Wonseok Shin, Ph.D.

As of November 2013

Appointment

Postdoctoral Scholar in Prof. Shanhui Fan's group at Stanford University

Contact Information

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Education

Stanford University 2006–2013
Ph.D. in Electrical Engineering (advisor: Prof. Shanhui Fan)

Stanford University 2004–2007
M.S. in Electrical Engineering

Seoul National University 1997–2001
B.S. in Physics and Mathematics

Industry Experience

Park Systems, Suwon, Korea 2001–2004
Software Engineer
Developed algorithms and software for scanning probe microscope (SPM), including
- non-contact mode SPM operation algorithm on DSP
- tip deconvolution algorithm for SPM images

Honors and Awards

Samsung Scholarship	2006–2011
National Research Foundation of Korea Fellowship	2004–2006
Summa cum laude graduate, Seoul National University	2001
Merit-based scholarship, Seoul National University	1997–2001
Bronze prize, the 18th Korea National Mathematics Contest for College Students	1999
Silver medal, the 8th Korean Mathematical Olympiad (KMO)	1994

Research Description

Efficient solution of the frequency-domain Maxwell's equations in 3D
To improve the performance of iterative solvers of the frequency-domain Maxwell's equations in 3D, I develop various techniques such as
- correct formulation of a differential equation for plasmonics
- correct choice of the perfectly matched layer (PML) absorbing boundary condition
- engineering the eigenvalue distribution of the Maxwell operator using the continuity equation
- symmetrizing the Maxwell operator while preserving the condition number of the operator

Combining these techniques, I have achieved more than 300-fold speedup in frequency-domain Maxwell's equations solvers.

Design of novel nanophotonic components
Using the efficient Maxwell's equations solver, I design novel nanophotonic components such as
- perfect bends and splitters in plasmonic waveguides
- efficient couplers between plasmonic and dielectric waveguides
- deep-subwavelength antennas with unidirectional radiation patterns

Analysis of the nature of the energy loss in plasmonic and metamaterial systems
The performance of plasmonic and metamaterial devices are limited by the energy loss in their metallic components. To understand the nature of the loss and hence to improve the performance of these devices, I examine
- relationship between electromagnetic modes and their loss in plasmonic and metamaterial systems
- fundamental bound of the loss of electromagnetic modes
- numerical solution of electromagnetic modes of plasmonic and metamaterial systems

Ph.D. Dissertation

W. Shin, "3D finite-difference frequency-domain method for plasmonics and nanophotonics," submitted to the Department of Electrical Engineering, Stanford University (2013).

Refereed Journal Publications

W. Shin, W. Cai, P. B. Catrysse, G. Veronis, M. L. Brongersma, and S. Fan, "Broadband sharp 90-degree bends and T-splitters in plasmonic coaxial waveguides," *Nano Letters*, vol. 13, pp. 4753–4758 (2013).

W. Shin and S. Fan, "Accelerated solution of the frequency-domain Maxwell's equations by engineering the eigenvalue distribution," *Optics Express*, vol. 21, pp. 22578–22595 (2013).

A. Raman, W. Shin, and S. Fan, "Upper Bound on the Modal Material Loss Rate in Plasmonic and Metamaterial Systems," *Physical Review Letters*, vol. 110, art. no. 183901 (2013).

W. Shin, A. Raman, and S. Fan, "Instantaneous electric energy and electric power dissipation in dispersive media," *Journal of Optical Society of America B*, vol. 29, pp. 1048–1054 (2012).

W. Shin and S. Fan, "Choice of the perfectly matched layer boundary condition for frequency-domain Maxwell's equations solvers," *Journal of Computational Physics*, vol. 231, pp. 3406–3431 (2012).

W. Cai, W. Shin, S. Fan, and M. L. Brongersma, "Elements for plasmonic nanocircuits with three-dimensional slot waveguides," *Advanced Materials*, vol. 22, pp. 5120–5124 (2010).

L. Verslegers, P. B. Catrysse, Z. Yu, W. Shin, Z. Ruan, and S. Fan,"Phase front design with metallic pillar arrays," *Optics Letters*, vol. 35, no. 6, pp. 844–846 (2010).

Conference Oral Presentations

W. Shin, W. Cai, P. B. Catrysse, G. Veronis, M. L. Brongersma, and S. Fan, "Plasmonic nano-coaxial waveguides for 90-degree bends and T-splitters," *CLEO*, San Jose, California, June 9–14, 2013.

W. Shin and S. Fan, "Choice of the perfectly matched layer boundary condition for iterative solvers of the frequency-domain Maxwell's equations," *the 28th Annual Review of Progress in Applied Computational Electromagnetics*, Columbus, Ohio, April 10–14, 2012.

W. Shin and S. Fan, "Accelerated solution of the frequency-domain Maxwell's equations by engineering the spectrum of the operator using the continuity equation," *the 12th Copper Mountain Conference on Iterative Methods*, Copper Mountain, Colorado, March 25–30, 2012.

W. Shin and S. Fan, "Choice of the Perfectly Matched Layer boundary condition for iterative solvers of the frequency-domain Maxwell's equations," *SPIE Photonics West*, San Francisco, California, January 21–26, 2012.

Seminar Presentations

W. Shin, "Brief introduction to the finite-difference frequency-domain (FDFD) method," a guest lecture in *EE256: Numerical Electromagnetics* at Stanford University, Stanford, California, May 24, 2013.

W. Shin, "3D finite-difference frequency-domain method for plasmonics and nanophotonics," a seminar at Korea University (host: Prof. Q-Han Park), Seoul, South Korea, April 4, 2013.

W. Shin, "3D finite-difference frequency-domain method for plasmonics and nanophotonics," *Exitonics Research Society Seminar* at KAIST (host: Prof. Doh Chang Lee), Daejun, South Korea, March 28, 2013.

W. Shin, "3D finite-difference frequency-domain method for plasmonics and nanophotonics," Global Research Laboratory Seminar at Seoul National University (host: Prof. Namkyoo Park), Seoul, South Korea, March 26, 2013.

W. Shin, "Modification of Maxwell's equations for iterative methods," *Linear Algebra and Optimization Seminar* at Stanford University, Stanford, California, February 21, 2013.

W. Shin, "3D finite-differenece frequency-domain method for plasmonics and nanophotonics," *Optics and Electronics Seminar* at Stanford University, Stanford, California, January 28, 2013.

W. Shin, "A large-scale FDFD solver of Maxwell's equations for nanophotonics," a seminar at KAIST (host: Prof. Yong-Hee Lee), Daejun, South Korea, August 19, 2009.

Poster Presentations

W. Shin, A. Raman, and S. Fan, "Upper bound on the modal material loss rate in plasmonic and metamaterial systems," *First Year Review of AFOSR MURI: Template-Directed Directionally Solidified Eutectic Metamaterials*, Dayton, Ohio, October 8–9, 2013.

W. Shin, A. Raman, and S. Fan, "Instantaneous electric energy density and power dissipation density in dispersive media," *IONS NA-3*, Stanford, California, October 13–15, 2011.

W. Shin and S. Fan, "Impact of the PMLs on the convergence of iterative methods of solving Maxwell's equations in the frequency domain," *Stanford University Photonics Retreat*, Marshall, California, April 8–10, 2011.

W. Shin and S. Fan, "A large-scale 3D finite-difference frequency-domain solver of Maxwell's equations for nanophotonics," *Stanford University Photonics Retreat*, Napa, California, April 9–11, 2010.

Patents

W. Shin and S. Fan, "Simulation of phenomena characterized by partial differential equations," under review by USPTO.

Academic Software Development

MaxwellFDFD `http://www.stanford.edu/~wsshin/maxwellfdfd`

MaxwellFDFD is a MATLAB-based package that solves the frequency-domain Maxwell's equations. It constructs a system of linear equations out of the frequency-domain Maxwell's equations by the finite-difference frequency-domain (FDFD) method, and hence the name MaxwellFDFD. The constructed system is solved by MATLAB's built-in direct solvers. The main features of MaxwellFDFD are as follows:

- built-in frequency-dependent dielectric constants for commonly used nanophotonic materials
- various object shapes such as box, sphere, cylinder
- various types of sources such as point source and plane wave source (with support for oblique emission)
- electric (**J**) and magnetic (**M**) current sources
- PEC, PMC, periodic, and Bloch boundary conditions
- uniaxial perfectly matched layer (UPML) and stretched-coordinate PML (SC-PML)
- total-field/scattered-field (TF/SF) method
- power flux calculation
- visualization of objects and sources
- visualization of solution fields

FD3D `http://www.stanford.edu/~wsshin/fd3d`

FD3D is a parallelized computational kernel for solving the frequency-domain Maxwell's equations. It is a companion program of MaxwellFDFD: users can easily generate the input files for FD3D from MaxwellFDFD, and read the solution calculated by FD3D into MaxwellFDFD for further analysis. FD3D is written in C using the PETSc library, and it runs on any LINUX clusters that support MPI communication.

Unlike MaxwellFDFD, FD3D solves the constructed system of linear equations by Krylov iterative solvers rather than direct solvers to avoid large memory consumption. Using the various techniques developed throughout my Ph.D. research, FD3D achieves more than 300-fold speedup compared with conventional iterative solvers of the frequency-domain Maxwell's equations.