

CONTACT INFORMATION	Room 8–311, MIT 77 Massachusetts Avenue Cambridge, MA 02139, USA E-mail: wsshin@mit.edu Website: http://www.mit.edu/~wsshin	
POST-DEGREE APPOINTMENTS	Applied Mathematics Instructor <i>Department of Mathematics, Massachusetts Institute of Technology</i>	2015–present
	Postdoctoral Associate (mentor: Prof. Steven G. Johnson) <i>Department of Mathematics, Massachusetts Institute of Technology</i>	2015–present
	Postdoctoral Scholar (mentor: Prof. Shanhui Fan) <i>Department of Electrical Engineering, Stanford University</i>	2013–2015
EDUCATION	Ph.D. in Electrical Engineering (advisor: Prof. Shanhui Fan) <i>Stanford University</i> Dissertation [link]: “3D finite-difference frequency-domain method for plasmonics and nanophotonics”	2013
	M.S. in Electrical Engineering <i>Stanford University</i>	2007
	B.S. in Physics & Mathematics <i>Seoul National University</i>	2001
TEACHING EXPERIENCE	Principal Instructor of EE 256: Numerical Electromagnetics <i>Department of Electrical Engineering, Stanford University</i> <ul style="list-style-type: none"> • Taught how to implement time- and frequency-domain Maxwell’s eqs. solvers. • Redesigned the course materials and assignments for more effective learning. • Evaluated by students as one of the 10 best EE courses in spring 2014. • Course evaluation: 4.82/5.00 (area mean: 4.35). • Instructor evaluation: 4.73/5.00 (area mean: 4.28). • Stanford Bulletin [link], course advertisement [link]. 	spring 2014
INDUSTRY EXPERIENCE	Software Engineer <i>Park Systems, Suwon, South Korea</i> Developed the following software for scanning probe microscopes (SPMs): <ul style="list-style-type: none"> • Data acquisition software on Texas Instruments’ digital signal processor in C • SPM head control software on Microsoft Windows in C++ (VC++) • Image editing software (similar to Photoshop) in Java (J2SE) 	2001–2004
HONORS & AWARDS	Samsung Scholarship (USD 50,000/year), <i>Samsung Scholarship Foundation</i> Summa cum laude graduate, <i>Seoul National University</i> Bronze prize, Collegiate Mathematics Competition, <i>Korean Mathematical Society</i> Silver medal, Korean Mathematical Olympiad (KMO), <i>Korean Mathematical Society</i>	2006–2011 2001 1999 1994

RESEARCH
OVERVIEW**Efficient solution of large-scale 3D Maxwell's equations in the frequency domain**

I develop efficient techniques for solving large-scale 3D Maxwell's equations in the frequency domain, based on deep understanding of the numerical properties of the Maxwell operator. For example, the following two techniques I developed through doctoral research achieved more than 300-fold enhancement of solver performance in plasmonics:

- An efficient diagonal preconditioner that greatly enhances the conditioning of the Maxwell operator in domains terminated by the perfectly matched layer (PML) [*J. Comput. Phys.* 2012]
- An added penalty term that deflates the large near-null space of the Maxwell operator while preserving the definiteness and conditioning of the operator [*Opt. Express* 2013]

In postdoctoral research, I am extending these techniques to other areas than plasmonics, and seeking to apply the techniques to eigenmode analysis and device optimization.

Design of novel nanophotonic components

Using the above efficient techniques for solving Maxwell's equations, I have designed the following novel nanophotonic components:

- Focusing lenses made in flat metallic films [*Opt. Lett.* 2010]
- Perfect bends and splitters in plasmonic waveguides [*Nano Lett.* 2013, *Adv. Mater.* 2010]
- Grating couplers launching surface plasmons unidirectionally [*Nano Lett.* 2014]
- Deep-subwavelength spectral separators [*Appl. Phys. Lett.* 2014]
- Plasmonic waveguide stub filters [*Opt. Express* 2015]

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 metallic components. I seek to understand the nature of the loss, thereby improving the performance of these devices. As groundwork I have explored the following topics:

- The analytic expressions of mode energy and modal loss rates [*J. Opt. Soc. Am. B* 2012]
- The fundamental upper bound of modal loss rates [*Phys. Rev. Lett.* 2013]

Using these results as a basis, I am investigating the possibility of practical plasmonic and metamaterial devices with reduced loss.

RESEARCH
PROJECTS
PARTICIPATED**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

Computational Techniques

2. W. Shin, S. Fan. "Accelerated solution of the frequency-domain Maxwell's equations by engineering the eigenvalue distribution of the operator." *Optics Express* **21** (2013): 22578–95 [[link](#)].
1. W. Shin, S. Fan. "Choice of the perfectly matched layer boundary condition for frequency-domain Maxwell's equations solvers." *Journal of Computational Physics* **231** (2012): 3406–31 [[link](#)].

Nanophotonic Component Designs

6. A. Mahigir, P. Dastmalchi, W. Shin, S. Fan, G. Veronis. "Plasmonic coaxial waveguide-cavity devices." *Opt. Express* **23** (2015): 20549–62 [[link](#)].
5. Y. Büyükalp, P. B. Catrysse, W. Shin, S. Fan. "Spectral light separator based on deep-sub-wavelength resonant apertures in a metallic film." *Applied Physics Letters* **105** (2014): 011114 [[link](#)].
4. T. Liu*, Y. Shen*, W. Shin*, Q. Zhu, S. Fan, C. Jin. "Dislocated double-layer metal gratings: an efficient unidirectional coupler." *Nano Letters* **14** (2014): 3848–54 [[link](#)] (*co-first authors).
3. W. Shin, W. Cai, P. B. Catrysse, G. Veronis, M. L. Brongersma, S. Fan. "Broadband sharp 90-degree bends and T-splitters in plasmonic coaxial waveguides." *Nano Letters* **13** (2013): 4753–58 [[link](#)].
2. W. Cai, W. Shin, S. Fan, M. L. Brongersma. "Elements for plasmonic nanocircuits with three-dimensional slot waveguides." *Advanced Materials* **22** (2010): 5120–24 [[link](#)].
1. L. Verslegers, P. Catrysse, Z. Yu, W. Shin, Z. Ruan, S. Fan. "Phase front design with metallic pillar arrays." *Optics Letters* **35** (2010): 844–46 [[link](#)].

Fundamental Physics

2. A. Raman, W. Shin, S. Fan. "Upper bound on the modal material loss rate in plasmonic and metamaterial systems." *Physical Review Letters* **110** (2013): 183901 [[link](#)].
1. W. Shin, A. Raman, S. Fan. "Instantaneous electric energy and electric power dissipation in dispersive media." *Journal of Optical Society of America B* **29** (2012): 1048–54 [[link](#)].

CONFERENCE
ORAL
PRESENTATIONS

4. W. Shin, W. Cai, P. B. Catrysse, G. Veronis, M. L. Brongersma, S. Fan. "Plasmonic nano-coaxial waveguides for 90-degree bends and T-splitters." *CLEO*, San Jose, California. June 9–14, 2013.
3. W. Shin, S. Fan. "Choice of the perfectly matched layer boundary condition for iterative solvers of the frequency-domain Maxwell's equations." *28th Annual Review of Progress in Applied Computational Electromagnetics*, Columbus, Ohio. Apr. 10–14, 2012.
2. W. Shin, S. Fan. "Accelerated solution of the frequency-domain Maxwell's equations by engineering the spectrum of the operator using the continuity equation." *12th Copper Mountain Conference on Iterative Methods*, Copper Mountain, Colorado. Mar. 25–30, 2012.
1. W. Shin, 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. Jan. 21–26, 2012.

- CONFERENCE POSTER PRESENTATIONS
2. W. Shin, A. Raman, 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. Oct. 8–9, 2013.
 1. W. Shin, A. Raman, S. Fan. “Instantaneous electric energy density and power dissipation density in dispersive media.” *IONS NA-3*, Stanford, California. Oct. 13–15, 2011.

ACADEMIC SOFTWARE DEVELOPMENT

MaxwellFDFD <http://www.mit.edu/~wsshin/maxwellfdfd.html>
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 major features:

- Dynamic nonuniform grid generation aligned with object boundaries
- Waveguide mode solver and waveguide-mode-generating current source
- 2D and 3D visualization of objects, sources, and solution fields
- Periodic array of objects
- Electric (**J**) and magnetic (**M**) current sources
- PEC, PMC, periodic, and Bloch boundary conditions
- Stretched-coordinate perfectly matched layer (SC-PML) and uniaxial PML (UPML)
- Total-field/scattered-field (TF/SF) method
- Power flux calculation

FD3D <http://www.mit.edu/~wsshin/fd3d.html>

Developed in C and Python using PETSc

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 import the solution calculated by FD3D into MaxwellFDFD for further analysis. FD3D uses PETSc for matrix and vector management, and it runs on any LINUX clusters that support MPI communication. FD3D is also equipped with Python scripts for spectrum analysis.

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 doctoral research, FD3D achieves more than 300-fold speedup compared with conventional iterative solvers of the frequency-domain Maxwell’s equations.

jemdoc+MathJax <http://www.mit.edu/~wsshin/jemdoc+mathjax.html>

Developed in Python

jemdoc is an open-source website generator that is widely used in the academia for generating personal and course websites. *MathJax* is an open-source project founded by AMS and SIAM for displaying \LaTeX equations on webpages. Combining these two existing platforms, I have developed *jemdoc+MathJax*, an open-source program for easily creating academic websites containing complex \LaTeX equations. See my interview with MathJax.org about jemdoc+MathJax [[link](#)].