Study on the Active Medium Coated Cylindrical Nano Particle Antenna

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Abstract— The gain medium coated cylindrical nano particle is presented, in which the core is filled by Ag and obey Drude model, the shell is the gain medium, which was silica doped with rare earth (erbium Er^{3+}) ions, and it obeys the Lorentz model for the relative permittivity. In the optical plane wave, we compared the silver coated gain medium cylindrical nano particle and the gain medium coated Ag cylindrical nano particle, both show strong radiation performance.

1. INTRODUCTION

Coated nano-particles incorporating metals have shown attractive future in biology, medicine [1–3], efficient solar cells, high resolution microscopy, optical communications [4–6], and sensor technologies. Metals at optical frequencies behave as epsilon negative (ENG) media for surface plasmonic character. By combining them with gain medium that was doped, e.g., with rare earth ions, these nano-sized particles can be used to achieve highly sub-wavelength resonators and lasing elements [7–13].

Active cylindrical nano antenna have many attractive performance characteristics, in which the active closed cylindrical nano-antenna have been studied in [11–14]. It exhibits good radiation ability and dual polarization behavior, but the peak band is very narrow. In [15] the anti-AC-CNP, the active medium shell coated the silver core nano particle, shows SCS peak similar as the AC-CNP, and the band is narrow too.

In this paper, we found that there are two symmetrical SCS peak at same height but different radius for the AC-CNP and anti-AC-CNP.

2. AC-CNP AND ANTI-AC-CNP MODEL

The AC-CNP and anti-AC-CNP models are shown in Fig. 1.

In Fig. 1(a), the annular shell and the top and bottom spacers are silver, whose properties are described by a Drude model [11]. The long axes of the two CNPs are parallel and their ends sit on a lossless silica substrate. The gain impregnated filling lies in the center of the nano-structures. This medium is taken to be lossless silica for the passive nano-antenna comparison cases.

In Fig. 1(b), the IAC-CNP structure is similar as Fig. 1(a), but the material of the shell and the core are exchanged.

The gain material for the active nano-antenna was selected following [11], which was silica doped with rare earth (erbium Er^{3+}) ions or quantum dots. It obeys the Lorentz model for the relative

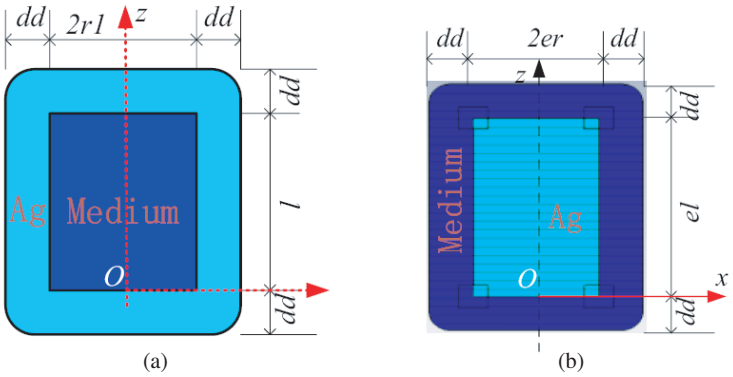

Figure 1: CST Model. (a) Parameters of a single closed active cylindrical CNP, (b) anti closed active cylindrical CNP.

permittivity:

$$\varepsilon_r(\omega) = \varepsilon_\infty + \frac{(\varepsilon_S - \varepsilon_\infty)\omega_0^2}{\omega_0^2 + j\omega\Gamma - \omega^2} \tag{1}$$

For a gain impregnated SiO_2 core, if $\kappa = -0.25$ at the specified resonance frequency, $f_0 = 600\,\text{THz}$, the resulting ε_r values are shown in Fig. 1 for the value of the damping frequency $\Gamma = 10^{-3}\omega_0$, ω_0 being the angular resonance frequency.

3. SIMULATION RESULTS

The CNP (basically a core-shell structure) has been studied by many researchers, e.g., [9, 10]. Its parameters and characteristics have been investigated thoroughly, but they all show single peak of SCS. As in [11] and as noted above, the CNP is filled with gain impregnated SiO_2. The source is a linearly polarized plane wave whose electric field vector is oriented along the axis of the cylinders. The coated film is silver and has a thickness equal to 6 nm. Here, the height of the core is $l = 33\,\text{nm}$, after optimization, the maximum peak of the SCS appear $-68.069\,\text{dBsm}$ at $f = 599.8223\,\text{THz}$ and $-81.9406\,\text{dBsm}$ at $600.2383\,\text{THz}$ corresponding to $r1 = 14.9\,\text{nm}$ and $r1 = 18.9775\,\text{nm}$ respectively, which are shown in Fig. 2.

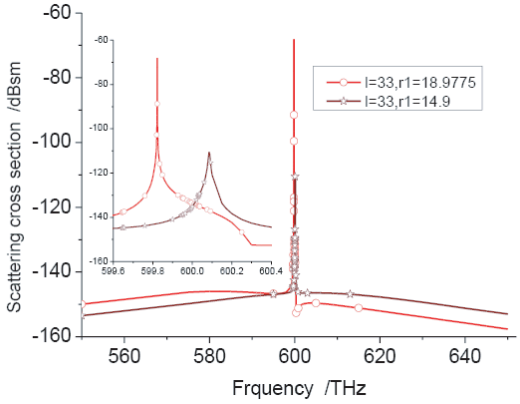

Figure 2: The scattering cross section of active coated cylindrical nano particle.

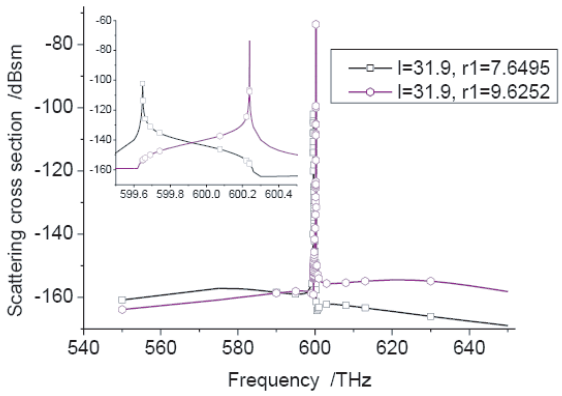

Figure 3: The scattering cross section of the anti active coated cylindrical nano particle.

Similarly, for the gain medium coated nano particle, the height of the core is $l = 31.9\,\text{nm}$, after optimization, the maximum peak of the SCS appear $-102.05832\,\text{dBsm}$ at $f = 599.6474\,\text{THz}$ and 73.6040-dBsm at $600.0915\,\text{THz}$ corresponding to $r1 = 7.6495\,\text{nm}$ and $r1 = 9.6252\,\text{nm}$ respectively, which are shown in Fig. 3.

4. CONCLUSIONS

The plane wave excitation of AC-CNP and anti AC-CNP respectively, both show symmetrical SCS peak by sweeping the core radius. For the AC-CNP, Here, the height of the core is $l = 33\,\text{nm}$, after optimization, the maximum peak of the SCS appear $-68.069\,\text{dBsm}$ at $f = 599.8223\,\text{THz}$ and $-81.9406\,\text{dBsm}$ at $600.2383\,\text{THz}$ corresponding to $r1 = 14.9\,\text{nm}$ and $r1 = 18.9775\,\text{nm}$ at $l = 33\,\text{nm}$ respectively; For the anti AC-CNP, the maximum peak of the SCS appear $-102.05832\,\text{dBsm}$ at $f = 599.6474\,\text{THz}$ and 73.6040-dBsm at $600.0915\,\text{THz}$ corresponding to $r1 = 7.6495\,\text{nm}$ and $r1 = 9.6252\,\text{nm}$ at $l = 31.9\,\text{nm}$ respectively.

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