Nano-Antenna for Optical Resolution Using Plasmonic Material as Substrate

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***Abstract*—In this paper, the concept to enhanced directivity of a electrically small subwavelength radiator containing plasmonic materials with negative permittivity at THz, infrared and optical frequencies have been explored theoretically. We study plasmonic resonances of a subwavelength core-shell spherical nanoantenna and simulate the far-field radiation patterns of such a structure when it is excited by a small dipole source. The size, shape and material of the nanoantenna determine the antenna response.**

I. Introduction And Background

To increase the radiation directivity towards specific directions, therefore, the use of electrically large antenna arrays are a common practice. This enlarges the total radiating area, allowing the designer to squeeze the beam in certain desired directions. The nano-sized optical antennas have the potential to confine and enhance optical electromagnetic fields, making nanoantennas essential tools for applications in integrated nano-optical devices and high-resolution microscopy [1]. Figure 1 is representing the structure of the nanoantenna that is simulated using CST Microwave Studio which is commercially available electromagnetic simulator based on the finite difference time domain technique. The shell of the nano-antenna is of gold where as the substrate used in the core of the antenna. Reducing the dimensions of radiators represents a challenge of great interest in the engineering community, owing to the several practical advantages of this opportunity in many fields. In this sense, the interest in THz, infrared and optical antenna technology has significantly increased in the recent years, since raising the frequency of operation may have significant impact in reducing the physical size of the antenna and in increasing its operational bandwidth [2]. The directivity can be increased more and more for a given electrical aperture with a fixed size [3], even though the efficiency, bandwidth and robustness of the antenna radiation decreases exponentially when trying to increase the directivity beyond the limit represented by a uniformly illuminated aperture of the same effective size. The limitation in the maximum directivity achievable with a given aperture size may be interestingly connected to the inherent limitation of lensing and focusing of subwavelength into a far field image. If we make a small aperture which directivity towards a given direction were possible, then one would speculate on the possibility of resolving different tiny details sense, it is interesting to remark that the resonance factor of antennas, a measure of the bandwidth and effective realizability of such super-directive radiators. Plasmonic materials have also been recently proposed as covers on simple radiating structures to maximize the power extracted from subwavelength radiators [4], but although these configurations possibly improve the antenna gain, efficiency and matching, the radiation pattern and directivity are noticeable. In this sense, nano-antenna technology based on plasmonic resonant nano-particles has also been subject of some recent numerical and experimental investigations [5]. In the following sections, we present theoretical and simulated results on the possibility of employing plasmonic materials to synthesize high-directivity nanoantennas supporting plasmonic resonances in subwavelength devices. The section II concerns with the simulation model of nanoantenna. The section III discusses the simulated results of the nanoantennas. Finally section IV concludes the work.

II. Simulation model

Figure 1 show the simulation model of nanoantennas which is consisting of inner and outer shells. The inner shell is made of plasmonic material and the outer shell is with gold. r_0 is the inner radius of the outer shell which is greater than the outer radius of inner shell, r. The ε_1 and ε_2 are the respective permittivity of the materials inside the inner and outer shells with propagation constant $k_i = \omega\sqrt{\varepsilon_i \mu_i}$, where ω is the angular frequency of excitation and μ_i (μ_1=μ_2=1) is the permeability of the materials. The feeding is performed along the z-axis and it is excited at the boundary of the two materials.

III. RESULTS

In order to realize the problem of the nanoantennas and the feeding of nanoantenna is very important. Even it is clear that the maximum gain for fixed current amplitude is obtained when the source is placed near the interface, the interest lies in the possibility of matching a real fed network for this radiating system in order to avoid high return loss. The simulation results for a subwavelength gold spherical shell is fed by a short dipole with a 50Ω. The geometry of the nanosphere considered here is r_0 = 38 nm, and r = 34 nm. This is consistent with any small dielectric resonator antenna, or any small-scale radiator. In order to realize the problem of the nano-antennas and the feeding of nano-antenna is of extreme importance.

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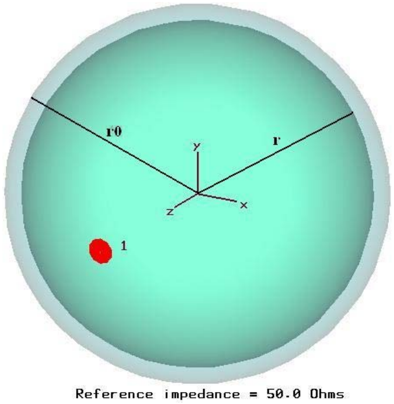

Figure 1: Simulation model of the nanoantenna at optical frequency.

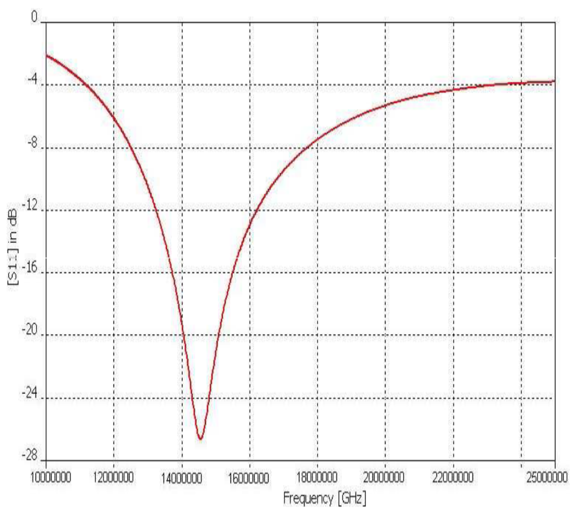

Figure 2: The frequency versus reflection losses of the nanoantennas at optical frequency.

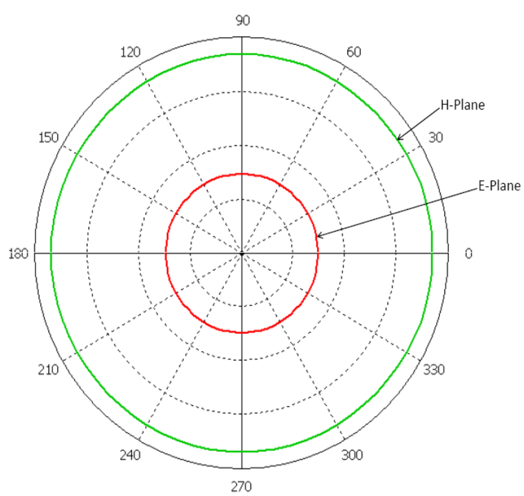

Figure 3: The gain of the electric and magnetic field plane of the nano-antenna at 1.46×10^{4} THz.

The return loss is -26.59 dB at the frequency 1.46×10^{4} THz as shown in the Fig. 2. The radiation efficiency and directivity of the proposed antenna is 63.51% and 2.77dBi, at frequency 1.46×10^{4} THz, respectively. Increasing the frequency of operation, however, does not necessarily allow squeezing the electrical size of the radiator for a desired level of performance.

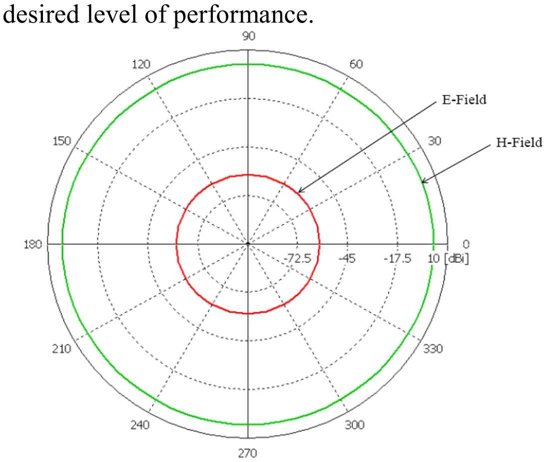

Figure 4: The directivity of the nano-antenna at the frequency 1.46×10^{4} THz.

The magnitude of the gain for the H-field main lobe is 0.4 dBi with the main lobe direction at 90 degrees at the frequency 1.46×10^{4} THz, and for E-field the main lobe magnitude comes out to be 0.4 dB with main lobe direction 30 degrees as shown in Fig. 3. The magnitude of the directivity for the H-field of the main lobe of the directivity is 2.3dBi with direction at 90 degrees at the frequency 1.46×10^{4} THz and the magnitude of the E-field main lobe comes out -60.4dBi at 30 degrees as shown in Fig. 4.

IV. CONCLUSION

We have presented simulated results of nanoantennas to synthesize efficient superdirective radiators. It should be noted that similar concepts could be applied to such antennas as receiving systems. Moreover in this case the angular position of the transmitter may exihibit sub-diffraction characteristics and sensitivity.

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