

# Wonseok Shin, Ph.D.

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CONTACT INFORMATION	Spilker Engineering and Applied Sciences, Box 249 348 Via Pueblo Stanford, CA 94305-4088, USA  E-mail: wsshin@stanford.edu Website: <a href="http://www.stanford.edu/~wsshin">http://www.stanford.edu/~wsshin</a>	
CURRENT APPOINTMENT	<b>Postdoctoral Scholar</b> <i>Prof. Shanhui Fan's group, Stanford University</i>	2013–present
EDUCATION	<b>Ph.D. in Electrical Engineering</b> (advisor: Prof. Shanhui Fan) <i>Stanford University</i> Dissertation: 3D Finite-Difference Frequency-Domain Method for Plasmonics and Nanophotonics  <b>M.S. in Electrical Engineering</b> <i>Stanford University</i>  <b>B.S. in Physics and Mathematics</b> <i>Seoul National University</i>	2006–2013       2004–2007    1997–2001
INDUSTRY EXPERIENCE	<b>Software Engineer</b> <i>Park Systems, Suwon, Korea</i> Developed software for Park Systems' scanning probe microscope (SPM), including <ul style="list-style-type: none"><li>• data acquisition software on Texas Instruments' digital signal processor in C</li><li>• control software on Microsoft Windows in C++ (VC++)</li><li>• image editing software (similar to Photoshop) in Java (J2SE)</li></ul>	2001–2004
TEACHING EXPERIENCE	<b>Principal Instructor of EE 256: Numerical Electromagnetics</b> <i>Stanford University</i>	scheduled in Spring 2014
HONORS AND AWARDS	Samsung Scholarship, <i>Samsung Scholarship Foundation</i> Graduate Study Abroad Scholarship, <i>Korea Science and Engineering Foundation</i> Summa cum laude graduate, <i>Seoul National University</i> Merit-based scholarship, <i>Seoul National University</i> Bronze prize, <i>Collegiate Mathematics Competition</i> , Korean Mathematical Society Silver medal, <i>Korean Mathematical Olympiad (KMO)</i> , Korean Mathematical Society	2006–2011 2004–2006 2001 1997–2001 1999 1994
PATENTS	<u>W. Shin</u> 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
- symmetrizing the Maxwell operator while preserving the condition number of the operator

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

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-difference 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), Daejeon, 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	<b>MaxwellFDFD</b>	<a href="http://www.stanford.edu/~wsshin/maxwellfdfd">http://www.stanford.edu/~wsshin/maxwellfdfd</a>
SOFTWARE	<i>Developed in MATLAB</i>	
DEVELOPMENT	<p>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:</p> <ul style="list-style-type: none"> <li>• built-in frequency-dependent dielectric constants for commonly used nanophotonic materials</li> <li>• various object shapes such as box, sphere, cylinder</li> <li>• various types of sources, especially the plane wave source with oblique emission</li> <li>• electric (<b>J</b>) and magnetic (<b>M</b>) current sources</li> <li>• PEC, PMC, periodic, and Bloch boundary conditions</li> <li>• uniaxial perfectly matched layer (UPML) and stretched-coordinate PML (SC-PML)</li> <li>• total-field/scattered-field (TF/SF) method</li> <li>• power flux calculation</li> <li>• visualization of objects and sources</li> <li>• visualization of solution fields</li> </ul>	

### 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.

REFERENCES	<p><b>Prof. Shanhui Fan</b>          Dept. of Electrical Engineering          Stanford University          Spilker Building          Stanford, CA 94305, USA          +1-650-724-4759          shanhui@stanford.edu</p>	<p><b>Prof. Jelena Vuckovic</b>          Dept. of Electrical Engineering          Stanford University          Spilker Building          Stanford, CA 94305, USA          +1-650-725-2288          jela@stanford.edu</p>	<p><b>Prof. Georgios Veronis</b>          School of Electrical Engineering and Computer Science          Louisiana State University          3104-D Patrick Taylor Hall          Baton Rouge, LA 70803, USA          +1-225-578-5552          gveronis@lsu.edu</p>
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