Light Scattering by Subwavelength Arrays of Silicon Nanowires

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Introduction: Contrarily to their plasmonic counterparts, high-index dielectric structures exhibit low optical losses and different nanostructures allowing engineering and control of near-field effects and far-field scattering show great promise as building elements of new devices and metamaterials. The possibility of controlling the spectral position of different resonant frequencies with different materials and geometries is being intensely explored[1,2].

In this work we use COMSOL Multiphysics® to analyze infrared scattering by subwavelength arrays of cylindrical nanowires and study the dependence of the resonance frequencies on the number of nanowires and geometric parameters of the array.

Computational Methods:

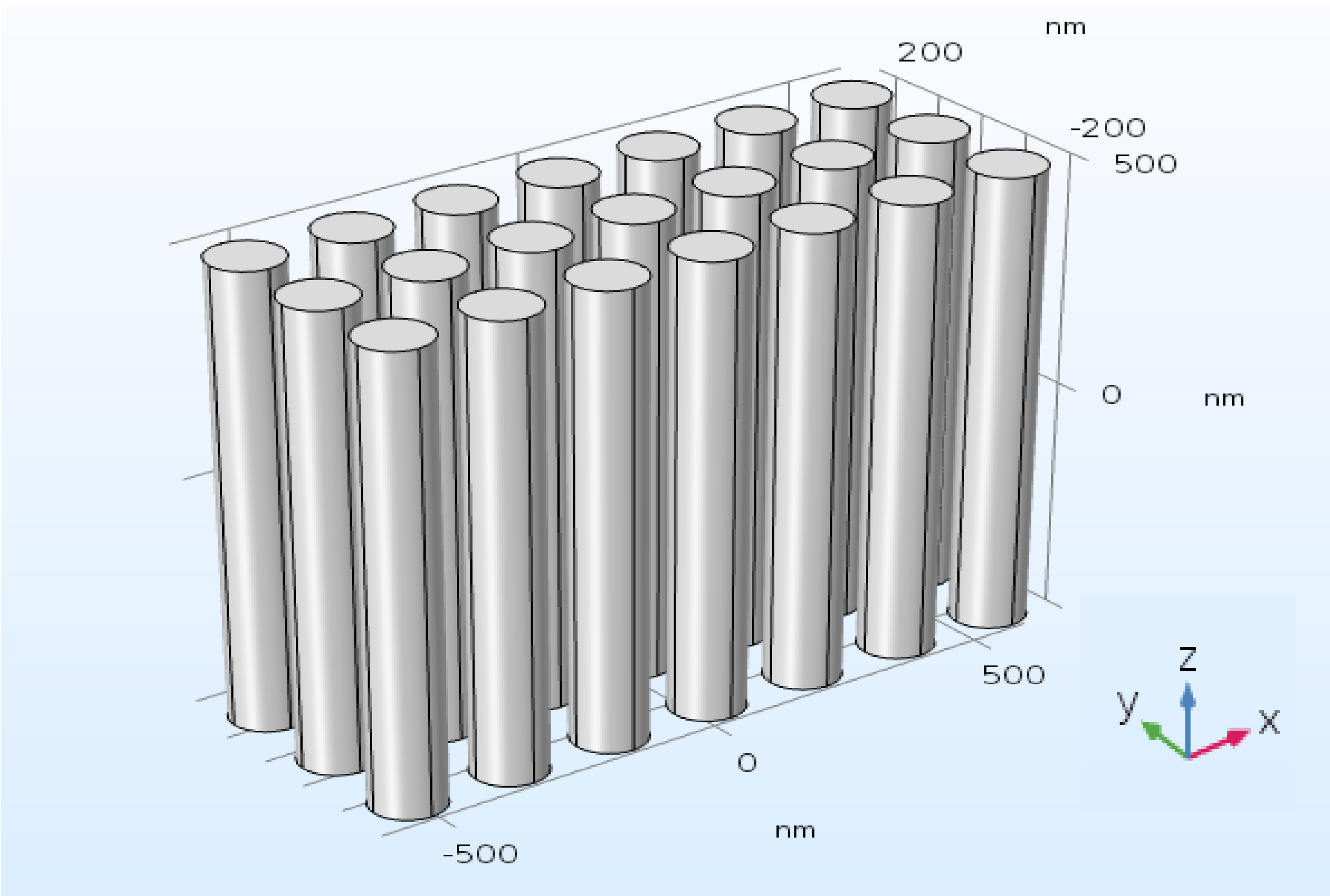

Figure 1. Schematic representation of the array, the length of the nanowires is 1 μm and the radius is 60 nm.

We use the Wave Optics Module within the electromagnetic waves frequency domain framework. The geometry of the problem is composed by the array of cylindrical nanowires and a spherical PML.

Maxwell wave eq. Is solved for the scattered electric field:

$$\nabla \times \left(\frac{1}{\mu_r} \nabla \times \mathbf{E}_{sca} \right) - k_0^2 \left(\varepsilon_r - j \frac{\sigma}{\omega \varepsilon_0} \right) \mathbf{E}_{sca} = 0$$

The time-average Poynting vector gives the energy flux:

$$\mathcal{P} = \frac{1}{2} \mathrm{Re}\left[\mathbf{E} \times \mathbf{H}^* \right] \xrightarrow{\mathbf{H}_{inc} = \frac{1}{\eta} \hat{\mathbf{k}} \times \mathbf{E}_{inc}} \mathcal{P}_{inc} = \frac{1}{2\eta} \left| \mathbf{E}_{inc} \right|^2 \hat{\mathbf{k}}$$

We define the scattering cross section as:

$$W_{sca} = \oiint_S \mathcal{P}_{sca} \cdot \mathbf{n} dS = \frac{1}{2} \oiint_S \mathrm{Re}\left[\mathbf{E}_{sca} \times \mathbf{H}_{sca}^* \right] \cdot \mathbf{n} dS \longrightarrow \sigma_{sca} = \frac{W_{sca}}{\mathcal{P}_{inc}}$$

Results: In contrast with the case of a single nanowire, the array gives rise to different resonance frequencies that depend on the number of nanowires, geometric parameters and light polarization axis.

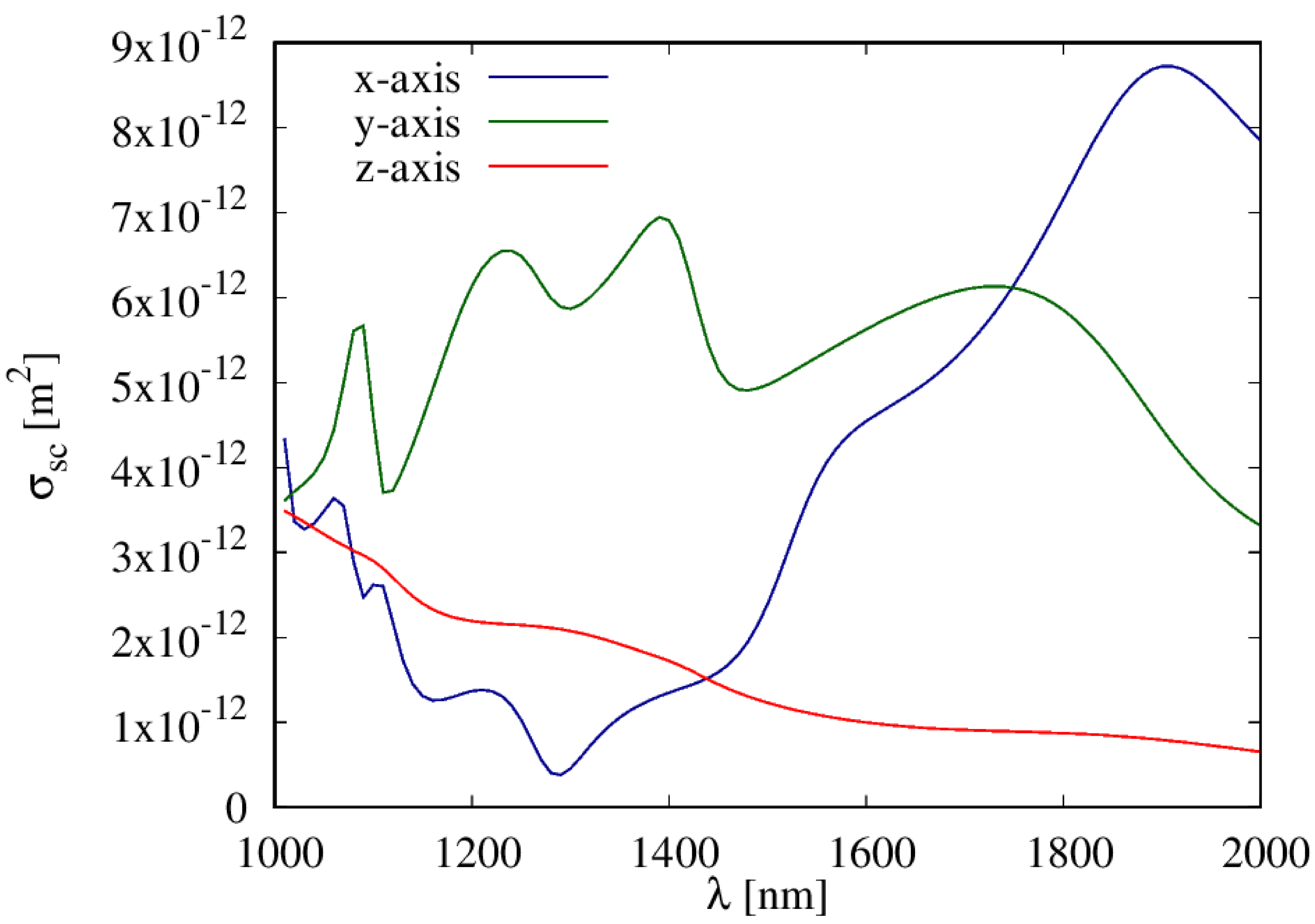

Figure 2. Scattering cross section versus wavelength for the shown array with light impinging from three different directions: x (blue) and y (green) axis polarized along the longitudinal direction and z (red) polarized along the y axis.

Conclusions: We showed that the array gives rise to resonance frequencies. The next steps of our work are to further modify the geometry of the array and to evaluate and interpret the spectral position of the peaks.

References:

1. B. S Luk'yanchuk et al. ACS Photonics **2**, 993-999 (2015)
2. S. Arslanagic, PRL **120**, 237401 (2018)