

Bo Zhao

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EDUCATION

Georgia Institute of Technology (Georgia Tech), Atlanta, GA Aug. 2011 - Dec. 2016

Ph.D. in Mechanical Engineering

Major: Heat Transfer Minor: Optics and Photonics

Advisor: Professor Zhuomin Zhang (Nanoscale Thermal Radiation Laboratory)

Dissertation: *Thermal Radiative Properties of Micro/Nanostructured Plasmonic Metamaterials Including Two-Dimensional (2D) Materials*

University of Science and Technology of China (USTC), Hefei, China Sept. 2007 - July 2011

B.S. in Mechanical Engineering

Major: Theoretical and Applied Mechanics

Thesis: *Experimental and Numerical Investigation on the Swimming of Larva Zebrafish*

RESEARCH EXPERIENCE

Postdoctoral Research Associate, Stanford University

Edward L. Ginzton Laboratory, Advisor: Professor Shanhui Fan Feb. 2017 - Present

- Analyzed a record-breaking near-field thermophotovoltaic system that converts thermal radiation from a heat source at 900 K to electricity with 11 W/cm² power density and > 40% efficiency

Graduate Research Assistant, Georgia Tech

Nanoscale Thermal Radiation Laboratory, Advisor: Professor Zhuomin Zhang Aug. 2011 - Jan. 2017

Far-Field Thermal Radiation

- Developed a 2D anisotropic RCWA algorithm for modeling radiative properties of periodic multilayer structures containing anisotropic materials
- Designed a wide-angle near-infrared polarizer with an extremely high extinction ratio
- Designed a high-performance wavelength-selective emitter using two-dimensional grating/thin-film metamaterials for thermophotovoltaics (TPV) applications
- Discovered the role of kinetic inductance on coherent thermal emission in metal gratings
- Achieved dual-band thermal emission based on an anisotropic metamaterial
- Proposed the three-polarization-angle method to calculate polarization-dependent radiative properties of arbitrary anisotropic materials
- Demonstrated for the first time ~3500% absorption enhancement in graphene using metamaterials
- Discovered blocking-assisted infrared transmission in graphene covered metallic gratings
- Discovered the strong plasmonic coupling phenomenon between a periodic graphene ribbon array and metallic nanostructures
- Discovered phonon-enabled location-dependent perfect absorption in hybrid structures constructed with hyperbolic material hexagonal boron nitride (hBN) and metal gratings

Near-Field Thermal Radiation

- Designed and built an experimental system for near-field radiative heat transfer measurement between planar plates down to 200 nm at room and cryogenic temperatures

- Discovered enhanced near-field heat transfer in 2D heterostructures enabled by surface plasmon-phonon polaritons (SPPs)
- Developed a general algorithm to calculate near-field radiative heat transfer between anisotropic periodic structures based on scattering theory and fluctuational electrodynamics

Undergraduate Research Assistant, USTC
Complex Fluid Flow Laboratory

Sept. 2009 - July 2011

- Built an experimental system to observe fish cruise swimming and simulated fish swimming using a self-developed C++ program based on lattice Boltzmann method (LBM)

TEACHING EXPERIENCES

Lead Graduate Teaching Assistant, Georgia Tech

ME4056 Mechanical Engineering Systems Lab (Undergraduate Level)

Aug. 2014 - Aug. 2016

Instructor of 8 comprehensive thermal-fluids labs to over 200 students. Developed skills include

- Coordinating with instructors (Profs. Zhuomin Zhang and Yogendra Joshi), school, and students
- Organizing weekly TA meetings, training new TAs, and maintaining lab instruments
- Designing grading guidelines to evaluate students' performance including lab reports, homework, and notebooks
- Teaching lab sections on experimental theory, experimentation, data analysis including uncertainty analysis and regression analysis
- Communicating and coordinating with students with diverse backgrounds
- Delivering three lectures on experimental theory to over 100 students

Graduate Teaching Practicum, Georgia Tech

ME4803/6309A Nanoscale Heat Transfer (Graduate Level)

Jan. 2016 - May 2016

Teaching practicum under mentorship of Prof. Zhuomin Zhang. Responsibilities include

- Designing and preparing materials on fundamentals of thermal radiation
- Giving three lectures (totally around 4 hours)
- Preparing homework related to fundamentals of thermal radiation
- Holding office hours to help the students to finish the homework

JOURNAL PUBLICATIONS

1. **Zhao, B.**, Guizal, B., Zhang, Z.M., Fan, S., and Antezza M., 2017, "Near-field heat transfer between graphene/hBN multilayers," *Physical Review B*, Vol. 95, p. 245437.
2. **Zhao, B.**, and Zhang, Z.M., 2017, "Resonance Perfect Absorption by Exciting Hyperbolic Phonon Polaritons in 1D hBN Gratings," *Optics Express*, Vol. 25, p. 7791.
3. **Zhao, B.**, and Zhang, Z.M., 2017, "Perfect Absorption with Trapezoidal Gratings Made of Natural Hyperbolic Materials," *Nanoscale and Microscale Thermophysical Engineering*, in press.
4. **Zhao, B.**, and Zhang, Z.M., 2017, "Perfect Mid-Infrared Absorption by Hybrid Phonon-Plasmon Polaritons in hBN/Metal-Grating Anisotropic Structures," *International Journal of Heat and Mass Transfer*, Vol. 106, p. 1025.
5. **Zhao, B.**, and Zhang, Z.M., 2017, "Enhanced Photon Tunneling by Surface Plasmon-Phonon Polaritons in Graphene/hBN Heterostructures," *ASME Journal of Heat Transfer*, Vol. 139, p. 022701.
6. Watjen, J.I.*, **Zhao, B.***, and Zhang, Z.M., 2016, "Near-Field Radiative Heat Transfer Between Doped-Si Parallel Plates Separated by a Spacing down to 200 nm," *Applied Physics Letters*, Vol. 109, p. 203112. * Equal contribution.

7. Watjen, J.I., Liu, X.L., **Zhao, B.**, and Zhang, Z.M., 2016, “A Computational Simulation of Using Tungsten Gratings in Near-Field Thermophotovoltaic Devices,” submitted to *ASME Journal of Heat Transfer*.
8. **Zhao, B.**, Sakurai, A., and Zhang, Z.M., 2015, “Polarization Dependence of the Reflectance and Transmittance of Anisotropic Metamaterials,” *Journal of Thermophysics and Heat Transfer*, Vol. 30, pp. 240-246.
9. **Zhao, B.**, and Zhang, Z.M., 2015, “Strong Plasmonic Coupling Between Graphene Ribbon Array and Metal Gratings,” *ACS Photonics*, Vol. 2, pp. 1611-1618.
10. **Zhao, B.**, Zhao, J.M., and Zhang, Z.M., 2015, “Resonance Enhanced Absorption in a Graphene Monolayer by Using Deep Metal Gratings,” *Journal of the Optical Society of America B*, Vol. 32, pp. 1176-1185. [OSA Publishing Top Downloads in June 2015]
11. Liu, X.L., **Zhao, B.**, and Zhang, Z.M., 2015, “Enhanced Near-Field Thermal Radiation and Reduced Casimir Stiction Between Doped-Si Gratings,” *Physical Review A*, Vol. 91, p. 062510.
12. Sakurai, A., **Zhao, B.**, and Zhang, Z.M., 2015, “Effect of Polarization on Dual-Band Infrared Metamaterial Emitters or Absorbers,” *Journal of Quantitative Spectroscopy and Radiative Transfer*, Vol.158, pp. 111-118.
13. Liu, X.L., **Zhao, B.**, and Zhang, Z.M., 2015, “Blocking-Assisted Infrared Transmission of Subwavelength Metallic Gratings by Graphene,” *Journal of Optics*, Vol. 17, p. 035004.
14. **Zhao, B.**, Zhao, J.M., and Zhang, Z.M., 2014, “Enhancement of Near-Infrared Absorption in Graphene with Metal Gratings,” *Applied Physics Letters*, Vol. 105, p. 031905-1/4.
15. **Zhao, B.**, and Zhang, Z.M., 2014, “Study of Magnetic Polaritons in Deep Gratings for Thermal Emission Control,” *Journal of Quantitative Spectroscopy and Radiative Transfer*, Vol. 135, pp. 81-89.
16. Sakurai, A., **Zhao, B.**, and Zhang, Z.M., 2014, “Resonant Frequency and Bandwidth of Metamaterial Emitters and Absorbers Predicted by an RLC Circuit Model,” *Journal of Quantitative Spectroscopy and Radiative Transfer*, Vol. 149, pp. 33-40.
17. **Zhao, B.**, Wang, L.P., Shuai, Y., and Zhang, Z.M., 2013, “Thermophotovoltaic Emitters Based on a Two-Dimensional Grating/Thin-Film Nanostructure,” *International Journal of Heat and Mass Transfer*, Vol. 67, pp. 637-645.
18. Liu, X.L., **Zhao, B.**, and Zhang, Z.M., 2013, “Wide-Angle Near-Infrared Polarizer with Extremely High Extinction Ratio,” *Optics Express*, Vol. 21, pp. 10502–10510.

BOOK CHAPTERS

1. **Zhao, B.**, and Zhang, Z.M., 2016, “Optical and Radiative Properties of Surfaces,” *Handbook of Thermal Science and Engineering/Radiative Heat Transfer Section*, Springer, Berlin, Germany, in press.

PROFESSIONAL EXPERIENCE & SERVICE

Grant Proposal Participation

- Major contributor to a successful proposal “Combining 2D Materials with 3D Nanostructures to Control Thermal Radiation”, NSF, \$300,000. Contributions include discussion of the main idea of the proposal, preparing the primary results, developing the experiment plan, and finishing the first draft for the technical section. PI: Prof. Zhuomin Zhang.
- Major participant in “Thermal Rectification Enabled by Nanoscale Radiative Heat Transfer” (NSF, \$252,000) and “Measurement of Near-Field Thermal Radiation between Flat Surfaces with a Nanogap” (DOE). PI: Prof. Zhuomin Zhang.

Journal Review & Service

- Reviewer for *Nature Communications*, *Scientific Reports*, *Applied Physics Letters*, *Physical Review Applied*, *Optics Express*, *Optics Letters*, *Journal of Quantitative Spectroscopy and*

Radiative Transfer, International Journal of Heat and Mass Transfer, and Journal of Applied Physics

- Reviewer for *6th International Conference on Metamaterials, Photonic Crystals and Plasmonics (META'15)*, *2016 President's Undergraduate Research Awards (PURA)*, and *11th Annual Undergraduate Research Spring Symposium* in Georgia Tech
- Student assistant for *ASME 2012 3rd Micro/Nanoscale Heat & Mass Transfer International Conference (MNHMT2012)*.

Membership

- Member of ASME (The American Society of Mechanical Engineers), AIAA (The American Institute of Aeronautics and Astronautics), and OSA (The Optical Society).

HONORS & AWARDS

- Georgia Tech Travel Grant Award June 2015
- Best Poster Award in 2013 ASME International Mechanical Engineering Congress & Exposition (IMECE), San Diego, CA, USA Nov. 2013
- Best Bachelor's Thesis Award in USTC (1%) June 2011
- China National Encouragement Scholarship (1‰) Oct. 2009
- First Prize of the 7th China National Zhou Pei-Yuan Competition in Mechanics (1‰) May 2009

CONFERENCE PRESENTATIONS

1. **Zhao, B.**, and Zhang, Z.M., 2016, "Enhanced Near-field Radiative Heat Transfer by Coupled Polaritons in Graphene/hBN Heterostructures," Progress in Electromagnetics Research Symposium (PIERS 2016), Shanghai, China, Aug. 8-11.
2. **Zhao, B.**, and Zhang, Z.M., 2016, "Experimental Demonstration of Near-field Thermal Radiation between Flat Plates at Submicron Distances," Progress in Electromagnetics Research Symposium (PIERS 2016), Shanghai, China, Aug. 8-11. (Invited.)
3. **Zhao, B.**, and Zhang, Z.M., 2016, "Perfect Absorption in hBN/Metal Grating Hybrid Anisotropic Structures," Fourth International Conference on Computational Methods for Thermal Problems (THERMACOMP2016), Atlanta, GA, July 6-8.
4. Watjen, J.I., **Zhao, B.**, and Zhang, Z.M., 2015, "Experimental Investigation of Near-Field Thermal Radiation between Flat Plates at Submicron Distances," ASME International Mechanical Engineering Congress and Exposition (IMECE 2015), Abstract No. IMECE2015-51070, Houston, TX, Nov. 13-19.
5. **Zhao, B.**, and Zhang, Z.M., 2015, "Thermal Radiation Control using Coupled Resonances between Graphene Ribbons and Metal Gratings," ASME International Mechanical Engineering Congress and Exposition (IMECE 2015), Abstract No. IMECE2015-51070, Houston, TX, Nov. 13-19.
6. **Zhao, B.**, Zhao, J.M., and Zhang, Z.M., 2015, "Enhanced Absorption of Graphene by Exciting Magnetic Polaritons and Surface Plasmon Polaritons," META'15, the 6th International Conference on Metamaterials, Photonic Crystals and Plasmonics, City College of New York, NYC, NY, Aug. 4-7.
7. **Zhao, B.**, Sakurai, A., and Zhang, Z.M., 2015, "Radiative Properties of Periodic Micro/Nanostructures for Arbitrary Polarization," 19th Symposium on Thermophysical Properties, Boulder, CO, June 21-26. [**Georgia Tech Travel Grant Award**]
8. Liu, X.L., **Zhao, B.**, and Zhang, Z.M., 2015, "Efficient Near-Field Energy Transfer and Relieved Casimir Stiction Between Sub-Wavelength Gratings," American Physical Society (APS) March Meeting, San Antonio, Texas, Mar. 2-6.

9. Sakurai, A., **Zhao, B.**, and Zhang, Z.M., 2014, "Prediction of the Resonance Condition of Metamaterial Emitters and Absorbers Using LC Circuit Model," 15th International Heat Transfer Conference (IHTC-15), Paper number IHTC15-9012/RAD-J-313, Kyoto, Japan, Aug. 10-15.
10. Watjen, J.I., **Zhao, B.**, and Zhang, Z.M., 2014, "An Experiment to Measure Near-field Radiation between Planar Surfaces at Nanoscale Distances," 11th AIAA/ASME Joint Thermophysics and Heat Transfer Conference, Atlanta, GA, June 16-20.
11. Sakurai, A., **Zhao, B.**, and Zhang, Z.M., 2014, "Dual Band Infrared Metamaterial Emitter and Absorber," 2nd International Workshop on Nano-Micro Thermal Radiation (NanoRad 2014), Shanghai, China, June 6-9.
12. **Zhao, B.**, and Zhang, Z.M., 2013, "Prediction of the Maximum Resonance Wavelength in Deep Gratings Based on Magnetic Polaritons," ASME International Mechanical Engineering Congress and Exposition (IMECE 2013), Abstract No. IMECE2013-67005, San Diego, CA, Nov. 15-21. **[Heat Transfer Best Poster Award at the ASME Society-Wide Micro/Nano Technology Forum]**
13. **Zhao, B.**, Wang, L.P., Shuai, Y., and Zhang, Z.M., 2012, "Excitation of Magnetic Polaritons in 2D Grating/Thin Film Structures for Thermophotovoltaic Emitters," ASME International Mechanical Engineering Congress and Exposition (IMECE 2012), Abstract No. IMECE2011-89081, Houston, TX, Nov. 9-15.
14. McNamara, A., **Zhao, B.**, Joshi, Y., Zhang, Z.M., 2012, "Multilayer Analytical Solution with Time Non-Homogeneous Boundary Conditions for Transient IR Thermal Measurements," 3rd ASME Micro/Nanoscale Heat and Mass Transfer International Conference, Abstract No. MNHMT2012-75366, Atlanta, GA, Mar. 3-6.

INVITED PRESENTATIONS

1. Micro/Nanoscale Thermal Radiation Control Using Nanostructures and 2D Materials, College of Energy and Mechanical Engineering, Shanghai University of Electric Power, China, Aug. 8, 2016.
2. Micro/Nanoscale Thermal Radiation Control Using Nanostructures and 2D Materials, Department of Thermal Science and Energy Engineering, University of Science and Technology of China, China, Aug. 5, 2016.
3. Micro/Nanoscale Thermal Radiation Control Using Nanostructures and 2D Materials, School of Energy Science and Engineering, Harbin Institute of Technology, China, July 16, 2016.
4. Micro/Nanoscale Thermal Radiation Control Using Nanostructures and 2D Materials, University of Michigan-Shanghai Jiao Tong University Joint Institute, Shanghai Jiao Tong University, China, July 14, 2016.

SKILLS

Programming & Software: C, C++, FORTRAN, Assembly language, MATLAB, Auto CAD, Tecplot, FDTD, COMSOL, Solidworks

Cleanroom Experiences: CVD, graphene fabrication, photolithography, FTIR, TAAS, AFM, SEM, ellipsometry