Michael Zwolak

Biophysical Measurement | Scientific Computing | Quantitative Biology

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Summary

[References are links]

I am a physicist and biophysical measurement scientist integrating experiment, data, theory, and computation to make complex systems quantitatively interpretable. At NIST, I lead programs from biomolecules to cells and tissues, connecting measurement design and data quality to mechanistic models and scientific computing. Selected contributions include:

- Developing a secondary-structure metric to compress and validate nucleic-acid ensembles [83]
- Formulating quantitative models of DNA fragmentation for biodosimetry and oncology [81]
- Designing time-series analyses revealing energy-transport pathways in peptides [64]
- Inventing a scaling construction to quantify access resistance in molecular dynamics [56, 51]
- Developing tensor-network representations that control entanglement growth in quantum transport [67]

Across these areas, I seek the natural measurement, representation, or algorithm that preserves what is needed for mechanism and prediction.

Select Achievements

Nanopore and ion-channel optimization	Ultrafast biomolecular thermometry	Tunneling-current DNA sequencing

Experience

***Group* & *Project Leader*, National Institute of Standards and Technology** 2014 - present

- Directing NIST's primary group for novel physical measurements in biology 2018 - present
- Setting multi-year strategy across a portfolio spanning biomolecules, cells, and tissues
- Leading physical scientists and biomedical engineers in integrated experimental and computational programs
- Developing models for biomolecular measurement, including quantitative FRET analysis of DNA folding
- Advancing high-throughput measurement, multiscale integration, and biomolecular dynamics

***Assistant Professor*, Oregon State University, Department of Physics** 2011 - 2014

- Established thermal transport as a tool to probe biomolecular structural transitions
- Taught graduate physics courses (Avg. Eval.: 5.4/6.0; dept.: 4.6; university: 4.9)

***Feynman* & *Director's Fellow*, Los Alamos National Laboratory** 2007 - 2011

- Developed transport simulations for biomolecular, nanopore, and open quantum many-body systems

Education

Ph.D., Physics, California Institute of Technology (GPA: 4.0/4.0) June 2008
Thesis: Dynamics and Simulation of Open Quantum Systems (unofficially 2007)

M.S., Physics, Virginia Polytechnic Institute (GPA: 4.0/4.0) May 2003
Thesis: DNA Electronics

Honors Baccalaureate, Virginia Polytechnic Institute (GPA: 3.8/4.0) May 2002
Thesis: Acceptor Behavior of C_{60}; Degrees: B.S. Chem Eng; B.S. Chem; B.A. Phil; Minors: Math & Physics

Technical Skills

Biomolecular Model Building · Analytical Calculations · Novel Methods and Algorithms · Tensor Networks · Data Compression · Information Theory
Clustering · Singular-Value Decomposition · Statistics · Molecular Dynamics (NAMD/LAMMPS) · Statistical Mechanics · Fortran · Julia · Matlab · Mathematica

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Research Leadership and Support

I lead the Biophysical and Biomedical Measurement Group at the National Institute of Standards and Technology (NIST), bringing together physical scientists, biomedical engineers, associate researchers, and theorists to develop quantitative measurements of biomolecules, cells, and tissues. I set scientific strategy across experimental measurement, simulation, data analysis, high-throughput methods, and biomolecular dynamics, with the goal of building reusable capabilities that connect observations to mechanistic and predictive models.

I spearheaded a clearer framework for defining NIST's role in funded collaborations with academic and clinical partners, helping make responsibilities and contributions to shared experimental programs more concrete from the outset. I participate as a Co-Investigator on a Wake Forest-led NIH U01 in human biodosimetry, contributing NIST measurement and modeling capabilities within the broader team.

Research Support

Physical Measurement Laboratory, NIST	2018 –
Center for Nanoscale Science and Technology, NIST	2014 – 2018
Co-PI, "Quantum Theory of Classical Reality" (Templeton, ~$170k/2yr)	2011 – 2013
Co-PI, "Cold atoms in quantum periodic potentials" (LANL, ~$1M/3yr)	2009 – 2012
Co-I, "Information Science for Understanding Complex Quantum Matter" (LANL)	2009 – 2012
Co-I, "Disentangling Quantum Entanglement" (LANL)	2008 – 2011
Richard P. Feynman Fellowship (LANL distinguished fellowship)	2008 – 2011
EMPD Postdoctoral Award (AVS, Electronic Materials & Processing Division)	2010
Director's Postdoctoral Fellowship (LANL)	2007 – 2008
Sigma Xi Grant-in-Aid of Research (as a graduate student, ~$1k)	2005
William A. Fowler Fellowship (Caltech, Gordon and Better Moore Foundation)	2003 – 2007
National Science Foundation Graduate Fellowship	2003 – 2006

Professional Activities

I strive to serve both my institution and the broader scientific community through a variety of efforts. I regularly referee for major journals and participate in advisory panels, and I have undertaken roles such as:

- Member (NIST): High-Performance Computing Steering Committee, Research Computing Infrastructure Group, Collaborative Tools Steering Group, Open Data Committee, among others
- Reviewer, Center for Integrated Nanotechnologies, LANL 2013 –
- Reviewer, Biomolecule detection and ionic phenomena (NWO, Netherlands) 2017 –
- Reviewer, National Centres of Competence (Swiss NSF) 2019
- Editorial Board, Scientific Reports 2011 – 2016
- Reviewer, Thermal-based medical diagnostics (Research Foundation, Flanders) 2014
- Session Chair, March APS, Open Quantum Systems and Decoherence 2011
- Co-organizer, Quantum Coherence and Decoherence, Benasque, Spain 2010
- Member, Quantum & Optical Science Exploratory Research Grant Committee 2010
- Co-organizer, Quantum Coherence and Decoherence, Benasque, Spain 2008

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Peer-Reviewed Publications

[* Corresponding author]

83. Clustering DNA and RNA molecular dynamics ensembles via secondary structure, S. Baral & **M. Zwolak***, to appear, Biophys. J. (2025).
82. Complex cooperativity in DNA origami revealed via design dependent defectivity, J. Majikes, A. Hasni, S. Haridas, J. Robertson, A. Pintar, **M. Zwolak** & J. A. Liddle*, under review, Nucleic Acids Res. (2025).
81. Single–Molecule Biodosimetry, M. Lamontagne, S. M. Newell, I. M. Pazos, R. E. Tosh, J. C. Polf, **M. Zwolak** & J. W. F. Robertson*, Anal. Chem. **97**, 22004 (2025).
80. Approaching the scaling limit of transport through lattices with dephasing, S. Sarkar, G. Wójtowicz, B. Gardas, M. M. Rams* & **M. Zwolak***, J. Chem. Phys. **163**, 114101 (2025).
79. Confluence of fractured resonances at points of dynamical many–body flare, B. De, G. Wójtowicz, M. M. Rams*, **M. Zwolak*** & J. Zakrzewski*, Phys. Rev. B, **110**, 155146 (2024).
78. Transport in a periodically driven tilted lattice via the extended reservoir approach: Stability criterion for recovering the continuum limit, B. De, G. Wójtowicz, J. Zakrzewski*, **M. Zwolak*** & M. M. Rams*, Phys. Rev. B, **107**, 235148 (2023).
77. Accumulative reservoir construction: Bridging continuously relaxed and periodically refreshed extended reservoirs, G. Wójtowicz, A. Purkayastha, **M. Zwolak*** & M. M. Rams*, Phys. Rev. B, **107**, 035150 (2023).
76. Best practice for improved accuracy: A critical reassessment of van't Hoff analysis of melt curves, J. M. Majikes, **M. Zwolak** & J. A. Liddle*, Biophys. J. **121**, 1986 (2022).
75. Amplification, inference, and the manifestation of objective classical information, **M. Zwolak***, Entropy, **24**, 781 (2022).
74. Dual current anomalies and quantum transport within extended reservoir simulations, G. Wójtowicz, J. E. Elenewski, M. M. Rams* & **M. Zwolak***, Phys. Rev. B, **104**, 165131 (2021).
73. Performance of reservoir discretizations in quantum transport simulations, J. E. Elenewski, G. Wójtowicz, M. M. Rams* & **M. Zwolak***, J. Chem. Phys. **155**, 124117 (2021).
72. Failure mechanisms in DNA self–assembly: Barriers to single–fold yield, J. M. Majikes, P. N. Patrone, A. J. Kearsley, **M. Zwolak** & J. A. Liddle*, ACS Nano, **15**, 3284 (2021).
71. Analytic expressions for the steady–state current with finite extended reservoirs, **M. Zwolak***, J. Chem. Phys. **153**, 224107 (2020).
70. Diffusion limitations and translocation barriers in atomically thin biomimetic pores, S. Sahu & **M. Zwolak***, Entropy, **22**, 1326 (2020).
69. Revealing thermodynamics of DNA origami folding via affine transformations, J. M. Majikes, P. N. Patrone, D. Schiffels, **M. Zwolak**, A. J. Kearsley, S. P. Forry & J. A. Liddle*, Nucleic Acids Res. **48**, 5268 (2020).
68. Open–system tensor networks and Kramers' crossover for quantum transport, G. Wójtowicz, J. E. Elenewski, M. M. Rams* & **M. Zwolak***, Phys. Rev. A, **101**, 050301 (2020).
67. Breaking the entanglement barrier: Tensor network simulation of quantum transport, M. M. Rams* & **M. Zwolak***, Phys. Rev. Lett. **124**, 137701 (2020).
66. Metal adsorbate interactions and the convergence of density functional calculations, C. Rohmann, M. A. Ochoa & **M. Zwolak***, J. Chem. Phys. **152**, 061102 (2020).
65. Optimal *in situ* electromechanical sensing of molecular species, M. A. Ochoa & **M. Zwolak***, J. Chem. Phys. **152**, 034109 (2020).
64. Topology, landscapes, and biomolecular energy transport, J. E. Elenewski, K. A. Velizhanin & **M. Zwolak***, Nat. Commun. **10**, 4662 (2019).
63. Revealing the emergence of classicality using nitrogen–vacancy centers, T. K. Unden, D. Louzon, **M. Zwolak**, W. H. Zurek & F. Jelezko*, Phys. Rev. Lett. **123**, 140402 (2019).

62. Optimal transport and colossal ionic mechano–conductance in graphene crown ethers, S. Sahu, J. Elenewski, C. Rohmann & **M. Zwolak*,** Sci. Adv. **5,** eaaw5478 (2019).
61. Colloquium: Ionic phenomena in nanoscale pores through 2D materials, S. Sahu & **M. Zwolak*,** Rev. Mod. Phys. **91,** 021004 (2019).
60. Generalized Voigt broadening due to thermal fluctuations of electromechanical nanosensors and molecular electronic junctions, M. A. Ochoa & **M. Zwolak*,** J. Chem. Phys. **150,** 141102 (2019).
59. An energy–resolved atomic scanning probe, D. Gruss, C.-C. Chien, J. T. Barreiro, M. D. Ventra & **M. Zwolak*,** New J. Phys. **20,** 115005 (2018).
58. Communication: Gibbs phenomenon and the emergence of the steady–state in quantum transport, **M. Zwolak*,** J. Chem. Phys. **149,** 241102 (2018).
57. A spin–1 representation for dual–funnel energy landscapes, J. E. Elenewski, K. A. Velizhanin & **M. Zwolak*,** J. Chem. Phys. **149,** 035101 (2018).
56. Golden aspect ratio for ion transport simulation in nanopores, S. Sahu & **M. Zwolak*,** Phys. Rev. E, **98,** 012404 (2018).
55. Educational commitment and social networking: The power of informal networks, J. P. Zwolak*, **M. Zwolak** & E. Brewe, Phys. Rev. PER, **14,** 010131 (2018).
54. Topological quantization of energy transport in micromechanical and nanomechanical lattices, C.-C. Chien, K. A. Velizhanin, Y. Dubi, B. R. Ilic & **M. Zwolak*,** Phys. Rev. B, **97,** 125425 (2018).
53. Defects in quantum computers, B. Gardas, J. Dziarmaga*, W. H. Zurek & **M. Zwolak,** Sci. Rep. **8,** 4539 (2018).
52. Metastable morphological states of catalytic nanoparticles, P. A. Lin, B. Natarajan, **M. Zwolak*** & R. Sharma*, Nanoscale, **10,** 4528 (2018).
51. Maxwell–Hall access resistance in graphene nanopores, S. Sahu & **M. Zwolak*,** Phys. Chem. Chem. Phys. **20,** 4646 (2018).
50. Communication: Master equations for electron transport: The limits of the Markovian limit, J. E. Elenewski, D. Gruss & **M. Zwolak*,** J. Chem. Phys. **147,** 151101 (2017).
49. Communication: Relaxation–limited electronic currents in extended reservoir simulations, D. Gruss, A. Smolyanitsky & **M. Zwolak*,** J. Chem. Phys. **147,** 141102 (2017).
48. Dehydration as a universal mechanism for ion selectivity in graphene and other atomically thin pores, S. Sahu, M. Di Ventra & **M. Zwolak*,** Nano Lett. **17,** 4719 (2017).
47. Ionic selectivity and filtration from fragmented dehydration in multilayer graphene nanopores, S. Sahu & **M. Zwolak*,** Nanoscale, **9,** 11424 (2017).
46. Redundancy of einselected information in quantum Darwinism: The irrelevance of irrelevant environment bits, **M. Zwolak*** & W. H. Zurek, Phys. Rev. A, **95,** 030101 (2017).
45. Enabling photoemission electron microscopy in liquids via graphene–capped microchannel arrays, H. Guo, E. Strelcov, A. Yulaev, J. Wang, N. Appathurai, S. Urquhart, J. Vinson, S. Sahu, **M. Zwolak** & A. Kolmakov*, Nano Lett. **17,** 1034 (2017).
44. Thermal transport in dimerized harmonic lattices: Exact solution, crossover behavior, and extended reservoirs, C.-C. Chien*, S. Kouachi, K. A. Velizhanin, Y. Dubi & **M. Zwolak*,** Phys. Rev. E, **95,** 012137 (2017).
43. Measurement–induced decoherence and information in double–slit interference, M. Kincaid, K. McLelland & **M. Zwolak*,** Am. J. Phys. **84,** 522 (2016).
42. Amplification, decoherence and the acquisition of information by spin environments, **M. Zwolak*,** C. J. Riedel & W. H. Zurek, Sci. Rep. **6,** 25277 (2016).

41. Landauer's formula with finite–time relaxation: Kramers' crossover in electronic transport, D. Gruss, K. A. Velizhanin & **M. Zwolak***, Sci. Rep. **6**, 24514 (2016).
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39. Crossover behavior of the thermal conductance and Kramers' transition rate theory, K. A. Velizhanin*, S. Sahu, C.-C. Chien, Y. Dubi & **M. Zwolak***, Sci. Rep. **5**, 17506 (2015).
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36. Nonequilibrium ionic response of biased mechanically controllable break junction (MCBJ) electrodes, K. Doi*, M. Tsutsui, T. Ohshiro, C.-C. Chien, **M. Zwolak**, M. Taniguchi*, T. Kawai*, S. Kawano* & M. Di Ventra*, J. Phys. Chem. C, **118**, 3758 (2014).
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33. Complementarity of quantum discord and classically accessible information, **M. Zwolak*** & W. H. Zurek, Sci. Rep. **3**, 1729 (2013).
32. Tunable thermal switching via DNA–based nano–devices, C.-C. Chien*, K. A. Velizhanin, Y. Dubi & **M. Zwolak***, Nanotechnology, **24**, 095704 (2013).
31. DNA sequencing via electron tunneling, **M. Zwolak*** & M. Di Ventra*, IEEE Int. Sym. Cir. Sys. 2295 (2012).
30. A quantum phase transition in a quantum external field: Superposing two magnetic phases, M. M. Rams, **M. Zwolak** & B. Damski*, Sci. Rep. **2**, 655 (2012).
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27. Bosonic and fermionic transport phenomena of ultracold atoms in one–dimensional optical lattices, C.-C. Chien, **M. Zwolak** & M. Di Ventra, Phys. Rev. A, **85**, 041601 (2012).
26. Non–local quantum superpositions of topological defects, J. Dziarmaga, W. H. Zurek* & **M. Zwolak**, Nat. Phys. **8**, 49 (2012).
25. Driving denaturation: Nanoscale thermal transport as a probe of DNA melting, K. A. Velizhanin*, C.-C. Chien, Y. Dubi & **M. Zwolak***, Phys. Rev. E, **83**, 050906 (2011).
24. Dehydration and ionic conductance quantization in nanopores, **M. Zwolak**, J. Wilson & M. D. Ventra, J. Phys.: Condens. Matter, **22**, 454126 (2010).
23. Redundant imprinting of information in nonideal environments: Objective reality via a noisy channel, **M. Zwolak**, H. T. Quan & W. H. Zurek, Phys. Rev. A, **81**, 062110 (2010).
22. Effect of noise on DNA sequencing via transverse electronic transport, M. Krems, **M. Zwolak**, Y. V. Pershin & M. D. Ventra*, Biophys. J. **97**, 1990 (2009).
21. Quantized ionic conductance in nanopores, **M. Zwolak**, J. Lagerqvist & M. Di Ventra, Phys. Rev. Lett. **103**, 128102 (2009).
20. Quantum Darwinism in a mixed environment, **M. Zwolak**, H. T. Quan & W. H. Zurek, Phys. Rev. Lett. **103**, 110402 (2009).

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19. Numerical ansatz for solving integro–differential equations with increasingly smooth memory kernels: spin–boson model and beyond, **M. Zwolak*,** Computational Science & Discovery, **1,** 015002 (2008).
18. Finite representations of continuum environments, **M. Zwolak*,** J. Chem. Phys. **129,** 101101 (2008).
17. Colloquium: Physical approaches to DNA sequencing and detection, **M. Zwolak*** & M. Di Ventra*, Rev. Mod. Phys. **80,** 141 (2008).
16. Influence of the environment and probes on rapid DNA sequencing via transverse electronic transport, J. Lagerqvist, **M. Zwolak** & M. D. Ventra*, Biophys. J. **93,** 2384 (2007).
15. Comment on "Characterization of the tunneling conductance across DNA bases", J. Lagerqvist, **M. Zwolak** & M. Di Ventra*, Phys. Rev. E, **76,** 013901 (2007).
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13. Sigma–profile database for using COSMO–based thermodynamic methods, E. Mullins, R. Oldland, Y. A. Liu*, S. Wang, S. I. Sandler, C.-C. Chen, **M. Zwolak** & K. C. Seavey, Ind. Eng. Chem. Res. **45,** 4389 (2006).
12. Fast DNA sequencing via transverse electronic transport, J. Lagerqvist, **M. Zwolak** & M. Di Ventra*, Nano Lett. **6,** 779 (2006).
11. Dynamical corrections to the DFT–LDA electron conductance in nanoscale systems, N. Sai, **M. Zwolak,** G. Vignale & M. Di Ventra*, Phys. Rev. Lett. **94,** 186810 (2005).
10. Inelastic effects on the transport properties of alkanethiols, Y.-C. Chen, **M. Zwolak** & M. Di Ventra*, Nano Lett. **5,** 621 (2005).
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5. Inelastic current–voltage characteristics of atomic and molecular junctions, Y.-C. Chen, **M. Zwolak** & M. Di Ventra*, Nano Lett. **4,** 1709 (2004).
4. Local heating in nanoscale conductors, Y.-C. Chen, **M. Zwolak** & M. Di Ventra*, Nano Lett. **3,** 1691 (2003).
3. Chaotic transport in low–dimensional superlattices, **M. Zwolak,** D. Ferguson & M. Di Ventra*, Phys. Rev. B, **67,** 081303 (2003).
2. Percolation study of defect tolerance in missing-crossbar networks, **M. Zwolak,** R. Zallen & M. Di Ventra*, Solid State Commun. **124,** 167 (2002).
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