Numerical Analysis Of Star-Shaped Nanostructures As Optical Detectors

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Abstract

With the use of COMSOL Multiphysics®, 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.

COMSOL Multiphysics® was the selected software 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, just the way that COMSOL Multiphysics® solves this kind of problems.
A simplified geometric modeling of the original structure was easily performed with the COMSOL's skills to construct the geometry (see figure 1), that will allow manipulating the dimensions of the geometry to carry out the characterization processes of interest.

Applying the Wave Optics Module and the LiveLink™ for MATLAB®, a resonance frequency was observed around 135 THz when the gold cover reaches 770 nm thick, this frequency is presented due to its particular interest in telecommunication applications at Tbits per second (Tb/s) frequencies. It is worth mentioning that the particular combination of these two modules allows us to perform the study that covers several thicknesses and the response of the electric field in the presence of the stellar geometry structure at a fixed frequency and varying the thickness of the gold layer.

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. 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 [3]. Figure 2 resumes the study of the structure as a sensor/detector.

Reference

REFERENCES
[1] J. E. Sanchez et al., "Resonance properties of Ag-ZnO nanostructures at terahertz

frequencies", Optics Express, vol. 23, no. 19, 2015.
[2] L. F. Lastras-Martínez et al., "Microreflectance difference spectrometer based on a charge coupled device camera...", Applied Optics, vol. 48, no. 30, 2009.
[3] K. S. Anuj, P. Ankit Kumar, and K. Baljinder "A Review of advancements (2007–2017) in plasmonics-based optical fiber sensors", Optical Fiber Technology, vol. 43, no. 2018.

Figures used in the abstract

Figure 1 : On the left, micrograph of the original structure produced by self-assembly and on the right its equivalent COMSOL® model.

Figure 2 : Numerical analysis demonstrates the changes in E-field without (2a) and with (2b) presence of a particle, summarized graphically in (2c).