Wonseok Shin, Ph.D.

As of July 2018

Contact Information

Room 2-232C, Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, MA 02139, USA

http://www.mit.edu/~wsshin
wsshin@mit.edu

Education

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

M.S. in Electrical Engineering — 2007
Stanford University

B.S. in Mathematics & Physics — 2001
Seoul National University

Academic Experience

Applied Mathematics Instructor — 2015–present
Department of Mathematics, Massachusetts Institute of Technology

Postdoctoral Associate (mentor: Prof. Steven G. Johnson) — 2015–present
Department of Mathematics, Massachusetts Institute of Technology

Postdoctoral Scholar (mentor: Prof. Shanhui Fan) — 2013–2015
Department of Electrical Engineering, Stanford University

Teaching Experience

Instructor of 18.335: Introduction to Numerical Methods — spring 2016–2017
Department of Mathematics, Massachusetts Institute of Technology
- Course on theory and techniques of numerical linear algebra
- Implement numerical algorithms in MATLAB (2016) and Julia (2017)
- Large graduate-level class (~40 students)

Instructor of EE 256: Numerical Electromagnetics — spring 2014
Department of Electrical Engineering, Stanford University
- Course on time- and frequency-domain Maxwell's equations solvers
- Rated by students as one of the 10 best EE courses (evaluation: 4.82/5.00)

Industry Experience

Software Engineer — 2001–2004
Park Systems, Suwon, South Korea
Developed the following software for scanning probe microscopes (SPMs):
- 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)

Honors & Awards

Samsung Scholarship (USD 50,000/year), *Samsung Scholarship Foundation*	2006–2011
Summa cum laude graduate, *Seoul National University*	2001
Bronze prize, Collegiate Mathematics Competition, *Korean Mathematical Society*	1999
Silver medal, Korean Mathematical Olympiad (KMO), *Korean Mathematical Society*	1994

Patent Applications

W. Shin, S. Fan. "Simulation of phenomena characterized by partial differential equations." Under review by USPTO (application number US 13/744,999) [link].

REFEREED JOURNAL PUBLICATIONS

Computational Techniques

6. R. Pestourie, C. Pérez-Arancibia, Z. Lin, W. Shin, F. Capasso, S. G. Johnson. "Inverse design of large-area metasurfaces." *In preparation*.
5. W. Shin, D. Liu, S. G. Johnson. "Fixed-point formulation of the steady-state *ab initio* laser theory for solution by a black-box Maxwell solver." *In preparation*.
4. N. Zhao, S. Verweij, W. Shin, S. Fan. "Accelerating convergence of an iterative solution of finite difference frequency domain problems via schur complement domain decomposition." *Optics Express* **26** (2018): 16925–39 [link].
3. Y. Shi, W. Shin, S. Fan. "Multi-frequency finite-difference frequency-domain algorithm for active nanophotonic device simulations." *Optica* **3** (2016): 1256–59 [link].
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

8. Y. Büyükalp, P. B. Catrysse, W. Shin, S. Fan. "Planar, ultra-thin, subwavelength spectral light separator for efficient, wide-angle spectral imaging." *ACS Photonics* **4** (2017): 525–35 [link].
7. S. A. Khan, C.-M. M. Chang, Z. Zaidi, W. Shin, Y. Shi, A. K. Ellerbee Bowden, O. Solgaard. "Metal-insulator-metal waveguides for particle trapping and separation." *Lab on a Chip* **16** (2016): 2302–8 [link].
6. A. Mahigir, P. Dastmalchi, W. Shin, S. Fan, G. Veronis. "Plasmonic coaxial waveguide-cavity devices." *Optics Express* **23** (2015): 20549–62 [link].
5. Y. Büyükalp, P. B. Catrysse, W. Shin, S. Fan. "Spectral light separator based on deep-subwavelength 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

4. W. Shin, S. Fan. "Unified picture of modal loss rates from microwave to optical frequencies in deep-subwavelength metallic structures: A case study with slot waveguides." *Applied Physics Letters* **107** (2015): 171102 [link].
3. A. Raman, W. Shin, S. Fan. "Metamaterial band theory: fundamentals & applications." *Science China Information Sciences* **56** (2013): 1–14 [link].
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 the Optical Society of America B* **29** (2012): 1048–54 [link].

Conference Oral Presentations

5. W. Shin, D. Liu, S. G. Johnson. “Fixed-point iterative solution of the microlaser mode equation using a black-box Maxwell’s equations solver via implicit Newton step calculation.” *15th Copper Mountain Conference on Iterative Methods*, Copper Mountain, Colorado. Mar. 2018.
4. W. Shin, W. Cai, P. B. Catrysse, G. Veronis, M. L. Brongersma, S. Fan. “Plasmonic nanocoaxial waveguides for 90-degree bends and T-splitters.” *CLEO*, San Jose, California. June 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. 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. 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. 2012.

Conference Poster Presentations

3. W. Shin, A. Raman, S. Fan. “Upper bound of Ohmic loss rates in deep-subwavelength metallic structures: from microwave to optical frequencies.” *AFOSR Annual Review of EM Contractors*, Arlington, Virginia. Jan. 2017.
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. 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. 2011.

Academic Software Development

MaxwellFDFD *developed in MATLAB* (since 2012) https://github.com/wsshin/maxwellfdfd
MaxwellFDFD is a MATLAB 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:

- Adaptive nonuniform grid generation aligned with object boundaries
- Waveguide mode solver
- Electric ($\mathbf{J}$) and magnetic ($\mathbf{M}$) current sources
- PEC, PMC, and Bloch-periodic boundary conditions with PML
- Total-field/scattered-field (TF/SF) method

FD3D *developed in C and Python* (since 2008) https://github.com/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 import the solution calculated by FD3D into MaxwellFDFD for further analysis. FD3D uses the PETSc library for distributed allocation of matrices and vectors, and it runs on any LINUX clusters that support MPI communication. Using the various techniques developed throughout my doctoral research, FD3D achieves more than 300-fold speedup compared to conventional iterative solvers of the frequency-domain Maxwell’s equations.

MaxwellFDM.jl *developed in Julia* (since 2016) https://github.com/wsshin/MaxwellFDM.jl
MaxwellFDM.jl is a single package that aims to eliminate the inconvenience of dealing with two separate programs—MaxwellFDFD and FD3D—for 3D simulation. It is being developed in Julia, a new open-source programming language that is as easy to use as MATLAB while as performant

as C thanks to the powerful type inference system. MaxwellFDM.jl is being devolped as the *ultimate* FDFD solver that fulfills all the major user requests collected throughout my doctoral and postdoctoral research. Most notably, it finally supports the full permittivity tensor for modeling anisotropic materials, and also subpixel smoothing for accurate modeling of curved surfaces on the rectangular finite-difference grid.

SALTBase.jl *developed in Julia* (since 2017) https://github.com/wsshin/SALTBase.jl
SALTBase.jl is a framework for building a software package to simulate multimode nanolasers. It aims to solve the laser mode equations called the steady-state *ab initio* laser theory (SALT)—the steady-state version of the semiclassical Maxwell–Bloch equations. SALTBase.jl implements my original *implicit Newton step calculation* method, which enables one to use any black-box Maxwell solver as the computational kernel for building a SALT solver scalable to 3D problems.

MaxwellSALT.jl *developed in Julia* (since 2017) https://github.com/wsshin/MaxwellSALT.jl
MaxwellSALT.jl is a simple SALT solver package built on top of SALTBase.jl, with MaxewllFDM.jl as a Maxwell solver. It demonstrates SALTBase.jl's capability to accept any black-box Maxwell solver as the computational kernel.

jemdoc+MathJax *developed in Python* (since 2013) https://github.com/wsshin/jemdoc_mathjax
jemdoc is an open-source website generator that is widely used in the academia for creating personal 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 beautifully rendered LaTeX equations. See my interview with MathJax.org about jemdoc+MathJax [link].

References

Prof. Shanhui Fan
Department of Electrical Engineering
Stanford University
Spilker Building
Stanford, CA 94305, USA
+1-650-724-4759
shanhui@stanford.edu

Prof. Steven G. Johnson
Department of Mathematics
Massachusetts Institute of Technology
Room 2-345
Cambridge, MA 02139, USA
+1-617-253-4073
stevenj@math.mit.edu

Prof. John W. M. Bush
Department of Mathematics
Massachusetts Institute of Technology
Room 2-446
Cambridge, MA 02139, USA
+1-617-253-4387
bush@math.mit.edu

Prof. Georgios Veronis
School of Electrical Engineering &
Computer Science
Louisiana State University
3104-D Patrick Taylor Hall
Baton Rouge, LA 70803, USA
+1-225-578-5552
gveronis@lsu.edu