

Edward S. Boyden, Ph. D.

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Vision To develop technologies that yield principles of how neural circuits generate behavior, go awry in brain disorders, and can be controlled to yield therapeutic outcomes.

Research and work activities

Massachusetts Institute of Technology, Cambridge, MA (2011-present)
Associate Professor, MIT Media Lab (Benesse Career Development Professor)
Investigator, MIT McGovern Institute
Joint Professor, MIT Department of Biological Engineering
Joint Professor, MIT Department of Brain and Cognitive Sciences
Leader, Synthetic Neurobiology Group
Developing tools for systematic analysis and engineering of the brain.

Massachusetts Institute of Technology, Cambridge, MA (2007-2011)
Assistant Professor, MIT Media Lab (Benesse Career Development Professor)
Joint Professor, MIT Department of Biological Engineering
Joint Professor, MIT Department of Brain and Cognitive Sciences
Leader, Synthetic Neurobiology Group
Developing tools for systematic analysis and engineering of the brain.

Massachusetts Institute of Technology, Cambridge, MA (2006-2007)
Visiting Scientist, MIT Media Lab; *Leader*, Neuroengineering and Neuromedia Group
Developing tools for systematic analysis and engineering of the brain.

Stanford University, Stanford, CA (2005-2006)
Helen Hay Whitney fellow, Depts. of Bioengineering, Applied Physics, Biological Sciences,
Inventing optical methods for accelerating neuroscience progress.

Boyden Innovations, Cambridge, MA (2005-present)
Sole proprietor, Independent inventor
Developing novel medical devices and applications of physics to systematic bioengineering.

Stanford University, Stanford, CA (1999-2005)
Hertz predoctoral fellow, NIH NRSA predoctoral fellow, Program in Neurosciences, Depts. of Molecular and Cellular Physiology and Neurobiology, with Drs. Jennifer Raymond and Richard Tsien.
Studied how neural circuits selectively engage plasticity to store specific memories.
Developed optical methods for controlling neural activity.

Bell Labs, Lucent Technologies, Murray Hill, NJ (1998-99)
Research assistant, with Drs. Sebastian Seung and Michale Fee.
Created an elementary phase-resetting model of birdsong stochasticity.
Helped implement active electrode stabilizer for neural recordings in awake animals.

Massachusetts Institute of Technology, MIT Media Lab, Cambridge, MA (1998-99)
Graduate research, with Dr. Neil Gershenfeld.
Design and fabrication of prototype nuclear magnetic resonance (NMR) quantum computer.
Engineered control software for the MIT ORCA-1 autonomous submarine.
Designed hardware for a MEMS accelerometer using electron-tunneling.

Massachusetts Institute of Technology, MIT Media Lab, Cambridge, MA (1996-98)
Research assistant, with Dr. Neil Gershenfeld.
Programmed machine-learning tools for reconstructing dynamics of a digital violin.
Created 3D, non-contact interactive design program based on electric field imaging of hands.

Activision, Inc., Santa Monica, CA (1997)
Research programmer
Designed real-time, physics-based animation engine for video games.

University of North Texas Chemistry Department, Denton, TX (1994-95)
Research assistant, with Dr. Paul Braterman
Research on the origins of life; synthesized and analyzed layered double hydroxides with intercalated anions.

Education

Stanford University, Stanford, CA (1999-2005)

GPA: 4.1/4.0

PhD candidate, Neurosciences

Thesis title: *Task-specific neural mechanisms of memory encoding*

Massachusetts Institute of Technology, Cambridge, MA (1995-99)

GPA: 5.0/5.0

M.Eng. Electrical Engineering and Computer Science

B.S. Electrical Engineering and Computer Science

B.S. Physics

Thesis title: *Quantum Computation: Theory and Implementation*

Texas Academy of Mathematics and Science, University of North Texas, Denton, TX (1993-95)

GPA: 4.0/4.0

Major awards (since 1998)

2012, World Economic Forum, Davos, Switzerland, Invited Speaker
2011, IET A F Harvey Engineering Research Prize
2011, New York Stem Cell Foundation Robertson Neuroscience Investigator Award
2011, TED, Invited Speaker
2011, NSF CAREER Award
2010, *Nature Methods* Method of the Year
2010, Paul Allen Distinguished Investigator Award in Neuroscience
2010, Aspen Brain Forum Prize in Neurotechnology, Finalist
2010, Eppendorf and Science Prize for Neurobiology, Finalist
2008, Discover Magazine, 20 Best Scientists Under Age 40
2008, NARSAD Young Investigator Award
2008, MIT Alumni Class Funds Award for Excellence in Educational Innovation
2008, Alfred P. Sloan Research Fellowship
2008, Department of Defense Post-Traumatic Stress Disorder Concept Award
2007, Discovery Science Channel, Top 5 'Best Science Moments 2007'
2007, Society for Neuroscience, Research Award for Innovation in Neuroscience (RAIN)
2007, NIH Director's New Innovator Award
2007, Wallace H. Coulter Foundation Early Career Translational Research Award in Biomedical Engineering
2006, *Technology Review* TR35, World's Top 35 Innovators under Age 35
2006, Fannie and John Hertz Foundation, Top Ph.D. Thesis Prize
2005, McKnight Technological Innovations in Neuroscience Award, Investigator
2005, Helen Hay Whitney Fellowship
2004, Dan David Prize Scholarship (Future Dimension, Brain Sciences)
2004, NIH Ruth L. Kirschstein National Research Service Award
1999, Fannie and John Hertz Fellowship
1999, MIT Microelectromechanical Systems design competition, 1st place
1998, International Autonomous Underwater Vehicle Competition, 1st place

Classes Taught

Bioinstrumentation Project Lab, 20.345, MIT (Spring 2011)

In-depth examination of instrumentation design, principles and techniques for studying biological systems, from single molecules to entire organisms. Lectures cover optics, advanced microscopy techniques, electronics for biological measurement, magnetic resonance imaging, computed tomography, MEMs, microfluidic devices, and limits of detection. Students select two lab exercises during the first half of the semester and complete a final design project in the second half. Lab emphasizes design process and skillful realization of a robust system.

Biological Instrumentation and Measurement, 20.309, MIT (Spring 2009, Spring 2010)

Sensing and measurement aimed at quantitative molecular/cell/tissue analysis in terms of

genetic, biochemical, and biophysical properties. Methods include light and fluorescence microscopies, and electro-mechanical probes (atomic force microscopy, optical traps, MEMS devices). Application of statistics, probability, signal and noise analysis, and Fourier techniques to experimental data. Preferences given to juniors and seniors.

Applications of Neuroengineering, MAS.882/9.433, MIT (Spring 2008, Spring 2009)
Project-focused course in which students take top-down approach to developing technologies that address critical clinical and basic-science problems of human brain function. Focus is on application of engineering principles to development of systematically powerful tools. Problem domains include neurological/psychiatric disorders, consciousness, and human cognitive augmentation. Students work in teams to apply cross-disciplinary (e.g., molecular, physical, nanotechnological) building blocks to design new tools for the analysis and engineering of the brain.

Principles of Neuroengineering, MAS.881/20.452/9.422, MIT (Fall 2007, Fall 2008, Fall 2009, Fall 2010, Fall 2011)
Covers principles underlying current and future technologies for brain analysis and engineering, for neurology, psychiatry, and neuroscience. Focuses on using biophysical, biochemical, and anatomical models to understand technology design constraints governing ability to observe and alter brain function. Topics include functional magnetic resonance imaging, electromagnetic recording/stimulation, neuropharmacology, optical cellular imaging, and gene/stem-cell therapy. Design projects by student teams.

Neurotechnology Ventures, MAS.883/9.455/20.454/15.128 (MAS.961/9.912J/HST.588 in Spring 2007; MAS.883/9.455/20.454/15.128/HST.588 Fall 2008-Fall 2009), MIT (Spring 2007, Fall 2008, Fall 2009, Fall 2010, Fall 2011)
A special seminar focused on the challenges of envisioning, planning and building startups; commercializing innovations from neuroscience; and the blossoming domain of neuroengineering. (Taught in collaboration with J. Bonsen and R. Ellis-Behnke.)

Social and professional activities

Professional activities: conferences and committees
2012, World Economic Forum, Davos, Switzerland, Discussion Leader
2011, Milken Institute, Accelerating Innovation in the Bioscience Revolution, Invited Participant and Panelist
2012, SPIE BiOS 2012 Meeting, Neurons and Photons Conference, San Jose, CA, Program Committee
2011, FENS-IBRO-SFN Summer School, Causal Neuroscience, Bertinoro, Italy, Faculty
2011, Allen Institute for Brain Science, Neural Coding Meeting, Invited Participant
2011, Marine Biology Laboratory, Neural Systems and Behavior Course, Visiting Faculty
2011, Arnold and Mabel Beckman Initiative for Macular Research, National Academies of Sciences, Arnold and Mabel Beckman Center, Irvine, CA, invited participant
2010-2014, NIH Molecular Neurogenetics (MNG), Study Section Member
2010, Society for Neuroscience Meeting, Mini-Symposium Co-Chair, "Towards the Second Generation of Optogenetic Tools," San Diego, CA
2010, Program Committee, First Augmented Human International Conference, '10, Megeve, France.
2010, Science Magazine, Workshop
2009, SPIE BiOS 2009 Meeting, Neurons and Photons Conference, San Jose, CA, Program Committee
2008, National Academies Keck Futures Initiative 2008: Complex Systems, Arnold and Mabel Beckman Center, Irvine, CA, invited participant
2008, NIH Blueprint for Neuroscience Research, Pain Grand Challenges/Transformative R01 Workshop, invited participant
2008, Computational and Systems Neuroscience (CoSyNe) Meeting, Workshop Organizer, "How to solve systems neuroscience problems with molecular tools," Snow Bird, Utah
2007, NIH Blueprint for Neuroscience Research, Neuroplasticity Workshop, invited participant
2007, BodyNets 2007 Conference, Florence, Italy, Technical Program Committee member
2006, United Kingdom Office of Horizon Scanning, Institute for the Future, Palo Alto, CA,

invited workshop participant
2000, NINDS Conference on Computational and Theoretical Neuroscience: From Synapse to Circuitry, writer

Professional: other

2011-present, Faculty of 1000 (F1000), Member
2010-present, Aspen Brain Forum, Scientific Advisory Board
2010-present, XPrize Foundation, occasional advisor
2009-present, *Technology Review*, columnist
2009-present, SPIE, member
2009-present, Lifeboat Foundation, Advisory Board
2007-present, *Technology Review*, official blogger/writer
2007-present, Fannie and John Hertz Foundation, Fellowship Interviewer
2000-present, Society for Neuroscience, member

MIT

2010, MIT McGovern Institute Symposium: Cells, Circuits, and Behavior, co-organizer
2009-present, MIT Interdepartmental Graduate Program in Biophysics, faculty member
2009-present, MIT Molecular and Cellular Neuroscience Track, faculty member
2009-present, MIT Microsystems Technology Laboratories, affiliate member
2008-present, MIT Department of Brain and Cognitive Sciences, Joint Professor
2007-present, MIT Media Lab Center for Human Augmentation, Co-Director
2007-2010, MIT McGovern Institute for Brain Research, Associate Faculty
2007-present, MIT Picower Center for Learning and Memory, Affiliate Faculty
2007-present, MIT Department of Biological Engineering, Joint Faculty
2007, MIT Department of Biological Engineering, Affiliate Faculty
2006-present, MIT Computational and Systems Biology Initiative, Faculty Member

Major Publications

Papers (peer-reviewed)

1. Maguire, Y., Boyden, E. S., Gershenfeld, N. (2000) Toward a table-top quantum computer, *IBM Systems Journal* 39:3&4, p.823.
2. Boyden, E. S., Raymond, J. L. (2003) Active reversal of motor memories reveals rules governing memory encoding, *Neuron* 39(6):1031-42.
3. Boyden, E. S.*, Katoh, A. *, Raymond, J. L. (2004) Cerebellum-dependent learning: The role of multiple plasticity mechanisms, *Annual Review of Neuroscience* 27:581-609. (* co-first authors)
4. Kimpo, R. R.*, Boyden, E. S.*, Katoh, A., Ke, M. C., Raymond, J. L. (2005) Distinct patterns of stimulus generalization of increases and decreases in VOR gain, *Journal of Neurophysiology* 94(5):3092-3100. (* co-first authors)
5. Boyden, E. S., Zhang, F., Bamberg, E., Nagel, G., Deisseroth, K. (2005) Millisecond-timescale, genetically-targeted optical control of neural activity, *Nature Neuroscience* 8(9):1263-1268.
6. Boyden, E. S., Katoh, A., Pyle, J. L., Chatila, T. A., Tsien, R. W., Raymond, J. L. (2006) Selective engagement of plasticity mechanisms for motor memory storage, *Neuron* 51(6):823-834.
7. Zhang, F., Wang, L.-P., Boyden, E. S., Deisseroth, K. (2006) Channelrhodopsin-2 and optical control of excitable cells, *Nature Methods* 3(10):785-92.
8. Han, X. and Boyden, E. S. (2007) Multiple-color optical activation, silencing, and desynchronization of neural activity, with single-spike temporal resolution, *PLoS ONE* 2(3): p. e299.
9. Wang, H., Peca, J., Matsusaki, M., Matsusaki, K., Noguchi, J., Qiu, L., Wang, D., Zhang, F., Boyden, E. S., Deisseroth, K., Kasai, H., Hall, W. C., Feng, G., Augustine, G. J. (2007)

High-speed mapping of synaptic connectivity using photostimulation in channelrhodopsin-2 transgenic mice, *Proceedings of the National Academy of Sciences* 104(19):8143-848.

10. Liao, Y. J., Safa, P., Chen, Y.-R., Sobel, R. A., Boyden, E. S., Tsien, R. W. (2008) Anti-Ca²⁺ channel antibody attenuates Ca²⁺ currents and mimics cerebellar ataxia *in vivo*, *Proceedings of the National Academy of Sciences* 105(7):2705-2710.

11. Han, X.*, Qian, X., Bernstein, J.G., Zhou, H.-H., Talei Franzesi, G., Stern, P., Bronson, R.T., Graybiel, A.M., Desimone, R., and Boyden, E.S. * (2009) Millisecond-Timescale Optical Control of Neural Dynamics in the Nonhuman Primate Brain, *Neuron* 62(2): 191-198. (* co-corresponding authors)

12. Han X, Qian X, Stern P, Chuong A and Boyden ES (2009) Informational Lesions: Optical Perturbation of Spike Timing and Neural Synchrony Via Microbial Opsin Gene Fusions. *Frontiers in Molecular Neuroscience* 2:12. doi:10.3389/neuro.02.012.2009

13. Chow, B. Y.*, Han, X.*, Dobry, A. S., Qian, X., Chuong, A. S., Li, M., Henninger, M. A., Belfort, G. M., Lin, Y., Monahan, P. E., Boyden, E. S. (2010) High-performance genetically targetable optical neural silencing by light-driven proton pumps, *Nature* 463:98-102. (* co-first authors)

14. Chan, S. Y., Bernstein, J. G., Boyden, E. S. (2010). Scalable Fluidic Injector Arrays for Viral Targeting of Intact 3-D Brain Circuits, *JoVE*. 35. <http://www.jove.com/index/details.stp?id=1489>, doi: 10.3791/1489

15. Knopfel, T., Lin, M. Z., Levskaya, A., Tian, L., Lin, J. Y., Boyden, E. S. (2010) Toward the Second Generation of Optogenetic Tools, *Journal of Neuroscience* 30(45):14998-15004.

16. Zorzos, A. N., Boyden, E. S.*, and Fonstad, C. G. (2010) Multiwaveguide implantable probe for light delivery to sets of distributed brain targets, *Optics Letters* 35(24):4133-5. (*corresponding author).

17. Desai M., Kahn I., Knoblich U., Bernstein J., Atallah H., Yang A., Kopell, N., Buckner R.L., Graybiel A. M., Moore C. I.*, and Boyden E. S.* (2011) Mapping Brain Networks in Awake Mice Using Combined Optical Neural Control and fMRI, *Journal of Neurophysiology* 105(3):1393-405. (* co-corresponding authors)

18. Han, X.*, Chow, B. Y.*, Zhou, H., Klapoetke, N. C., Chuong, A., Rajimehr, R., Yang, A., Baratta, M. V., Winkle, J., Desimone, R., Boyden, E. S. (2011) A high-light sensitivity optical neural silencer: development and application to optogenetic control of non-human primate cortex, *Frontiers in Systems Neuroscience*. 5:18. doi: 10.3389/fnsys.2011.00018 (* co-first authors)

19. Doroudchi, M. M., Greenberg, K. P., Liu, J., Silka, K. A., Boyden, E. S., Lockridge, J. A., Arman, A. C., Janani, R., Boye, S. E., Boye, S. L., Gordon, G. M., Matteo, B. C., Sampath, A. P., Hauswirth, W. W., Horsager, A. (2011) Virally delivered Channelrhodopsin-2 Safely and Effectively Restores Visual Function in Multiple Mouse Models of Blindness, *Molecular Therapy*, 19(7):1220-9

20. Boyden, E.S. (2011) A history of optogenetics: the development of tools for controlling brain circuits with light. *F1000 Biology Reports* 3:11. doi:10.3410/B3-11.

21. Chow, B. Y., Chuong, A. S., Klapoetke, N. C., Boyden, E. S. (2011) Synthetic Physiology: Strategies for Adapting Tools from Nature for Genetically-Targeted Control of Fast Biological Processes, Chapter 18, *Methods in Enzymology: Synthetic Biology, Part A: Methods for Part/Device Characterization and Chassis Engineering*, edited by Christopher Voigt, Volume 497, Elsevier.

22. Wentz, C. T., Bernstein, J. G., Monahan, P., Guerra, A., Rodriguez, A., Boyden, E. S. (2011) A Wirelessly Powered and Controlled Device for Optical Neural Control of Freely-

23. Chow, B. Y. and Boyden, E. S. (2011) Synthetic Physiology, *Science* 332(6037):1508-1509.
24. Tsunematsu, T., Kilduff, T., Boyden, E. S., Takahashi, S., Tominaga, M., Yamanaka, A. (2011) Acute optogenetic silencing of orexin/hypocretin neurons induces slow wave sleep in mice, *Journal of Neuroscience*, 31(29): 10529-10539.
25. Joo, J., Chow, B. Y., Prakash, M., Boyden, E. S., Jacobson, J. M. (2011) Face-selective electrostatic control of hydrothermal zinc oxide nanowire synthesis, *Nature Materials*, 10(8):596-601.
26. McCarthy, M. M., Moore-Kochlacs, C., Xuan Gu, T., Boyden, E. S., Han, X., Kopell, N. J. (2011) Striatal origin of the pathologic beta oscillations in Parkinson's disease, *Proceedings of the National Academy of Sciences*, 108(28):11620-5.
27. Bernstein, J. G., Garrity, P. A.*, Boyden, E. S.* (2011) Optogenetics and thermogenetics: technologies for controlling the activity of targeted cells within intact neural circuits, *Current Opinion in Neurobiology*, in press, doi:10.1016/j.conb.2011.10.023. (* co-corresponding authors)
28. Chow, B. Y., Han, X., Boyden, E. S. (2011) Genetically encoded molecular tools for light-driven silencing of targeted neurons, invited paper, *Progress in Brain Research*. In press
29. Bernstein, J. G., Boyden, E. S. (2011) Optogenetic tools for analyzing the neural circuits of behavior, in press, *Trends in Cognitive Sciences*. doi:10.1016/j.tics.2011.10.003
30. Kahn, I. * Desai, M., Knoblich, U., Bernstein, J., Henninger, M., Graybiel, A. M., Boyden, E. S.*, Buckner, R. L. *, Moore, C. I. * (2011) Characterization of the Functional MRI Response Temporal Linearity via Optical Control of Neocortical Pyramidal Neurons, *Journal of Neuroscience* 31(42):15086-15091. (* co-corresponding authors)
31. Kleinlogel, S., Terpitz, U., Legrum, B., Gokbuget, D., Boyden, E. S., Bamann, C., Wood, P. G., Bamberg, E. (2011) A gene-fusion strategy for stoichiometric and co-localized expression of light-gated membrane proteins, *Nature Methods*, advance online publication. doi:10.1038/nmeth.1766
32. Borgers, C., Talei Franzesi, G., LeBeau, F., Boyden, E. S., Kopell, N. (2011) Minimal size of cell assemblies coordinated by gamma oscillations, *PLoS Computational Biology*, accepted.

Conference Papers and Talks (Refereed)

1. Schoner, B., Cooper, C., Douglas, C. L., Boyden, E. S., Gershenfeld, N. A. (1999) Data-driven modeling of acoustical instruments, *Journal of the Acoustic Society of America* 105(2):1328.
2. Fletcher, R., Omojola, O., Boyden, E. S., Gershenfeld, N. (1999) Reconfigurable Agile Tag Reader Technologies for Combined EAS and RFID capability, *Proceedings of the Second IEEE Workshop on Automatic Identification Advanced Technologies*, Summit, New Jersey.
3. Boyden, E. S., Tsien, R. W., Chatila, T. A., Raymond, J. L. (2003) Is oppositely directed motor learning implemented with inverse plasticity mechanisms?, *Proceedings of the Annual Symposium on Advances in Computational Motor Control, Volume 2*, Emanuel Todorov and Reza Shadmehr, editors, New Orleans, Louisiana.
4. Boyden, E. S., Chatila, T. A., Raymond, J. L. (2004) The contribution of inverse plasticity

mechanisms to cerebellum-dependent learning. *Talk, at Computational and Systems Neuroscience (CoSyNe)*, Cold Spring Harbor, NY, March 24-28, 2004.

5. Han, X., and Boyden, E. S. (2007) Two-color, bi-directional optical voltage control of genetically-targeted neurons, *Spotlight Presentation, at Computational and Systems Neuroscience (CoSyNe)*, Salt Lake City, UT, Feb 22-25, 2007.

6. Bernstein, J. G., Han, X., Henninger, M. A., Ko, E. Y., Qian, X., Franzesi, G. T., McConnell, J. P., Stern, P., Desimone, R., and Boyden, E. S. (2008) Prosthetic systems for therapeutic optical activation and silencing of genetically-targeted neurons. *Proc Soc Photo Opt Instrum Eng* 6854:68540H.

7. Chow B, Han X, Qian X and Boyden E (2009). High-performance halorhodopsin variants for improved genetically-targetable optical neural silencing. *Frontiers in Systems Neuroscience. Conference Abstract: Computational and systems neuroscience*. doi: 10.3389/conf.neuro.10.2009.03.347

8. Boyden E, Franzesi G T, Qian X, Li M, Han X, Borgers C, Kopell N J, Le Beau F and Whittington M A (2009). Probing mechanisms of gamma rhythmogenesis with cell type-specific optical neural control. *Frontiers in Systems Neuroscience. Conference Abstract: Computational and systems neuroscience*. doi: 10.3389/conf.neuro.10.2009.03.299

9. Doroudchi, M. M., Greenberg, K. P., Zorzos, A. N., Hauswirth, W. W., Fonstad, C. G., Horsager, A., Boyden, E. S. (2011) Towards Optogenetic Sensory Replacement, *33rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC '11)*.

10. Boyden, E. S. (2011) Optogenetics. *33rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC '11)*.

11. Kodandaramaiah, S., Krijnen, M., Go, J., Malik, S., Sondej, N., Khatait, J. P., Boyden, E. S., Aarts, R. G. K. M., Brouwer, D. M., Forest, C. F. (2011) Characterization of translation of fused silica micropipettes in non-rectilinear trajectories, *Proceedings of the 26th Annual Meeting of the American Society for Precision Engineering*, Denver, CO.

Patents and Patent Applications

Total: 210 patents or patents pending.

GENBANK Contributions, Nucleotide

1. GenBank: EF537649.1. Synthetic construct mammalian codon-optimized halorhodopsin gene, complete cds. Submitted 4/4/2007.
2. GenBank: EU714030.1. Synthetic construct channel rhodopsin-2-GFP (ChR2-GFP) gene, complete cds. Submitted 5/11/2008.
3. GenBank: GU045593.1. Synthetic construct Arch gene, complete cds. Submitted 9/28/2009.
4. GenBank: GU045594.1. Synthetic construct Arch-GFP gene, complete cds. Submitted 9/28/2009.
5. GenBank: GU045595.1. Synthetic construct Mac gene, complete cds. Submitted 9/28/2009.
6. GenBank: GU045596.1. Synthetic construct Mac-GFP gene, complete cds. Submitted 9/28/2009.
7. GenBank: GU045597.1. Synthetic construct ss-Prl-Arch gene, complete cds. Submitted 9/28/2009.
8. GenBank: GU045598.1. Synthetic construct ss-Arch-GFP-ER2 gene, complete cds. Submitted 9/28/2009.
9. GenBank: GU045599.1. Synthetic construct ss-Prl-Arch-GFP gene, complete cds. Submitted 9/28/2009.
10. GenBank: HM367071. Synthetic construct ArchT gene, complete cds, 747 bases.

Submitted May 27, 2010.

11. GenBank: HM367072, Synthetic construct ArchT-GFP gene, complete cds, 1476 bases. Submitted May 27, 2010.

Theses

1. Boyden, E. S. (1999) Quantum Computing: Theory and Implementation, *Master's Thesis in Electrical Engineering and Computer Science, Bachelor's Thesis in Physics*, Massachusetts Institute of Technology.
2. Boyden, E. S. (2005) Task-selective neural mechanisms of memory encoding, *Ph. D. Thesis in Neurosciences*, Stanford University.

Synthetic Neurobiology Memos

1. Synthetic Neurobiology Memo #1 (2006) Optical Fiber/Laser System for In Vivo (Multicolor) Light Delivery for Brain Neuromodulation. Online.
2. Synthetic Neurobiology Memo #2 (2009) Lentivirus production for high-titer, cell-specific, in vivo neural labeling. Online.
3. Synthetic Neurobiology Memo #4 (2009) Very Simple Off-The-Shelf Laser and Viral Injector Systems for In Vivo Optical Neuromodulation. Online.
4. Synthetic Neurobiology Memo #3 (2009) Circuit Boards and Software for Heart Rate and Galvanic Skin Response Measurements. Online.

Byline Articles

1. Boyden, E. S. (2000) Computational and Theoretical Neuroscience: From Synapse to Circuitry. National Institutes of Health/National Institute of Neurological Disorders and Stroke, Technical Report for Workshop of April 28, 2000.
2. Boyden, E. S. (2007) Engineering the Brain ('Notebooks' column), *Technology Review*, March/April 2007 issue, p. 34-35.
3. Boyden, E. S. In Pursuit of Human Augmentation. Ed Boyden's Blog. *Technology Review*. 9/17/07. (<http://www.technologyreview.com/blog/boyden/21839/>).
4. Boyden, E. S. Open Philanthropy. Ed Boyden's Blog. *Technology Review*. 9/24/07. (<http://www.technologyreview.com/blog/boyden/21850/>).
5. Boyden, E. S. Synthetic Neurobiology. Ed Boyden's Blog. *Technology Review*. 10/9/07. (<http://www.technologyreview.com/blog/boyden/21871/>).
6. Boyden, E. S. How to Think. Ed Boyden's Blog. *Technology Review*. 11/13/07. (<http://www.technologyreview.com/blog/boyden/21925/>).
7. Boyden, E. S. Training a Generation of Neuroengineers. Ed Boyden's Blog, *Technology Review*. 4/22/08. (<http://www.technologyreview.com/blog/boyden/22055/>).
8. Boyden, E. S. Inverting the Core. Ed Boyden's Blog. *Technology Review*. 7/14/08. (<http://www.technologyreview.com/blog/boyden/22096/>).
9. Boyden, E. S. Research as a Community-Building Activity Ed Boyden's Blog. *Technology Review*. 7/28/08. (<http://www.technologyreview.com/blog/boyden/22102/>).
10. Boyden, E. S. Averting Disasters, Preventing Problems. Ed Boyden's Blog. *Technology Review*. 9/2/08. (<http://www.technologyreview.com/blog/boyden/22122/>).

11. Boyden, E. S. Civilization as Experiment. Ed Boyden's Blog. *Technology Review*. 1/19/09. (<http://www.technologyreview.com/blog/boyden/22512/>).
12. Boyden, E. S. (2009) The Singularity and the Fixed Point. Column, *Technology Review*. 9/4/2009. (<http://www.technologyreview.com/biomedicine/23354/>).
13. Boyden, E. S. and Chow, B. Y. (2010) Defining An Algorithm For Inventing From Nature. Column, *Technology Review*. 1/19/2010.
14. Boyden, E. S. (2010) Controlling the brain with light. *SPIE Newsroom*. 6/10/2010.
15. Boyden, E. S., Allen B. D., Fritz D. (2010) Brain Coprocessors, Column, *Technology Review*. 9/23/2010.
16. Boyden, E. S. (2010) "Molecular Tools for Controlling Brain Circuits with Light," Eppendorf and Science Prize for Neurobiology Competition Essay, *Science Magazine*.
17. Boyden, E. S. (2011) The Birth of Optogenetics, *The Scientist*, July 2011 Issue. (Cover Story.)
18. Boyden, E. S. (2011) Optogenetics: Using Light to Control the Brain, Cerebrum, The Dana Foundation, November 2011.

Other writings

1. Boyden, E. S. (1996) The Practical Physicist's OpenGL tutorial. Online.
2. Boyden, E. S. (1997) Tree-based Cluster Weighted Modeling: Towards A Massively Parallel Real-Time Digital Stradivarius. Online.
3. Boyden, E. S. (1997) A physics-based animation engine. Online.
4. Altshuler, R. C., Boyden, E. S., Chase, C. C., Davis, B. M., Delatorre, F. J., Edelson, J., Elgart, J. D., Gates, H. G., Hancher, M. D., Hasan, L. M., Huang, A. S., Knaian, A. N., Lee, F., Newburg, S. O., Polito, B. F., Reynolds, M. S., Smith, E. D., Warmann, E. C. (1998) The ORCA-1: An Autonomous Underwater Vehicle. Online.
5. Boyden, E. S., El Rifai, O., Hubert, B., Karpman, M., Roberts, D. (1999) A High-Performance Tunneling Accelerometer. Online.

Book chapters

1. Task Group Summary 6 (The Brain), *The National Academies Keck Futures Initiative: Complex Systems: Task Group Summaries*, 2009, ISBN 0-309-13725-X, National Academies Keck Future Initiative, National Academies Press, Washington DC.
2. Boyden, E. S., Han, X., Talei Franzesi, G., Chan, S., Bernstein, J., Qian, X., Li, M. (2009) New Techniques for Investigating Brain Rhythms: Optical Neural Control and Multielectrode Recording, In: *Rhythms of the Neocortex: Where Do They Come From and What Are They Good For?* (Kopell N., ed.) pp. 65-75. Washington, DC: Society for Neuroscience.
3. Chow, B. Y., Han, X., Bernstein, J. G., Monahan, P. E., Boyden, E. S. (2011) Light-Activated Ion Pumps and Channels for Temporally Precise Optical Control of Activity in Genetically Targeted Neurons, Chapter 6, *Photosensitive Molecules for Controlling Biological Function*, edited by James J. Chambers and Richard H. Kramer, Neuromethods Series Volume 55, 2011, DOI: 10.1007/978-1-61779-031-7, Humana Press.
4. Boyden, E.S. (2010) Optogenetics. Chapter in *McGraw-Hill Yearbook of Science & Technology*, McGraw-Hill.

**Invited talks
and other
talks**

Invited talks

1. Boyden, E. S. (2003) How multiple plasticity mechanisms contribute to versatile motor learning. Stanford Neurosciences Program 2003 Retreat, Monterey, CA.
2. Boyden, E. S. (2005) Causal roles of neurons and neural circuits in learning and behavior. Hertz Foundation Scholars 2005 Retreat, Pt. Reyes, CA.
3. Boyden, E. S. (2006) Solving the brain systematically: tools for the analysis and engineering of neural circuits. Google Tech Talk series, Google, Mountain View, CA.
4. Boyden, E. S. (2006) Cutting-edge technologies for the systematic analysis of neural circuit dynamics. UCSF, Program in Bioengineering Seminar Series, San Francisco, CA.
5. Boyden, E. S. (2006) Resolving the computational role of specific neural circuit elements. McGovern Institute, MIT, Cambridge, MA.
6. Boyden, E. S. (2006) Towards the analysis of cortical computation via optical control of neural activity. Computation and Neural Systems, Caltech, Pasadena, CA.
7. Boyden, E. S. (2006) Enabling technologies for controlling neural circuit functions. Brain Science Program, Brown University, Providence, RI.
8. Boyden, E. S. (2006) Technologies for the systematic analysis of neural circuit function. Center for Brain Science, Harvard University, Cambridge, MA.
9. Boyden, E. S. (2006) Neural Circuit Technology: Towards New Brain Interfaces and Biological Tools. MIT Media Laboratory, MIT, Cambridge, MA.
10. Boyden, E. S. (2006) Engineering tools for engineering the brain. Division of Engineering, Brown University, Providence, RI.
11. Boyden, E. S. (2006) Ultraprecise biological interfaces: Controlling life with light. Opening night talk, Science Foo (SciFoo) Camp, Google, Mountain View, CA.
12. Boyden, E. S. (2006) Launching the Open Brain Stimulator Project. Session leader, Foo Camp, O'Reilly Media, Sebastopol, CA.
13. Boyden, E. S. (2006) The future of neural devices. Stanford Biodesign Program, Stanford, CA.
14. Boyden, E. S. (2006) Systematic approaches for understanding neural circuit function. Center for Basic Neuroscience, UT Southwestern Medical School, Dallas, TX.
15. Boyden, E. S. (2007), Technologies for the Precise Control of Neural Circuits. Sloan-Swartz Seminars on Theoretical Neurobiology, Salk Institute for Biological Studies, San Diego, CA.
16. Boyden, E. S. (2007) New Technologies for Repairing Neural Computations. The Stanley Center for Psychiatric Research, MIT, Cambridge, MA.
17. Boyden, E. S. (2007) Technologies for engineering neural circuit function. Department of Biological Engineering, MIT, Cambridge, MA.
18. Boyden, E. S. (2007) Engineering the Brain: Towards Systematic Cures for Neural Disorders. MIT Media Lab H2.0 (Human 2.0) Symposium, MIT, Cambridge, MA. <http://h20.media.mit.edu/pdfs/esb2007-0509.pdf>
19. Boyden, E. S. (2007) Engineering the Brain. Department of Psychiatry, Harvard/MGH, Boston, MA.

20. Boyden, E. S. (2007) Towards enabling ultraprecise optical prosthetics. Massachusetts Eye and Ear Infirmary, Boston, MA.
21. Boyden, E. S. (2007) What Do We Need to Know, to do Practical Cognitive Augmentation? Presented with Vaughan Bell, Science Foo (SciFoo) Camp, Google, Mountain View, CA.
22. Boyden, E. S. (2007) Brain-Engineering Technologies: Towards Making us Smarter and Happier. AARP National Event and Expo, Boston, MA.
23. Boyden, E. S. (2007) Engineering the Brain. Emerging Technologies (aka TR ETC, EmTech) Conference at MIT, Sept. 25-27, 2007
24. Boyden, E. S. (2007) Towards ultraprecise optical prosthetics for treating pain: enabling technologies and testing. MGH-Charlestown, Boston, MA.
25. Boyden, E. S. (2007) Controlling neural circuits: towards synthetic neurobiology. Harvard University Division of Applied Sciences, Cambridge, MA.
26. Boyden, E. S. (2007) Principles of controlling neural circuit functions: towards synthetic neurobiology. Intel Corporation, Santa Clara, CA.
27. Boyden, E. S. (2007) Neural Control Technologies and Uses Thereof. Innerspace Foundation, Boston, MA.
28. Boyden, E. S. (2008) Towards a New Generation of Intelligent Brain Interfaces. Canon.
29. Boyden, E. S. (2008) Engineering the brain. Honda.
30. Boyden, E. S. (2008) Talking to the Mind: New Approaches to Engineering the Brain. The International House of Japan. Tokyo, Japan.
31. Boyden, E. S. (2008) New Ideas on how to Get Information Into and Out of the Brain. NEC.
32. Boyden, E. S. (2008) New Ideas on how to Get Information Into and Out of the Brain. Hitachi.
33. Boyden, E. S. (2008) Optical Neuron Control: Understanding and Engineering Normal and Pathological Neural Dynamics. Boston University.
34. Boyden, E. S. (2008) Genetically-Targeted Optical Neuromodulation: Towards Circuitwide Control of Normal and Pathological Neural Computation. Computational and Systems Neuroscience (CoSyNe) Workshop, Snowbird, UT.
35. Boyden, E. S. (2008) Synthetic Neurobiology: Towards Engineering Brain Circuits for Health and Human Augmentation. O'Reilly ETech (Emerging Technology) Conference, San Diego, CA.
36. Boyden, E. S. (2008) Optical Neural Control: Understanding Normal and Pathological Neuronal Circuit Dynamics. MIT Modern Optics and Spectroscopy Seminar Series, Cambridge, MA.
37. Boyden, E. S. (2008) Optical Neural Control: Analyzing and Engineering Normal and Pathological Neuronal Circuit Dynamics. Psychiatry Department, Yale University, New Haven, CT.
38. Boyden, E. S. (2008) Optical Neural Control: Analyzing and Engineering Normal and Pathological Neuronal Circuit Dynamics. Brain and Cognitive Sciences Department, MIT, Cambridge, MA.

39. Boyden, E. S. (2008) Prosthetic Systems for Therapeutic Optical Activation and Silencing of Genetically-Targeted Neurons. MEMS for Implantable Medical Devices Symposium, MIT, Cambridge, MA.
40. Boyden, E. S. (2008) Optical Neural Control: Analyzing and Engineering Normal and Pathological Neuronal Circuit Dynamics. 2008 Neuroscience Spring Symposium, University of Michigan.
41. Boyden, E. S. (2008) Prosthetic Optical Fiber Systems for Therapeutic Neural Activation and Silencing. Corning, Inc., Corning, NY.
42. Boyden, E. S. (2008) Controlling neural circuit elements to understand and engineer their roles in cognition. NYU, New York City, NY.
43. Boyden, E. S. (2008) Optical Neural Control: Analyzing and Engineering Normal and Pathological Neuronal Circuit Dynamics. Neuron to Synapse Meeting, Harvard Medical School, Boston, MA.
44. Boyden, E. S. (2008) Repairing Neural Circuits: Principles for Thinking About Epilepsy, Depression, and Schizophrenia. Kavli Science Journalism Workshop 'Frontiers of Brain Science,' Knight Science Journalism Fellowships Program, MIT, Cambridge, MA.
45. Boyden, E. S. (2008) Optical Neural Control: Analyzing and Engineering Normal and Pathological Neuronal Circuit Dynamics. Neuroimaging Groups presentation, Marine Biology Laboratory, Woods Hole, MA.
46. Boyden, E. S. (2008) What should we really be doing, to understand neural systems?. Grass Lab Tuesday night talk, Marine Biology Laboratory, Woods Hole, MA.
47. Boyden, E. S. (2008) Optical Brain Control: Analyzing and Engineering Normal and Pathological Neural Circuit Dynamics. Integrative Brain Research Symposium, Sapporo, Japan.
48. Boyden, E. S. (2008) Optical Brain Control: Analyzing and Engineering Normal and Pathological Neural Circuit Dynamics. NIMH Intramural Retreat, Gettysburg, PA.
49. Boyden, E. S. (2008) Optical Neuron Control: Towards Principles of Controlling Neural Circuits. Integrative Approaches to Brain Complexity Conference, Cold Spring Harbor/Wellcome Trust, Wellcome Trust Conference Center, Hinxton, UK.
50. Boyden, E. S. (2008) Optical methods for controlling and correcting neural circuit functions. In Vivo Imaging in Recovery After Neural Injury: From Microimaging in Animal Models to Functional Imaging in Man. Satellite Symposium to the American Congress of Rehabilitation Medicine (ACRM) and the American Society of Neurologic Rehabilitation (ASNR) Joint Educational Conference, Toronto, Canada.
51. Barry, B., Boyden, E., Lang, E. (2008) Software Technologies in the Delivery of Intelligent Language Hypnosis Engines. Procedural Hypnosis: From Bench Top to Bedside (Symposium), 59th Annual Scientific Program, October 24-26, 2008 Hypnosis 2008: Foundations & Frontiers, Society for Clinical and Experimental Hypnosis.
52. Boyden, E. S. (2008) High-Precision Genetically-Targeted Optical Control of Normal and Pathological Neural Computations. HHMI Conference on Genetic Manipulation of Neuronal Activity, Janelia Farm, Ashburn, VA.
53. Boyden, E. S. (2008) Optical Brain Control: Analyzing and Engineering Normal and Pathological Neural Circuit Dynamics. Carolina Biophysics Symposium, Chapel Hill, NC.
54. Boyden, E. S. (2008) Optical Brain Control: Analyzing and Engineering Normal and

Pathological Neural Circuit Dynamics. MIT Synthetic Biology Working Group, Cambridge, MA.

55. Boyden, E. S. (2009) Novel Tools for Precisely Controlling Brain Functions. Brain Research Center and Student Biotechnology Network, University of British Columbia, Vancouver, Canada.

56. Boyden, E. S. (2009) Optical Brain Control: Analyzing and Engineering Normal and Pathological Neural Circuit Dynamics. CIMIT Forum, Boston, MA.

57. Boyden, E. S. (2009) Optical Brain Control: Analyzing and Engineering Normal and Pathological Neural Circuit Dynamics. Dept. of Bioengineering, University of Pennsylvania, Philadelphia, PA.

58. Boyden, E. S. (2009) Optical Control Of Normal and Pathological Neural Circuit Computations. McGovern Symposium, Tsinghua University, Beijing, China.

59. Boyden, E. S. (2009) Optical Neural Control: Towards Systematic Parsing of the Role of Cell Types in Normal and Abnormal Neural Computation. MGH-HST Martinos Center Brainmap Series, Cambridge, MA.

60. Boyden, E. S. (2009) Optical Brain Control: Towards New Therapies for Brain Disorders. Optical Society of America (New England Section Meeting), Cambridge, MA.

61. Boyden, E. S. (2009) Optical Neural Control: Analyzing and Engineering Normal and Pathological Neural Circuit Dynamics. Tufts Neuroscience Symposium, Tufts University, Cambridge, MA.

62. Boyden, E. S. (2009) Towards Understanding The Circuits of Cognition: Engineering Tools for Analyzing Primate Brain Dynamics. Along with Xue Han, New England Primate Research Center (NEPRC), Harvard Medical School, Southborough, MA.

63. Boyden, E. S. (2009) Optical Activation of Neurons. Challenges for 21st Century Photonics, CIPS, MIT, Cambridge, MA.

64. Boyden, E. S. (2009) Optical Brain Control: Towards New Insights and Therapies. Psychiatric Genetics and Translational Research Seminar, Massachusetts General Hospital, Boston, MA.

65. Boyden, E. S. (2009) Enabling Systematic Neuroscience with Novel Optical Neural Control Strategies. Cold Spring Harbor Laboratories, NY.

66. Boyden, E. S. (2009) Optical Neural Control Prosthetics. No Barriers Festival, Miami, FL.

67. Boyden, E. S. (2009) Optical Cell-Specific Neuromodulation: Towards Engineering the Brain for Therapeutic Purposes. Medtronic, Minneapolis, MN.

68. Boyden, E. S. (2009) Optical control of the brain: Understanding thought, engineering cures. HST Summer Institute Biomedical Optics Lecture Series, Massachusetts General Hospital, Boston, MA.

69. Boyden, E. S. (2009) Technologies for controlling neural circuit dynamics. Sloan-Swartz 2009 Annual Meeting on Computational Neuroscience.

70. Boyden, E. S. (2009) Enabling Systematic Neuroscience with Novel Optical Neural Control Strategies. Indiana University, Bloomington, IN.

71. Boyden, E. S. (2009) Systematic Optical Control of Neural Circuits. Fifth Annual NIH Director's Pioneer Award Symposium, National Institutes of Health, Bethesda, MD.

72. Boyden, E. S. (2009) Synthetic Neurobiology: Optically Engineering the Brain to Augment Its Function. Singularity Summit, New York City, NY.
73. Boyden, E. S. (2009) Enabling Systematic Neuroscience with Novel Optical Neural Control Strategies, Salk Institute, San Diego, CA.
74. Boyden, E. S. (2009) Enabling Systematic Neuroscience with Novel Optical Neural Control Strategies, Caltech, Pasadena, CA.
75. Boyden, E. S. (2009) Enabling Systematic Neuroscience with Novel Optical Neural Control Strategies, NIH, Bethesda, MD.
76. Boyden, E. S. (2009) Enabling Systematic Neuroscience with Novel Optical Neural Control Strategies. University of Texas at Austin, Austin, TX.
77. Boyden, E. S. (2009) Enabling Systematic Neuroscience with Novel Optical Neural Control Strategies, UNC, Chapel Hill, NC.
78. Boyden, E. S. (2009) Enabling Systematic Neuroscience with Novel Optical Neural Control Strategies, USC, Los Angeles, CA.
79. Boyden, E. S. (2009) Engineering the Brain, NextGens Technologies Symposium, TTI/Vanguard, Salt Lake City, UT.
80. Boyden, E. S. (2010) Entering Information Into the Brain to Shape Emotion, Thought, and Action, XPrize Foundation Workshop, MIT, Cambridge, MA.
81. Boyden, E. S. (2010) Novel Optical Biological Control Tools: Towards Enabling Integrative Analysis of Neural Systems, Spivack Distinguished Lecture, Boston University, Boston, MA.
82. Boyden, E. S. (2010) Novel Optical Biological Control Tools: Enabling Integrative Analysis and Engineering of Neural Systems, Center for Brain Science, Harvard University, Cambridge, MA.
83. Boyden, E. S. (2010) Novel Optical Biological Control Tools: Towards Enabling Integrative Analysis of Neural Systems, A Meeting of the Minds in Monaco, 1st International Congress on Alzheimer's Disease and Advanced Neurotechnologies, Monaco.
84. Boyden, E. S. (2010) Novel Optical Biological Control Tools: Enabling Integrative Analysis and Engineering of Neural Systems, University of Illinois Urbana-Champaign, Champaign, Illinois.
85. Boyden, E. S. (2010) Novel Optical Biological Control Tools: Enabling Integrative Analysis and Engineering of Neural Systems, Wake Forest University, Winston-Salem, NC.
86. Boyden, E. S. (2010) Novel Optical Biological Control Tools: Enabling Integrative Analysis and Engineering of Neural Systems, Lincoln Labs, MA.
87. Boyden, E. S. (2010) Novel Optical Biological Control Tools: Enabling Integrative Analysis and Engineering of Neural Systems, University of Massachusetts, Amherst.
88. Boyden, E. S. (2010) Optical Neuron Control: Discovery and Engineering of A Second Generation of Tools, Baylor College of Medicine, Houston, TX.
89. Boyden, E. S. (2010) Enabling Systematic Neuroscience with Novel Optical Neural Control Strategies, Yale, New Haven, CT.
90. Boyden, E. S. (2010) Controlling Brain Circuits with Light, Lester Wolfe Workshop in Laser Biomedicine: Optogenetics - Probing the Brain with Light, George R. Harrison

Spectroscopy Laboratory/MGH Wellman Center for Photomedicine/Harvard—MIT Division of Health Sciences and Technology/CIMIT, Boston, MA

91. Boyden, E. S. (2010) Controlling the Brain with Light, International Forum The Brain Revolution, in honor of Rita Levi Montalcini's 101st birthday, Rome, Italy.
92. Boyden, E. S. (2010) Brain Co-Processors for Analyzing and Augmenting the Mind, Big Ideas for Busy People, Cambridge Science Festival, Cambridge, MA
93. Boyden, E. S. (2010) Optical Neural Control: A Platform for Cell-Specific Neuromodulation Therapy, Neurotechnology Industry Organization Neurotech Investing and Partnering Conference, Boston, MA.
94. Boyden, E. S. (2010) Controlling Brain Circuits with Light, Academia Sinica Symposium, Picower Institute for Learning and Memory, MIT, Cambridge, MA.
95. Boyden, E. S., (2010) Controlling Brain Circuits with Light, Max Planck Institute for Biological Cybernetics, Tübingen, Germany.
96. Boyden, E. S. (2010) Controlling Brain Circuits with Light, European Union Commission, Forum on Implantable Medical Technologies, Medical Devices Expert Group, Working Group on New & Emerging Technologies, Brussels, Belgium.
97. Boyden, E. S. (2010) In Vivo Imaging and Control of Neural Networks: Watching the Brain in Action, Introductory talk, 16th German-American Frontiers of Science Symposium, Potsdam Germany.
98. Boyden, E. S. (2010) Controlling Brain Circuits with Light: Enabling Integrative Analysis and Engineering of Neural Systems, 27th Symposium of the Center for Visual Science, University of Rochester, Rochester, NY.
99. Boyden, E. S. (2010) Controlling Brain Circuits with Light, H+ Summit, Harvard University, Cambridge, MA.
100. Boyden, E. S. (2010) Controlling Brain Circuits with Light: Enabling Integrative Analysis and Engineering of Neural Systems, Translational Research and Vision, National Eye Institute 40th Anniversary Symposium, NIH, Bethesda, MD.
101. Boyden, E. S. (2010) Controlling Brain Computations with Light. Multi-modal Neural Training Program Symposium, Carnegie Mellon University and University of Pittsburgh, Pittsburgh, PA.
102. Boyden, E. S. (2010) Optogenetics: Targeted Control of Brain Circuits With Light, Gordon Research Conference on Lasers in Medicine and Biology, Holderness, New Hampshire.
103. Boyden, E. S. (2010) Brain Co-Processors. Science Foo (SciFoo) Camp, Google, Mountain View, CA. (Selected as highlighted talk for presentation in final session.)
104. Boyden, E. S. (2010) Optical Control of Biological and Neural Functions Using Retinal Proteins, 14th International Conference on Retinal Proteins, Santa Cruz, CA.
105. Boyden, E. S. (2010) New Optical Reagents and Strategies for Controlling Neural Circuit Dynamics, Gordon Conference on Mechanisms Of Epilepsy & Neuronal Synchronization, Waterville, ME.
106. Boyden, E. S. (2010) Enabling Systematic Neuroscience with Novel Optical Neural Control Strategies, INCF Neuroinformatics Congress, Kobe, Japan.
107. Boyden, E. S. (2010) Controlling the Brain with Light: From Genomic Mining of

Molecular Tools, to Neural Circuit Solving, UNC-Wilmington.

108. Boyden, E. S. (2010) Controlling Brain Circuits With Light, EmTech@MIT, Cambridge, MA.

109. Boyden, E. S. (2010) Controlling Brain Circuits With Light, Aspen Brain Forum: Building Better Brains: Neural Prosthetics and Beyond, Aspen, Colorado.

110. Boyden, E. S. (2010) Controlling Brain Computations: Towards New Brain Insights and Brain Therapies, Allen Institute for Brain Science Symposium, Open Questions in Neuroscience, Seattle, WA.

111. Boyden, E. S. (2010) Controlling brain circuits with light: Harnessing ecological diversity and molecular optimization to make new neuroscience tools, Genetic Manipulation of Neuronal Activity II, Janelia Farm, VA.

112. Boyden, E. S. (2010) Novel optical neural control tools: towards enabling integrative analysis of neural systems, Minisymposium: Toward the Second Generation of Optogenetic Tools (Minisymposium co-chair), Society for Neuroscience, San Diego, CA.

113. Boyden, E. S. (2010) Controlling Brain Circuits with Light: Towards the Next Generation of Tools. Harvard Neurobiology and Children's Hospital, Boston, MA.

114. Boyden, E. S. (2010) Controlling Brain Circuits with Light, Purdue University, West Lafayette, IL.

115. Boyden, E. S. (2010) Controlling Brain Circuits with Light, Medical University of South Carolina, Charleston, SC.

116. Boyden, E. S. (2011) Inventing Tools for Controlling Brain Circuits With Light, Harvard School of Engineering and Applied Sciences, Cambridge, MA.

117. Boyden, E. S. (2011) Optogenetics. Alfred Mann Foundation, Valencia, CA.

118. Boyden, E. S. (2011) Controlling the Brain With Light. Plenary Lecture, "Hot Topics" Opening Session, SPIE, Moscone Center, San Francisco, CA.

119. Boyden, E. S. (2011) Controlling Brain Circuits with Light: Enabling Integrative Analysis and Engineering of Neural Systems, Issekutz Memorial Lecture, Dalhousie University, Halifax, Canada.

120. Boyden, E. S. (2011) Controlling Brain Circuits with Light: Optogenetics, Association for Research in Otolaryngology MidWinter Meeting, Baltimore, MD.

121. Boyden, E. S. (2011) Controlling Brain Circuits With Light, TED (Technology, Entertainment, and Design Conference), Long Beach, CA.

122. Boyden, E. S. (2011) Optogenetics: Molecular Tools & Hardware for Controlling the Brain with Light, UT Health Sciences, Houston, TX.

123. Boyden, E. S. (2011) Optogenetics: Controlling Brain Circuits with Light, University of Chicago, Chicago, IL.

124. Boyden, E. S. (2011) Optical reagents and strategies for controlling neural circuit dynamics, Boehringer Ingelheim Fonds 103rd International Titisee Conference, Genetic analysis of neural circuits, Titisee, Germany.

125. Boyden, E. S. (2011) Controlling Brain Circuits With Light, University of Freiburg, Freiburg, Germany.

126. Boyden, E. S. (2011) Optogenetics: Tools for Controlling Brain Circuits with Light, Cornell Weill Medical College, New York, NY.
127. Boyden, E. S. (2011) Controlling Brain Circuits with Light, Keynote Talk, University of Pennsylvania Mahoney Institute of Neurological Sciences, 27th Annual Retreat, Philadelphia, PA.
128. Boyden, E. S. (2011) Controlling The Brain With Light: New Molecular Tools and Devices for Optogenetics, Molecular and Cellular Neuroscience Seminar Series, MIT, Cambridge, MA.
129. Boyden, E. S. (2011) Controlling brain circuits with light: New tools for analyzing neural systems. 15th Annual Conference on Cognitive and Neural Systems, Boston University, Boston, MA.
130. Boyden, E. S. (2011) Optogenetics and Neurodegeneration. New Frontiers in Neurodegeneration Symposium, UMass Medical School Neurotherapeutics Institute/Biogen Idec, Cambridge, MA.
131. Boyden, E. S. (2011) Optogenetics: Controlling Brain Circuits With Light, Dept of Pharmacology, Oxford University, Oxford, UK.
132. Boyden, E. S. (2011) Towards Understanding the Brain as a Computational Circuit, Dept of Physiology, Oxford University, Oxford, UK.
133. Boyden, E. S. (2011) Optogenetics: New Toolsets for Controlling Brain Circuits with Light, Karolinska Institute, Stockholm, Sweden.
134. Boyden, E. S. (2011) Controlling Brain Circuits With Light: Analyzing and Engineering Neural Circuit Dynamics, Genetic and Neural Complexity of Psychiatry, Santorini, Greece.
135. Boyden, E. S. (2011) Optogenetics: Tools for Controlling Brain Circuits With Light, National Institute for Drug Abuse, Baltimore, MD.
136. Boyden, E. S. (2011) Optogenetics: Controlling Brain Circuits With Light, University of Washington, Seattle, WA.
137. Boyden, E. S. (2011) Massively-Parallel Recording of Neural Activity: System Prototypes, Allen Distinguished Investigators Symposium, Seattle, WA.
138. Boyden, E. S. (2011) New Technologies for Analyzing and Engineering the Brain: How 21st Century Tools are Opening up New Fronts on Thought, Emotion, and Disease New Technologies for Analyzing and Engineering the Brain: How 21st Century Tools are Opening up New Fronts on Thought, Emotion, and Disease, Kavli Science Journalism Workshop 'Brain Science,' Knight Science Journalism Fellowships Program, MIT, Cambridge, MA.
139. Boyden, E. S. (2011) Controlling Brain Circuits with Light: Molecules, Hardware, Strategies, and Applications, "Causal Neuroscience: interacting with neural circuits," FENS-IBRO-SFN School, Bertinoro, Italy.
140. Boyden, E. S. (2011) Optogenetics: Tools for Controlling Brain Circuits With Light, BioMethods Boston Conference, Boston, MA.
141. Boyden, E. S. (2011) Optogenetics: New Tools for Controlling Brain Circuits with Light, University of Louisville, Kentucky.
142. Boyden, E. S. (2011) Technologies for the Systematic Analysis of How Brain Circuits Perform Computations, Keynote, 4th Conference on Artificial General Intelligence, Google, Mountain View, CA.

143. Boyden, E. S. (2011) Optogenetics: Controlling the Brain with Light, MIT Club of Northern California.
144. Boyden, E. S. (2011) Optogenetics and Other Neural Circuit Analysis Tools, Halcyon Molecular, Redwood City, CA.
145. Boyden, E. S. (2011) Optogenetics and Other Neural Circuit Analysis Tools, UC Berkeley.
146. Boyden, E. S. (2011) Optogenetics and Other Neural Circuit Analysis Tools, Erasmus MC, Rotterdam, The Netherlands.
147. Boyden, E. S. (2011) Optogenetics: Controlling Neural Circuits with Light, 7th NIH Inter-Institute Workshop on Optical Diagnostic and Biophotonic Methods from Bench to Bedside, NIH, Bethesda, MD.
148. Boyden, E.S. (2011) Optogenetics: Controlling Brain Circuits With Light, 7th NIH Director's Pioneer Award Symposium, Bethesda, MD.
149. Boyden, E.S. (2011) Optogenetics and Other Neural Circuit Analysis Tools, Keynote, Harvard Biophysics Retreat.
150. Boyden, E.S. (2011) Neural Networks for Solving Neural Networks, Networks Solving Networks Meeting, MIT Media Lab, Cambridge, MA.
151. Boyden, E.S. (2011) Optogenetics: Controlling Brain Circuits With Light, Keynote, Taiwan Neuroscience Society Meeting, Taipei, Taiwan.
152. Boyden, E. S. (2011) Optogenetics and Other Neural Circuit Analysis Tools, Adrian Lecture, University of Cambridge, Cambridge, UK.
153. Boyden, E. S. (2011) Controlling brain circuits with light: Towards systematic analysis of neural circuit functions. Symposium on the Emerging Genetics and Neurobiology of Severe Mental Illness, Broad Institute, Cambridge, MA.
154. Boyden, E. S. (2011) Optogenetics and Other Neural Circuit Analysis Tools, Champalimaud Institute for the Unknown, Lisbon, Portugal.
155. Boyden, E. S. (2011) Engineering the Mind, Ar Seminar Series for the Public, Inaugural Lecture, Champalimaud Institute for the Unknown, Lisbon, Portugal.
156. Boyden, E. S. (2011) Enhancing the Brain - Past, Present and Future, Honors Colloquium, University of Rhode Island.
157. Boyden, E. S. (2011) "Technologies for Analyzing the Computations of the Brain", invited talk, IBM Watson Research Center, Yorktown Heights, NY.
158. Boyden, E. S. (2011) "Optogenetics and Other Neural Circuit Analysis Tools," 15th Annual Future of Light Symposium, Boston University Photonics Center, Boston University, Boston, MA.
159. Boyden, E. S. (2011) "Optogenetics and Other Neural Circuit Analysis Tools," Albert Einstein College of Medicine, Bronx, NY.
160. Boyden, E. S. (2011) "Optogenetics and Other Neural Circuit Analysis Tools," University of Connecticut.
161. Boyden, E. S. (2011) "Optogenetics: Tools for Controlling the Brain With Light," 14th Annual International Symposium on Neural Regeneration, Monterey, CA.

162. Boyden, E. S. (2011) "Optogenetics and Other Neural Circuit Analysis Tools," Sackler Lecture, Leiden University Medical Center, Leiden, The Netherlands.

Other non-peer-reviewed talks and conference papers

1. Schoner, B., Cooper, C., Douglas, C., Boyden, E. S., Gershenfeld, N. (1998) Cluster Weighted Modeling for Time Series (How to Build a Digital Strad). Workshop on Nonlinear Dynamics and Statistics, Issac Newton Institute, Cambridge.
2. Chen, G., Foletti, D. L., Boyden, E. S., Holz, R. W., Scheller, R. H., Tsien, R. W. (2000) Differential functions of Rab3A in regulating excitatory and inhibitory transmission in hippocampal neurons. Society for Neuroscience, Online.
3. Boyden, E. S., Raymond, J. L. (2002) Induction, timecourse, and persistence of mouse vestibulo-ocular reflex adaptation. Society for Neuroscience, Online.
4. Boyden, E. S., Chatila, T. A., Raymond, J. L. (2003) Motor memories in the vestibulo-ocular reflex of CaMKIV knockout mice. Society for Neuroscience, Online.
5. Mong, C., Cao, Y. Q., Boyden, E. S., Abbott, L. C., Tsien, R. W. (2003) Properties of cortical spreading depression across visual cortex in mice with spontaneous mutations in P/Q-type Ca²⁺ channels. Society for Neuroscience, Online.
6. Liao, Y. J., Boyden, E. S., Tsien, R. W. (2003) Anti-calcium channel antibody affects cerebellar synaptic transmission in a model of acquired channelopathy. Society for Neuroscience, Online.
7. Liao, Y. J., Safa, P., Boyden, E. S., Tsien, R. W. (2004) Antibody-mediated altered cerebellar transmission. Channels, Receptors, and Synapses Meeting, Cold Spring Harbor, NY, April 2004.
8. Kimpo, R. R., Katoh, A., Boyden, E. S., Raymond, J. L. (2004) Patterns of generalization constrain encoding of learned opposite changes in the vestibulo-ocular reflex. Society for Neuroscience, Online.
9. Liao, Y. J., Safa, P., Boyden, E. S., Tsien, R. W. (2004) Antibody-mediated channelopathy in a model of paraneoplastic cerebellar ataxia. Society for Neuroscience, Online.
10. Boyden, E. S., Content-selective neural mechanisms of memory encoding. (2005) Catalyzing the Future, Fannie and John Hertz Foundation Symposium.
11. Boyden, E. S., Zhang, F., Bamberg, E., Nagel, G., and Deisseroth, K. (2005) Millisecond-timescale optical control of neural computation via channelrhodopsin-2. Talk, at Society For Neuroscience, Online.
12. Zhang, F., Boyden, E. S., Deisseroth, K. (2005) Genetic and optical strategies for using channelrhodopsin-2 to control diverse neural functions. Society for Neuroscience, Online.
13. Boyden, E. S., Safa, P., Pyle, J. L., Neogi, M., Raymond, J. L., Tsien, R. W. (2005) Gene expression patterns in the medial vestibular nucleus indicate the direction of motor learning in the vestibulo-ocular reflex. Talk, at Society for Neuroscience, Online.
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