Genetic Algorithm for Geometry Optimization of Optical Antennas

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Abstract

A genetic algorithm [1] was programmed in MATLAB® software where a link was made to COMSOL Multiphysics® software where the electromagnetic simulations were performed. The results were returned to MATLAB® where the fitness function was evaluated. Iterative changes or adjustments are then made to optimize the solution, and the new proposed nanostructure is analyzed using COMSOL® software until a fixed number of iterations was achieved.

The genetic algorithm performs the nanostructure analysis required to suggest a geometry that approaches the optimal design conditions, assuming a (two-dimensional) flat nanostructure. The solution space is constrained to dimensions near the optical wavelength for an antenna irradiated by a normal-incident electromagnetic wave.

The COMSOL LiveLink™ for MATLAB® [2] is a module that links COMSOL software and MATLAB in two modes. Each of these configurations has a specific applicability range that can be adapted to particular cases. As previously mentioned, MATLAB software performs the geometry generation calculations and COMSOL software runs the simulation and produces antenna response data for a given frequency. These data are then transferred to MATLAB software and used to perform the necessary genetic algorithm adjustments. This process is repeated until a convergence value is reached.

Figure 1 illustrates the MATLAB and COMSOL models, which together comprise the genetic algorithm. The geometry obtained at the end of the genetic algorithm execution is shown in Figure 2(a). Figure 2(b) illustrates the data point at which the maximum optical energy absorption-emission is obtained in the terahertz range.

Many studies use analogies between nanostructure geometries and conventional radiofrequency macroscopic antenna geometries based on the assumption that their behaviors can be extrapolated to optical frequencies. However, the proposed computational model demonstrated that nanoantenna geometries require further study. The nanoantenna shape analyzed in this study does not feature a conventional geometry, such as those utilized for the radiofrequency range. Figure 3 shows a comparison between the classical dipole (a), the dipole generated by the algorithm after the first iteration (b) and the final geometry, which is based on the lowest electromagnetic field loss at the dipole center (c).

The proposed alternative genetic algorithm was applied to improve dipole geometry while accounting for the nanoscopic scale properties of these structures. Our results demonstrate that the final nanoantenna shape is significantly different than the classical case in the context of providing the optimal electromagnetic field concentration.

The results of this study will be used in future nanostructure fabrication and characterization studies using two materials with different Seebeck coefficients (one positive and one negative). The materials will generate maximum heating in the region of interest, producing a direct electric current [3] that can be stored in batteries for subsequent use. This will contribute to the creation of renewable energy devices.

Reference

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Figures used in the abstract

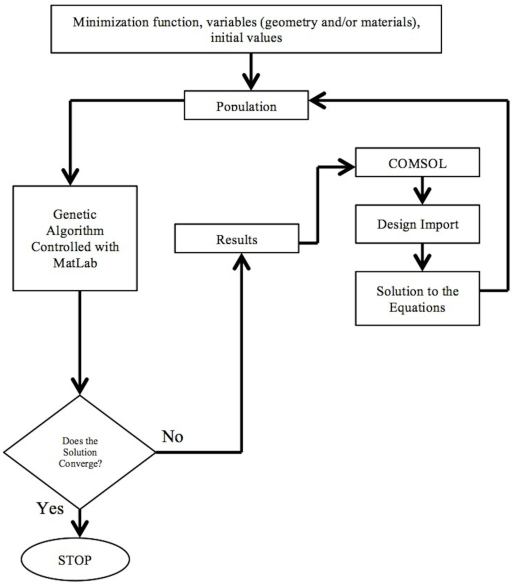

Figure 1: Flow diagram of the application process, noting the links between the COMSOL and MATLAB software packages.

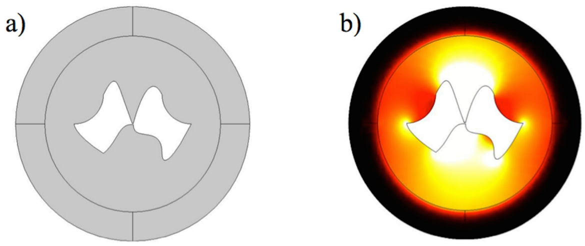

Figure 2: (a) Geometry obtained after the genetic algorithm optimization function application. (b) Finite element simulation of the nanostructure electromagnetic radiation pattern.

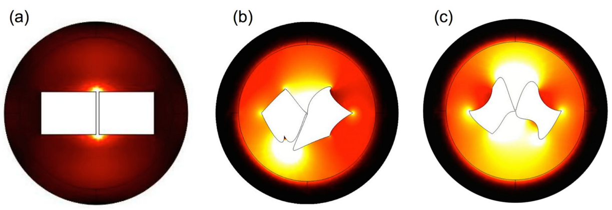

Figure 3: Electromagnetic field concentration comparison. Panel (a) shows a classical dipole; (b) shows the first iteration of the genetic algorithm; and (c) shows the final geometry, which is based on the maximum electromagnetic field concentration at the center of the nanostructure.