Numerical Analysis of Star-shaped Nanostructures as Optical Detectors

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Abstract

A full characterization of star shaped geometry structures of silver-zinc oxide (Ag-ZnO-Au) study is presented. Analysis with different thicknesses of gold cover, as well as with different lengths and additional arrangements of the structure have been carried out and the interaction of the electromagnetic field with a test nanoparticle has been added to the study, demonstrating possible applications for telecommunications and/or as a sensor or particle detector.

Method

Due to the geometric shape of the structure [1], such as the narrow angular regions and length of the arms with respect to the center, in addition to the variables that are intended to be studied, such as the interaction between more than one structure and other sub-particles, it allows the properties of the analysis by numerical calculation addressing the resolution of electromagnetic properties by the finite element method.
A simplified geometric modeling of the original structure was performed (see figure 1), that will allow manipulating the dimensions of the geometry to carry out the characterization processes of interest.

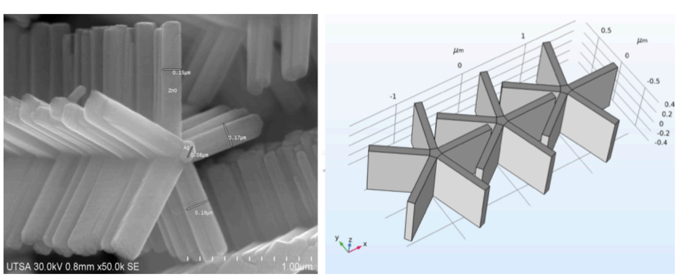

Fig. 1. On the left, micrograph of the original structure produced by self-assembly and on the right its equivalent CAD model.

Numerical characterization

Figure 2 shows the resonance frequency observed around 135 THz when the gold cover reaches 770 nm thick. It is worth mentioning that the study covers several thicknesses, however the one related to this frequency is presented due to its particular interest in telecommunication applications at Tbits per second (Tb/s) frequencies. In the same way, the response of the electric field was simulated in the presence of the stellar geometry structure at a fixed frequency and varying the thickness of the gold layer (figure 2).

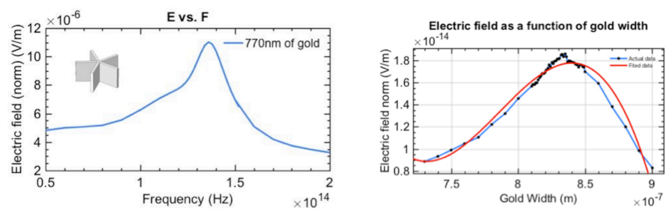

Fig. 2. On the left, resonance as a function of the frequency for a fixed gold layer thickness of 770 nm. On the right, plasmonic response as a function of the thickness of the gold coverage at a fixed frequency of 100 THz.

Results and discussion

The results allow us to suggest (among others) an application (work in progress) for the detection of dielectric and/or conductive particles with specific shapes (due to the star geometry), by applying a modified arrangement for the microreflectance difference spectrometer based on a charge coupled device camera [2] and its respective algorithm based on "curvelets" (an adaptation taken of [3]).
The ability to detect particles of certain dimensions and/or shapes is useful in fields such as medicine (diseases diagnosis), ecology (contaminant detection) chemistry (identification of specific molecules) and so on [4].
Figure 3 resumes the study of the structure as a sensor/detector.

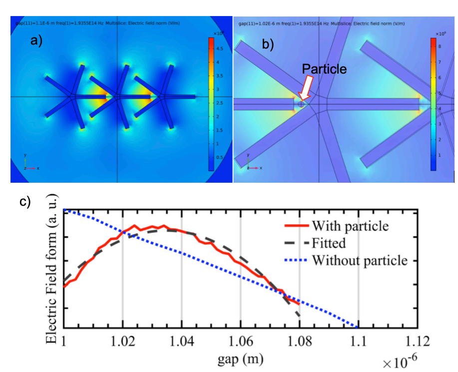

Fig. 3. Numerical analysis demonstrates the changes in E-field without (3a) and with (3b) presence of a particle, summarized graphically in (3c).

A lot of other useful information was obtained that give us data for other studies/analysis. Figure 4 depicts some other experiments that involve wave-polarization (Figs. 4a and 4b) and the far-field electromagnetic radiation pattern (Fig. 4c and 4d).

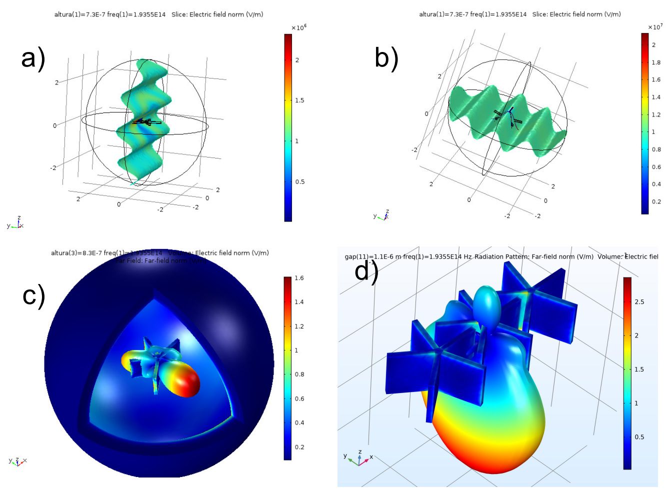

Fig. 4. a) Electromagnetic wave traveling across z-axis and y-polarized. b) Electromagnetic wave traveling across y-axis and z-polarized. c) and d) some far-field radiation pattern obtained in the study.

References

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