A surface integral equation framework for light scattering in layered media

P. S. Mavrikakis [1,*], O. J. F. Martin [1]

[1] *Nanophotonics and Metrology Laboratory, EPFL, Lausanne, CH-1015, Switzerland*
[*] *parmenion.mavrikakis@epfl.ch*

The rigorous modeling of light scattering within stratified backgrounds is critical for modern optics. The surface integral equation (SIE) method offers a powerful framework for analyzing scattering phenomena [1]. However, its application to layered environments is often hindered by the complexity of the associated Green's functions. In this work, we introduce HELIOS, a C++ SIE solver that overcomes such limitations. It integrates a robust singularity extraction technique [2] that handles singularities, ensuring numerical stability and allowing for the arbitrary placement of scatterers within a stratified medium. Furthermore, the code implements a tabulation-interpolation scheme [3] to accelerate the matrix-filling process [4]. By circumventing repeating integral evaluations, computational overhead is significantly reduced. This approach is particularly advantageous for modeling stratified systems – such as biosensors, nanophotonic devices, and optical coatings – since high accuracy and efficiency are retained without increasing the degrees of freedom. The versatility and accuracy of HELIOS are presented through numerical examples, highlighting its potential to advance research in nanophotonics.

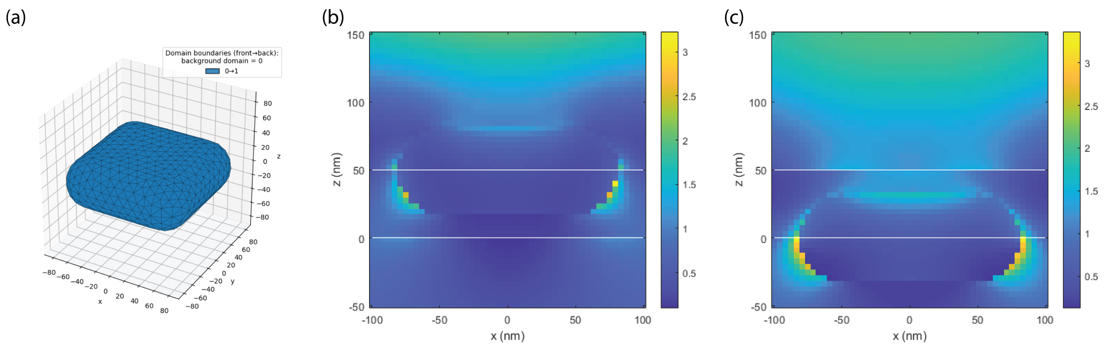

Fig. 1. Au nanoscatterer embedded in a stratified medium. (a) Discretized surface mesh of the scatterer's geometry, and (b)-(c) total electric near-field distributions in the $y = 0$ plane at an excitation wavelength of $\lambda = 500$ nm. The system is illuminated by a plane wave propagating in the $-z$ direction and polarized along the x-axis. The layered background consists of a dielectric slab ($\varepsilon_r = 2.25$) bounded by air, with interfaces located at $z_1 = 0\ \mathrm{nm}$ and $z_2 = 50\ \mathrm{nm}$.

Acknowledgement: This research was supported by the Swiss National Science Foundation (SNSF) under project 200021 212758.

References

[1] P. S. Mavrikakis, O. J. F. Martin, "Surface Integral Equations in Computational Electromagnetics: A Comprehensive Overview of Theory, Formulations, Discretization Schemes and Implementations", Appl. Comput. Electromagn. Soc. J. **40**, 279 (2025).
[2] S. Pratama, D. van Oosten, "Efficient and versatile surface integral approach to light scattering in stratified media", Opt. Express **23**, 21741 (2015).
[3] U. Hohenester, "Nanophotonic resonators in stratified media with the nanobem toolbox", Comput. Phys. Commun. **294**, 108949 (2024).
[4] W. C. Chew, J. L. Xiong, M. A. Saville, "A Matrix-Friendly Formulation of Layered Medium Green's Function", IEEE Antennas Wirel. Propag. Lett. **5**, 490 (2006).