INNOVATION PARTNERSHIPS
UNIVERSITY OF MICHIGAN

Fast Hybrid Method for Full-Wave Simulations of Metasurfaces with and without Substrate

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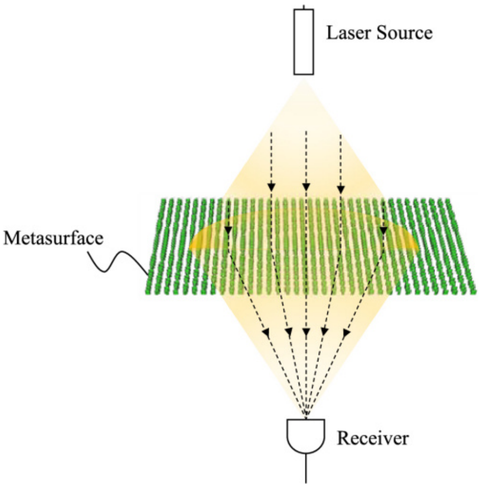

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Category
Semiconductor, MEMS, and Electronics
Software & Content

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OVERVIEW

Ultra-fast, memory-efficient electromagnetic simulation for realistic, large-scale metasurfaces

- Simulates metasurfaces thousands of times faster and with less memory than commercial solvers
- Metasurface design, optimization, characterization, and quantum/optical device engineering

BACKGROUND

Metasurfaces—engineered surfaces composed of arrays of subwavelength scatterers—have revolutionized control over electromagnetic waves in optics, microwaves, terahertz, and quantum domains. Traditionally, analyzing and designing metasurfaces relied on computational electromagnetics using commercial solvers like COMSOL, CST, FEKO, and HFSS. These methods demand extensive CPU time and memory, especially as designs scale to thousands of scatterers or involve substrates, limiting their practicality for large or complex metasurfaces. Analytical and quasi-analytical models exist but often oversimplify, neglecting critical inter-element interactions or substrate effects. As the demand for rapid prototyping, iterative design, and device optimization grows, there is a critical need for a simulation approach that combines the rigor and accuracy of full-wave methods with dramatically reduced computational requirements. An efficient, scalable solver is essential to keep pace with advances in metasurface-enabled technologies and their applications in optics, communications, imaging, and quantum science.

INNOVATION

Researchers at the University of Michigan have developed the Fast Hybrid Method (FHM) for full-wave electromagnetic simulation of metasurfaces, accommodating both free-space and substrate-supported arrangements. FHM leverages the Foldy-Lax multiple scattering formalism, extracting T-matrix representations of individual scatterers—computed once using any commercial or custom electromagnetic solver—and storing these for rapid reuse. Interactions among thousands of unit cells are then calculated via fast iterative algorithms and accelerated using advanced Fast Fourier Transform (FFT) operations, efficiently summing scattered fields. Key advances include rigorous support for infinite substrate effects (unavailable in most commercial solvers), library-based handling of arbitrarily rotated or shaped scatterers, and hybrid VCW/VSW basis expansions for both planar and volumetric metasurfaces. Comparative studies show FHM achieves up to 469x speedup and reduces memory demand by over two orders of magnitude—in some cases enabling simulations that would otherwise be impossible on standard computing hardware. Real-world applications span the design and optimization of lenses, antennas, OAM beam generators, novel quantum devices, and more.

ADDITIONAL INFORMATION

REFERENCES:

Jongwoo Jeong and Leung Tsang, "Wave scattering by metasurfaces using the fast hybrid method," Opt. Express 33, 37868-37881 (2025)

INTELLECTUAL PROPERTY:

Pending

KEYWORDS:

Metasurface, Full-wave simulation, Optics, Photonics