Inverse Design of Plasmonic Nano-Antenna

Zhou Zeng[1], Prabhukumar Venuthurumilli[1], Xianfan Xu[1,*]

*corresponding author, E-mail: xxu@ecn.purdue.edu

Abstract

We develop a new method for inverse design of plasmonic nano-antennas. We demonstrate the accuracy of this method for a plasmonic antenna used for heat-assisted magnetic recording (HAMR). We also use non-linear material interpolation to counter the non-physical field amplification, and filtering-and-projection regularization to ensure manufacturability of the design. Successful design of a plasmonic aperture to produce an electric field as small as 60 nm x 30 nm is presented.

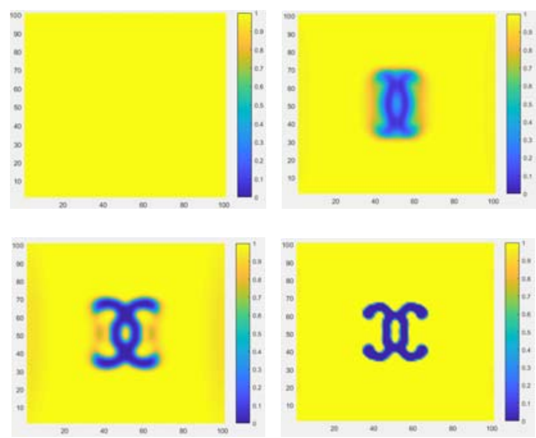
1. Introduction

Inverse design of plasmonic structures has only been reported in recent years and is almost exclusively based on frequency-domain solvers such as the Finite Element Method (FEM). FDTD method is not a popular choice in the inverse design of plasmonics due to the problem rooted in plasmonics where numerical error in electromagnetic simulations of plasmonic structures is highest at the metal-dielectric interfaces. we develop a new method of calculating discrete sensitivity with the FDTD method and incorporate this method into the density-based topology optimization framework [1]. The method accepts any objective function that is only dependent of frequency-domain variables, i.e., solutions of Maxwell's equations at a designated frequency. As a result, the method solves similar problems as the wide-spread FEM-based approach which also gives solutions in frequency domain. The accuracy of the method is illustrated through design of a plasmonic nano-antenna to produce a field as small as 60nm x 30 nm.

2. Results and Discussion

Bowtie aperture antennas are known to produce highly localized fields and have potential applications in optical lithography [2] and high density data storage [3]. The enhanced electric fields are confined within only a tiny region of the nanometer length scale near the surface of the nanostructures and decay significantly thereafter. As an example, we use our method to design an antenna to produce a field with a size of 60nm x 30 nm in magnetic material.

Figure 1 shows the evolution of the antenna during the inverse calcuation, for generating an electric filed of the size of 60nm x 30 nm. The material used is gold film of 60 nm thick, and the field is produced in magnetic recording medium whose properties are given in [3]. Figure 2 shows the obtained filed from such an antenna. It is seen that the design can produce a desired field of nanometer size.



Figuer 1: 1st (top left) 14th (top right) 24th (bottom left) and 34th (bottom right, and final) iterations of the inversion calculation of the antenna for producing a confined field.

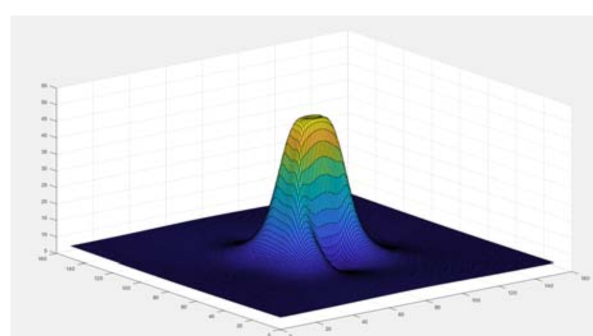


Figure 2: Final field distribution in magnetic recording medium.

3. Conclusions

We present a method for inverse design of plamonic antennas using the FDTD method as the direct solver. A density-based topology optimization method with the FDTD method and the filtering-and-projection regularization is carried out to successfully recover near field patterns of a plasmonic bowtie aperture antenna.

Acknowledgements

Support to this work by ASTC – Advanced Storage Technology Consortium and the National Science Foundation is acknowledged.

References

[1] T. Borrvall, J. Petersson, Topology optimization using regularized intermediate density control, Comput. Methods Appl. Mech. Eng. 190 (2001) 4911–4928. doi:10.1016/S0045-7825(00)00356-X.

[2] X. Wen, A. Datta, L.M. Traverso, L. Pan, X. Xu, E.E. Moon, High throughput optical lithography by scanning a massive array of bowtie aperture antennas at near-field, Sci. Rep. 5 (2015) 16192. doi:10.1038/srep16192.W.M. Kays, M.E. Crawford, *Heat transfer*, Wiley, New York, pp.256-258, 1990.

[3] N. Zhou, X. Xu, A.T. Hammack, B.C. Stipe, K. Gao, W. Scholz, E.C. Gage, Plasmonic near-field transducer for heat-assisted magnetic recording, Nanophotonics. 3 (2014) 141–155. doi:10.1515/nanoph-2014-0001.