

JEFFREY M. SHAINLINE

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PHYSICIST, QUANTUM NANOPHOTONICS GROUP

APPLIED PHYSICS DIVISION, PHYSICAL MEASUREMENT LABORATORY

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

address 325 Broadway, Boulder, CO, 80305

email jeffrey.shainline@nist.gov

phone (303) 497-6292

PROFESSIONAL NARRATIVE

Semiconductor electronics has transformed society, impacting industries including transportation, appliances, defense, and of course computing. Great potential in this technological domain remains to be realized through the integration of semiconductor devices with other components adding new physical attributes. By including photonic components, we can dramatically increase the communication bandwidth of semiconductor systems. Adding superconducting circuitry enables new sensor concepts for single-photon detection as well as information processing in the manner carried out by the brain. My research contributions are at this confluence, where semiconductors, superconductors, and photonics converge and complement each other. My team at NIST is developing large arrays of superconducting single-photon detectors employing semiconducting circuitry to read out the signals from millions of pixels to achieve high-resolution, high-frame-rate imaging sensors. Such technology aims to observe the activity of each of the 10 billion transistors on a semiconductor processor chip during operation. We are also developing brain-inspired computational hardware to create artificial neurons that compute with superconducting electronics—the fastest, most energy-efficient known circuits—and communicate with light at the single-photon level. This technology appears capable of creating computational systems with the same number of neurons and synapses as the human brain, while operating 250,000 times faster. My research mission is to develop hardware integrating semiconductors, superconductors, and photonics to serve the American semiconductor industry through precision measurements and to answer fundamental questions about the physical limits of cognition.

PROFESSIONAL RESEARCH EXPERIENCE

2/2024—present NIST Staff Scientist, Project Leader
6/2023—1/2024 CHIPS Detail, Acting Program Manager
1/2017—6/2023 NIST Staff Scientist, Project Leader
2/2015—1/2017 NIST Term Employee
2/2013—2/2015 National Research Council Postdoctoral Fellow

*National Institute
of Standards and
Technology*

Applied Physics Division, Quantum Nanophotonics / Faint Photonics Groups

- CHIPS Detail as Acting Program Manager, assessed 250 internal NIST project briefs, organized a portfolio of projects to serve the CHIPS Metrology R&D grand challenges, and worked with two others to make recommendations for \$109M in funding for the Metrology R& D program.
- Leading the Physics and Hardware for Intelligence project with 12 team members
- Demonstrating superconducting optoelectronic hardware for use in large-scale neural computing systems and single-photon sensor arrays
- Developing the theoretical foundation for the emerging field superconducting optoelectronic networks
- Co-PI/technical lead for numerous DARPA and IARPA programs
- Received the NIST Bronze Medal for monolithic integration of single-photon detectors with Josephson junctions for metrology and advanced computing

8/2010—2/2013 Postdoctoral Research Associate

Group of Prof. Miloš Popović

- Led photonic device design for the DARPA POEM program to integrate silicon photonics with CMOS electronics for processor-to-memory links. This included design, layout, and testing of devices such as modulators, filter banks, and grating couplers integrated with CMOS electronics in a 45 nm CMOS process as part of a three-university collaboration with an industry partner. This program led to the first demonstration of optical links between processor and memory on a monolithic optoelectronic chip.
- Succeeded in implementing critical devices such as optical modulators in both a bulk CMOS DRAM process and an SOI CMOS logic process.
- Led a project to utilize multimode interference in guided wave optical structures to enable low-loss placement of electrical/mechanical contacts and waveguide crossings.

EDUCATION

PhD in Physics 2005-2010 Brown University
 Adviser: Jimmy Xu
 Thesis topic: Silicon microdisks for subwavelength and dynamic photonic circuit elements
 Honors:

*Bachelor's Degree
in Physics* 2002-2005 University of Colorado, Boulder
 Adviser: Chris Greene
 Thesis topic: S-wave scattering in one- and two-channel central potentials
 Honors: Magna Cum Laude

SELECTED JOURNAL PUBLICATIONS

h-index: 31; full list on [Scholar](#)

- 2024 1. S. Khan, B.A. Primavera, R.P. Mirin, S.W. Nam, and J.M. Shainline "Monolithic integration of superconducting-nanowire single-photon detectors with Josephson junctions for scalable single-photon sensing", *Supercond. Sci. Technol.*, 37, 035011 (2024).
- 2023 2. J.M. Shainline, B.A. Primavera, and S. Khan, "Phenomenological model of superconducting optoelectronic loop neurons", *Phys. Rev. Research*, 5, 013164 (2023).
- 2022 3. S. Khan, B.A. Primavera, J. Chiles, A.N. McCaughan, S.M. Buckley, A.N. Tait, A. Lita, J. Biesecker, A. Fox, D. Olaya, R.P. Mirin, S.W. Nam, and J.M. Shainline, "Superconducting optoelectronic single-photon synapses", *Nature Electronics*, 5, 650-659 (2022).
- 2021 4. J.M. Shainline, "Optoelectronic intelligence", *Applied Physics Letters*, 118, 160501 (2021).
- 2020 5. J.M. Shainline, "Does Cosmological Evolution select for technology?", *New. J. Phys.*, 22, 073064 (2020).
- 2019 6. A.N. McCaughan, V.B. Verma, S.M. Buckley, J.P. Allmaras, A.G. Kozorezov, A.N. Tait, S.W. Nam and J.M. Shainline, "A superconducting thermal switch with ultrahigh impedance for interfacing superconductors to semiconductors", *Nature Electronics*, 2, 451 (2019).
- 2019 7. J.M. Shainline, S.M. Buckley, A.N. McCaughan, J.T. Chiles, A. Jafari-Salim, M. Castellanos-Beltran, C.A. Donnelly, M.L. Schneider, R.P. Mirin, and S.W. Nam, "Superconducting Optoelectronic Loop Neurons", *J. Appl. Phys.*, 126, 044902 (2019). ([Featured article](#))
- 2018 8. J. Chiles, S. Buckley, S.W. Nam, R.P. Mirin, and J.M. Shainline, "Design, fabrication, and metrology of 10×100 multi-planar integrated photonic routing manifolds for neural networks," *APL Photonics*, 3, 106101 (2018).

- 2017
9. J. Chiles, S. Buckley, N. Nader, S.W. Nam, R.P. Mirin, and J.M. Shainline, "Multi-planar amorphous silicon photonics with compact interplanar couplers, cross talk mitigation, and low crossing loss," *APL Photonics*, 2, 116101 (2017). (Editor's Pick)
 10. S. Buckley, J. Chiles, A.N. McCaughan, G. Moody, K.L. Silverman, M.J. Stevens, R.P. Mirin, S.W. Nam, and J.M. Shainline, "All-silicon light-emitting diodes waveguide-integrated with superconducting single-photon detectors," *APL*, 111, 141101 (2017).
 11. J.M. Shainline, S.M. Buckley, R.P. Mirin, and S.W. Nam, "Superconducting optoelectronic circuits for neuromorphic computing," *Phys. Rev. Applied*, 7, 034013 (2017). (Editors' Suggestion)
- 2015
12. C. Sun, M.T. Wade, Y. Lee, J.S. Orcutt, L. Alloatti, M.S. Georgas, A.S. Waterman, J.M. Shainline, R.R. Avizienis, S. Lin, B.R. Moss, R. Kumar, F. Pavanello, A.H. Atabaki, H.M. Cook, A.J. Ou, J.C. Leu, Y.-H. Chen, K. Asanović, R.J. Ram, M.A. Popović, and V.M. Stojanović, "Single-chip microprocessor that communicates directly using light," *Nature*, 528, 534 (2015).
 13. C.M. Gentry, J.M. Shainline, M.T. Wade, M.J. Stevens, S.D. Dyer, X. Zeng, F. Pavanello, T. Gerrits, S.W. Nam, R.P. Mirin, and M.A. Popović, "Quantum-correlated photon pairs generated in a commercial 45 nm complementary metal-oxide-semiconductor microelectronic chip," *Optica*, 2, 1065 (2015).
- 2013
14. J.M. Shainline, J. Orcutt, M.T. Wade, K. Nammari, O. Tehar-Zahav, Z. Sternberg, R. Meade, R.J. Ram, V. Stojanović and M.A. Popović, "Depletion-mode polysilicon optical modulators in a bulk CMOS process," *Optics Letters*, 38, 2729 (2013).
 15. J.M. Shainline, J.S. Orcutt, M.T. Wade, K. Nammari, B. Moss, M. Georgas, C. Sun, R.J. Ram, V. Stojanović, and M. Popović, "Depletion-mode carrier-plasma optical modulator in zero-change advanced CMOS", *Optics Letters*, 38, 2657 (2013).

PATENTS

1. J. Chiles and J.M. Shainline, "Semiconductor junction with lateral heterostructure", U.S. Provisional Patent Application serial number 63/467,542, filed July 25, 2023.
2. J.M. Shainline, S. Khan, and B. Primavera, "Superconducting optoelectronic circuit to record photon arrival time", U.S. Provisional Patent Application serial number 63/467,534, filed May 18, 2023.
3. J.M. Shainline, A.N. McCaughan, and S. Khan, "Readout of arrays of superconducting single-photon detectors through integration with superconducting and semiconducting electronic circuits", U.S. Provisional Patent Application serial number 63/467,542, filed May 18, 2023.
4. J.M. Shainline, "Superconductor-semiconductor circuit for transducing current to charge for readout of superconductor current-storage elements", U.S. Provisional Patent Application serial number 63/467,551, filed May 18, 2023.
5. S. Khan and J.M. Shainline, "Fiber-to-chip coupler", U.S. Patent Number 11480736, Issue date: Oct. 25th, 2022.
6. J.M. Shainline, "Fluxonic processor and processing photonic synapse events", U.S. Patent Number 11468000, Issue date: Oct. 11th, 2022.
7. J.M. Shainline, A.N. McCaughan, S.W. Nam, and M. Castellanos-Beltran, "Josephson junction circuits for single-photon optoelectronic neurons and synapses", U.S. Patent Number 11283002, Issue date: March 22nd, 2022.
8. J.M. Shainline, S.M. Buckley, and S.W. Nam, "Neuromimetic circuit", U.S. Patent Number 11258415, Issue date: Feb. 22nd, 2022.
9. M.A. Popović, J. Shainline, J.S. Orcutt and V. Stojanović, "Depletion-mode carrier-plasma optical modulator in zero-change advanced CMOS", US Patent 10,996,538B2 (filed June 12, 2013, issued May 4, 2021). The utility is also filed as PCT application "Optical modulator from standard fabrication processing", WO2014201286 A1.

10. R. Meade, K. Mehta, E. Megged, J. Orcutt, M. Popović, R. Ram, J. Shainline, Z. Sternberg, V. Stojanović and O. Tehar-Zahav, "Method and optoelectronic structure providing polysilicon photonic devices with different optical properties," three patents with claims examined separately: US Patent 9,768,330 (filed on Aug 25, 2014; issued Sep 19, 2017); US Patent 10,312,388 (filed Aug 25, 2014, divisional on Aug 16, 2017, issued June 4, 2019); (filed Aug 25, 2014, divisional on Apr 19, 2019; issued Jan 26, 2021).
11. O. Tehar-Zahav, Z. Sternberg, R. Meade, E. Megged, J.S. Orcutt, J.M. Shainline, M. Popović and V. Stojanović, "Selective polycrystalline silicon defect-state detector formation."
12. R. Meade, J.S. Orcutt, M. Popović, J. Shainline, Z. Sternberg, V.M. Stojanović and O. Tehar-Zahav, "Method and Structure Providing Front-End-of-Line and Back-End-of-Line Coupled Waveguides", US Patent 9,778,416 (filed Sep 19, 2013; issued Oct 3, 2017; MIT Case 16586JK, joint MIT-CU-Micron).

PROFESSIONAL AFFILIATIONS

- Americal Physical Society (APS)
- Optica
- International Electronics and Electrical Engineers (IEEE)
- ASM / Electronic Device Failure Analysis Society (EDFAS)
- Materials Research Society (MRS)

February 13, 2024