Wonseok Shin, Ph.D.

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Contact Information

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Current Appointment

Postdoctoral Scholar — 2013–present
Prof. Shanhui Fan's group, Stanford University

Education

Ph.D. in Electrical Engineering (advisor: Prof. Shanhui Fan) — 2006–2013
Stanford University
Dissertation:
3D Finite-Difference Frequency-Domain Method for Plasmonics and Nanophotonics

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

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

Industry Experience

Software Engineer — 2001–2004
Park Systems, Suwon, Korea
Developed software for Park Systems' scanning probe microscope (SPM), including

- data acquisition software on Texas Instruments' digital signal processor in C
- control software on Microsoft Windows in C++ (VC++)
- image editing software (similar to Photoshop) in Java (J2SE)

Teaching Experience

Principal Instructor of EE 256: Numerical Electromagnetics — scheduled in Spring 2014
Stanford University

Honors and Awards

Samsung Scholarship, *Samsung Scholarship Foundation*	2006–2011
Graduate Study Abroad Scholarship, *Korea Science and Engineering Foundation*	2004–2006
Summa cum laude graduate, *Seoul National University*	2001
Merit-based scholarship, *Seoul National University*	1997–2001
Bronze prize, *Collegiate Mathematics Competition*, Korean Mathematical Society	1999
Silver medal, *Korean Mathematical Olympiad* (KMO), Korean Mathematical Society	1994

Patents

W. Shin and S. Fan, "Simulation of phenomena characterized by partial differential equations," under review by USPTO (serial number 13/744,999).

RESEARCH OVERVIEW

Efficient solution of the frequency-domain Maxwell's equations in 3D

I develop various techniques to improve the performance of iterative solvers of the frequency-domain Maxwell's equations in 3D. The techniques I have developed are

- 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

Combining these techniques, I have achieved more than 300-fold speedup in solver performance.

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 explore the followings in plasmonic and metamaterial systems:

- efficient numerical solution of electromagnetic modes
- analytic expression of the modal loss rates
- fundamental bound of the modal loss rates

FUNDED RESEARCH PROJECTS

Template-Directed Directionally Solidified Eutectic Metamaterials 2012–2015
Multidisciplinary University Research Initiative (MURI)
Sponsor: Air Force Office of Scientific Research (AFOSR)
PI: Prof. Paul Braun at UIUC

Integrated Hybrid Nanophotonic Circuits 2011–2014
Multidisciplinary University Research Initiative (MURI)
Sponsor: Air Force Office of Scientific Research (AFOSR)
PI: Prof. Mark Brongersma at Stanford University

Modeling, Computation, and Analysis of Optical Responses of Nano Structures 2010–2013
Collaborative Research in the *Division of Mathematical Sciences* (DMS)
Sponsor: National Science Foundation (NSF)
PI: Prof. Shanhui Fan at Stanford University

Robust and Complex On-Chip Nanophotonics 2009–2014
Multidisciplinary University Research Initiative (MURI)
Sponsor: Air Force Office of Scientific Research (AFOSR)
PI: Prof. Shanhui Fan at Stanford University

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, "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.

Academic Software Development

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

Developed in MATLAB

MaxwellFDFD is a MATLAB-based package that solves the frequency-domain Maxwell's equations. It constructs a system of linear equations out of 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. MaxwellFDFD has the following features:

- built-in frequency-dependent dielectric constants for commonly used nanophotonic materials
- various object shapes such as box, sphere, cylinder
- various types of sources, including the plane wave source with oblique emission
- electric ($\mathbf{J}$) and magnetic ($\mathbf{M}$) 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

Developed in C and Python

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 uses the PETSc library for matrix and vector management, 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.