling at longer wavelength gives rise to the stronger peak (peak 2).The extinction increases as the number of wires increases in the array.

References

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Figures

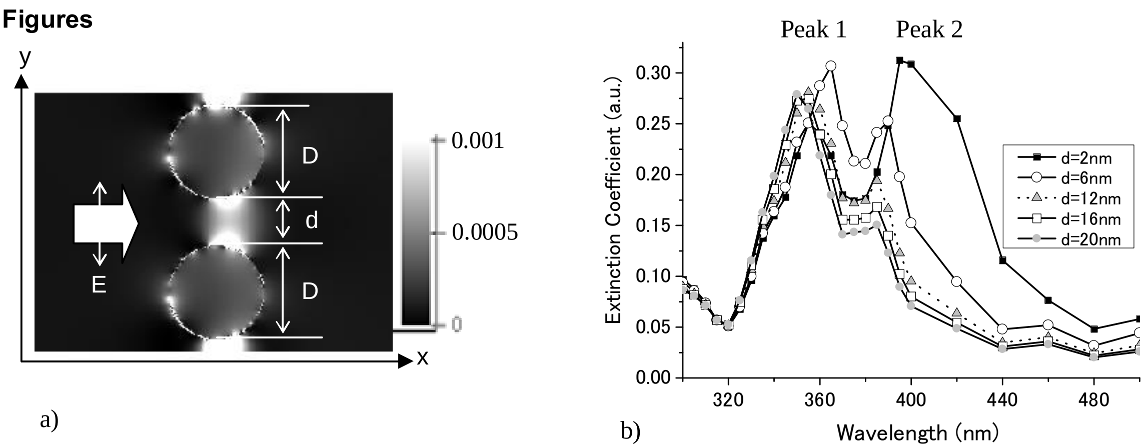

Fig.1. a) Intensity of the scattered field around a pair of nanowires in TM mode at a wavelength of 350nm, $d = 20nm$, $D = 40nm$; b) extinction spectra with d : 20nm, 16nm, 12nm, 6nm and 2nm.