

Navin Khaneja
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Personal: Born, 5 December, 1972. Citizen of India. Visa Status, H-1B.

Professional Preparation:

Indian Institute of Technology, Kanpur	Electrical Engineering	B.Tech	1994
Washington University, St. Louis	Mathematics	M.A.	1996
Washington University, St. Louis	Electrical Engineering	M.S.	1996
Harvard University	Applied Mathematics	M.A.	1999
Harvard University	Applied Mathematics	Ph.d.	2000

Experience: Associate Professor of Electrical Engineering July 2005-Present
Harvard University
Assistant Professor of Electrical Engineering July 2001-June 2005
Harvard University
Assistant Professor of Mathematics July 2000-June 2001
Dartmouth College

Research Interest:

Control and applications, NMR spectroscopy, quantum control and information science.

Awards: Bessel Prize, Humboldt Foundation, 2005.

Alfred P. Sloan Fellow, 2003.

National Science Foundation Career Award, 2001.

Jury award for outstanding thesis in the area of control theory, Harvard University, 2000.

National talent search scholarship, awarded by National Council of Education, Research and Training (NCERT), India, 1988-1994.

Teaching Graduate Classes taught at Harvard include “control and estimation of dynamic systems” (ES202), “stochastic control” (ES203) and “nonlinear control” (ES209). Undergraduate classes include, “probability with applications to electrical engineering” (ES 150) and “introduction to operations research” (ES 102).

Graduate Students

Jamin Sheriff, James Lin, Jr. Shin Li (Washington University), Haidong Yuan (MIT), Dionisis Stefanatos (Greece), Brent Pryor (Mitre Corporation, MA), Andrew Johnson (Lincoln Labs, MA).

Post-docs Robert Zeier, Mark Byrd (Southern Illinois University) and Randy Scott (Draper Labs).

Journal Publications

1. N. Khaneja, N. C. Nielsen, "Triple oscillating field technique for accurate distance measurements by solid-state NMR", *Journal of Chemical Physics* 128, 015103 (2008).
2. H. Yuan, R. Zeier and N. Khaneja, "Elliptic functions and time-optimal control in linear spin topologies with unequal couplings", *Phys. Rev. A*, in press (2008).
3. N. Khaneja, "Switched control of electron nuclear spin systems" *Phys. Rev. A*, 76, 032326 (2007).
4. L. Jiang, J. Taylor, N. Khaneja and M. D. Lukin, "Optimal approach to quantum communication by dynamic programming", *Proceedings of National Academy of Sciences*, 104, 17291 (2007).
5. J. Hansen, C. Kehlet, M. Bjerring, T. Vosegaard, S. J. Glaser, N. Khaneja, and N. C. Nielsen, "Optimal control based design of composite dipolar recoupling experiments by analogy to single-spin inversion pulses", *Chem. Phys. Lett.*, 447, 154-161 (2007).
6. H. Yuan, S.J. Glaser and N. Khaneja, "Geodesics for efficient creation and propagation of order along Ising spin chains" *Phys. Rev. A*, 76, 012316 (2007).
7. N. Khaneja, B. Heitmann, A. Spoerl, H. Yuan, T. Herbrueggen and S.J. Glaser, "Shortest paths for efficient control of indirectly coupled qubits", *Phys. Rev. A*, 75, 012322(2007).
8. C. Kehlet, M. Bjerring, A.C. Sivertsen, T. Kristensen, J.J. Enghild, S.J. Glaser, N. Khaneja, N.C. Nielsen, "Optimal control based NCO and NCA experiments for spectral assignment in biological solid-state NMR spectroscopy", *J. Magn. Reson.* 188, 216-230 (2007).
9. B. Pryor and N. Khaneja, "Fourier decompositions and pulse design algorithms for NMR in inhomogeneous fields", *J. Chem. Phys.*, **125**, 194111 (2006).
10. N. Khaneja, "Sensitivity enhanced recoupling experiments in solid state NMR by gamma preparation", *Journal of Magnetic Resonance* **183**, 261 (2006).
11. J.S. Li and N. Khaneja, "Control of inhomogeneous quantum ensembles", *Phys. Rev. A*, **73**, 030302 (2006).
12. N. Khaneja, C. Kehlet, S.J. Glaser, N. Nielsen, "Composite dipolar recoupling: anisotropy compensated coherence transfer in solid state NMR", *J. Chem. Phys.*, **124**, 114503 (2006).
13. H. Yuan and N. Khaneja, "Reachable sets of bilinear control system with time varying drift", *System and Control Letters*, **55**, 501 (2006).
14. S. J. Glaser, T. Schulte-Herbruggen, N. Khaneja, "Non-Computing Applications of Quantum Information in NMR", *Informatik Forsch. Entw.* 21, 65-71 (2006).
15. J. L. Neves, B. Heitmann, T. O. Reiss, H. H. R. Schor, N. Khaneja, S. J. Glaser, "Exploring the limits of polarization transfer efficiency in homonuclear three spin systems", *J. Magn. Reson.* 181, 126-134 (2006).
16. T. E. Skinner, K. Kobzar, B. Luy, R. Bendall, W. Bermel, N. Khaneja, S. J. Glaser, "Optimal control design of constant amplitude phase-modulated pulses: application to calibration-free broadband excitation", *J. Magn. Reson.* 179, 241-249 (2006).
17. Z. Tosner, S. J. Glaser, N. Khaneja, and N. C. Nielsen, "Effective Hamiltonians by optimal control: solid-state NMR double-quantum and isotropic dipolar recoupling", *J. Chem. Phys.* 125, 184502-1-184502-10 (2006).
18. H. Yuan and N. Khaneja, "Time optimal control of coupled qubits under non-stationary interactions", *Phys. Rev. A* **72** 040301(R) (2005).

19. D. Stefanatos, N. Khaneja, S.J. Glaser, "Relaxation optimized transfer of spin order in Ising chains", *Phys. Rev. A* **72**, 062320 (2005).
20. H. Mabuchi and N. Khaneja, "Principles and applications of control in quantum systems", *International Journal of Robust and Nonlinear Control* **15** 647-667 (2005).
21. T. Vosegard, C. Kehlet, N. Khaneja, S.J. Glaser, N. C. Nielsen, "Improved excitation schemes for multiple-quantum magic-angle spinning experiments for quadrupolar nuclei designed using optimal control theory", *J. Am. Chem. Soc.* **127** 13768 (2005).
22. C. Kehlet, T. Vosegard, N. Khaneja, S.J. Glaser, N.C. Nielsen, "Low power homonuclear dipolar recoupling in solid state NMR developed using optimal control theory", *Chem. Phys. Lett.* **414** 204 (2005).
23. B. Luy, K. Kobzar, T.E. Skinner, N. Khaneja, S.J. Glaser, "Construction of universal rotations from point to point transformations", *J. Magn. Reson.* **176**, 179-186 (2005).
24. K. Kobzar, B. Luy, N. Khaneja, S. J. Glaser, "Pattern Pulses: design of arbitrary excitation profiles as a function of pulse amplitude and offset", *J. Magn. Reson.* **173**, 229-235 (2005).
25. D. P. Frueh, T. Ito, Jr-Shin Li, G. Wagner, S.J. Glaser, N. Khaneja, "Sensitivity enhancement in NMR of macromolecules by application of optimal control theory", *J. Biomol. NMR* **32**, 23-30 (2005).
26. N. Khaneja, F. Kramer, S.J. Glaser, "Optimal experiments for maximizing coherence transfer between coupled spins", *J. Magn. Reson.* **173**, 116-124 (2005).
27. N. Khaneja, T. Reiss, C. Kehlet, T.S. Herbrüggen, S.J. Glaser, "Optimal control of coupled spin dynamics: design of NMR pulse sequences by gradient ascent algorithms", *J. Magn. Reson.* **172**, 296-305 (2005).
28. T. Schulte-Herbrueggen, A.K. Spoerl, N. Khaneja, S.J. Glaser, "Optimal control-based efficient synthesis of building blocks of quantum algorithms seen in perspective from network complexity towards time complexity", *Phys. Rev. A*, **72**, 042331 (2005).
29. T. E. Skinner, T. O. Reiss, B. Luy, N. Khaneja, S. J. Glaser, "Tailoring the optimal control cost function to a desired output: application to minimizing phase errors in short broadband excitation pulses", *J. Magn. Reson.* **172**, 17-23 (2005).
30. N. Khaneja, Jr. Shin Li, C. Kehlet, B. Luy, S.J. Glaser, "Broadband relaxation optimized polarization transfer in magnetic resonance", *Proceedings of National Academy of Sciences, USA.* **101**, 14742-47 (2004).
31. S. Dionisis, N. Khaneja, S.J. Glaser, "Optimal control of spin dynamics in the presence of longitudinal and transverse relaxation", *Phys. Rev. A* **69**, 022319, (2004).
32. C.T. Kehlet, A.C. Sivertsen, M. Bjerring, T.O. Reiss, N. Khaneja, S.J. Glaser, N.C. Nielsen, "Improving solid-state NMR dipolar recoupling by optimal control", *J. Am. Chem. Soc.* **126**, 10202-03 (2004).
33. K. Kobzar, T. E. Skinner, N. Khaneja, S. J. Glaser, B. Luy, "Exploring the limits of broadband excitation and inversion pulses", *J. Magn. Reson.* **170**, 236-243 (2004).
34. T. E. Skinner, T. O. Reiss, B. Luy, N. Khaneja, S. J. Glaser, "Reducing the duration of broadband excitation pulses using optimal control with limited RF amplitude", *J. Magn. Reson.* **167**, 68-74 (2004).
35. S.E. Sklarz, D.J. Tannor and N. Khaneja, "Optimal control of quantum dissipative dynamics: analytic solution for cooling a three level Lambda system", *Phys. Rev. A* **69**, 053408 (2004).
36. N. Khaneja, B. Luy, and S.J. Glaser, "Boundary of quantum evolution under decoherence", *Proceedings of National Academy of Sciences* **100**, no. 23, 13162-66 (2003).
37. N. Khaneja, T. Reiss, B. Luy, S. J. Glaser, "Optimal control of spin dynamics in the presence of relaxation", *J. Magn. Reson.* **162**, 311-319 (2003).

38. T. Reiss, N. Khaneja, S.J. Glaser, "Broadband geodesic pulses for three spin systems: Time-optimal realization of effective trilinear coupling terms and swap gates", *J. Magn. Reson.* **165**, 95-101 (2003).
39. T.E. Skinner, T. Reiss, B. Luy, N. Khaneja, S.J. Glaser, "Application of optimal control theory to the design of broadband excitation pulses for high resolution NMR.", *J. Magn. Reson.* **163**, 8-15 (2003).
40. M.S. Byrd and N. Khaneja, "Characterization of the positivity of the density matrix in terms of the coherence vector representation", *Phys. Rev. A* **062322** (2003).
41. "Increasing the size of NMR quantum computers", S. J. Glaser, R. Marx, T. Reiss, T. Schulte-Herbruggen, N. Khaneja, J. M. Myers, A. F. Fahmy in: *Quantum Information Processing*, pp. 53-65, Eds.: G. Leuchs, T. Beth (Wiley-VCH) (2003).
42. N. Khaneja, S.J. Glaser and R.W. Brockett, "Sub-Riemannian geometry and optimal control of three spin systems", *Phys. Rev. A* **65**, 032301 (2002).
43. N. Khaneja, S. J. Glaser, "Efficient transfer of coherence through Ising Spin chains", *Phys. Rev. A* **66**, 060301(R) (2002).
44. T. Reiss, N. Khaneja and S.J. Glaser, "Time-Optimal coherence-order-selective transfer of in-phase coherence in Heteronuclear IS spin systems", *J. Magn. Reson.* **154**, 192-195 (2002).
45. N. Khaneja and S.J. Glaser, "Cartan decomposition of $SU(2^n)$ and control of spin systems", *Chemical Physics* **267**, 11-23, (2001).
46. N. Khaneja, R.W. Brockett and S.J. Glaser, "Time optimal control of spin systems", *Phys. Rev. A* **63**, 032308 (2001).
47. R.W. Brockett and N. Khaneja, "On the stochastic control of quantum ensembles", Chapter in *System Theory: Modeling, Analysis and Control*, Kluwer Academic Publishers (1999).
48. N. Khaneja, M. I. Miller and U. Grenander, "Dynamic programming generation of curves on brain surfaces", *IEEE transactions on Pattern Analysis and Machine Intelligence* **20**, No 11 (1998).
49. M. Bakircioglu, U. Grenander, N. Khaneja and M.I. Miller, "Curve matching on brain surfaces using frenet distances", in *Special Issue of Human Brain Mapping*, 6:329-333 (1998).
50. F. Yamaguchi, T.D. Ladd, C. Master, Y. Yamamoto, N. Khaneja, "Efficient decoupling and recoupling in solid state NMR quantum computing", quant-ph/0411099.
51. R. Zeier, H. Yuan and N. Khaneja, "Time-optimal synthesis of unitary transformations in coupled fast and slow qubit system", *Phys. Rev. A*. (submitted).
52. N. Khaneja "Imaging inhomogeneous magnetic fields with pulse sequences and linear gradients", *J. Chem. Phys.* (submitted).

Conference Publications

1. J.S. Li and N. Khaneja, "Ensemble control on Lie groups" IFAC Symposium on Nonlinear Control Systems, Pretoria, South Africa (2007).
2. B. Pryor and N. Khaneja, "Fourier synthesis technique for control of inhomogeneous quantum systems" IEEE Conference on Decision and Control, New-Orleans (2007).
3. J.S. Li and N. Khaneja, "Ensemble controllability of linear systems" IEEE Conference on Decision and Control, New-Orleans (2007).
4. J.S. Li and N. Khaneja, "Ensemble controllability of the Bloch equations" IEEE Conference on Decision and Control, San-Diego (2006).

5. B. Pryor and N. Khaneja, "Optimal control of homonuclear spin dynamics subject to relaxation" IEEE Conference on Decision and Control, San-Diego (2006).
6. H. Yuan and N. Khaneja, "Time optimal control of spin systems with unequal couplings" IEEE Conference on Decision and Control, San-Diego (2006).
7. H. Yuan and N. Khaneja, "Reachable set of bilinear control system with time varying drift", IEEE Conference on Decision and Control, Spain (2005).
8. D. Stefanatos and N. Khaneja "Semi-definite programming and reachable set of dissipative bilinear control system", IEEE Conference on Decision and Control, Spain (2005).
9. D. Yamins, S. Wydo and N. Khaneja "Group control and the 1D equigrouping problem", IEEE Conference on Decision and Control, Bahamas(2004).
10. N. Khaneja, S.J. Glaser, "Optimal control of coupled spins in presence of cross-correlated relaxation", IEEE Conference on Decision and Control (2003).
11. S. Dionisis, N. Khaneja, S.J. Glaser, "Optimal control of coupled spins in presence of longitudinal and transverse relaxation", IEEE Conference on Physics and Control, St. Petersburg, Russia (2003).
12. N. Khaneja, S.J. Glaser, "Constrained bilinear systems", IEEE Conference on Decision and Control (2002).
13. N. Khaneja, S.J. Glaser, R.W. Brockett, "Subriemannian geodesics and time optimal control of spin systems", American Control Conference (2002).
14. R.W. Brockett, N. Khaneja, S.J. Glaser, "Optimal input design for NMR identification problem", IEEE Conference on Decision and Control (2001).
15. N. Khaneja and R. Brockett, "Dynamic feedback stabilization of nonholonomic systems," IEEE Conference on Decision and Control (1999).

Profession Activities:

Member: Institute of electronics and electrical engineers(IEEE), society of industrial and applied mathematics (SIAM), american physical society (APS).

Reviewed publications for science, journal of magnetic resonance, IEEE transaction of automatic control, system and control letters, mathematics of signals and systems, physical D, SIAM journal on control and optimization, physical review, journal of chemical physics, quantum information processing, control and decision conference (CDC) and american control conference (ACC). Served on NSF review panels on quantum and biological inspired computing. Co-organized workshops on 'control of quantum systems' in the CDC conference 2002, 2004. Co-organized the first meeting on principles and applications of control in quantum systems (Pracqsys), Caltech 2004. Organizer of the second meeting on principles and applications of control in quantum systems, Harvard 2006. Served on international program committees for Pracqsys 2004, 2005, 2006 and 2007. Served on the scientific committee for the first meeting on "control, constraints and quanta" in Poland (2007) and "Mathematical foundations of quantum information and control", in Madrid, Spain (2008). Co-organizer of the school on "Quantum Control of Light and Matter" to be held at Kavli-Institute of theoretical physics in Santa-Barbara in 2009.

Selected Lectures:

- "Optimal control in magnetic resonance", Indian Institute of Science, Bangalore, December 2007.

- “Control of spin ensembles”, Control, Constraint and Quanta meeting, ESF Mathematics Conference, Poland, Oct 2007.
- “Controllability and switching in quantum systems”, Pracqsys meeting, Sydney, July 2007.
- “Control of nuclear spin systems”, SIAM meeting, San Francisco, June 2007.
- “Fourier synthesis methods for robust control of quantum dynamics”, DAMOP meeting, Calgary, June 2007.
- “Geometry and control in quantum information science”, April 2007, MIT.
- “Fourier synthesis methods for robust control of quantum dynamics”, Control and Dynamic systems meeting, December 2006.
- “Dynamics and control of spin systems”, MIT, September 2006.
- “Optimal control in magnetic resonance” Pracqsys meeting, Cambridge, August 2006.
- “Lie theory in quantum control ” Feynmann Festival, August, 2006.
- “Lie algebras and robust control of quantum Dynamics” Group Theoretical Methods in Physics, June, 2006.
- “Applications of control theory to biomolecular NMR”, University of Pennsylvania, January 2006.
- “Applications of control theory to coherent spectroscopy and quantum information processing”, Max Planck Institute of Quantum Optics, Germany, December 2005.
- “ Composite dipolar recoupling in Solid State NMR”, Magnet Lab, MIT, December 2005.
- “ Control of spin systems”, LIDS Colloquium, MIT, September 2005.
- “Optimal control of spin dynamics in the presence of relaxation”, Gordon Conference on Quantum Control, August 2005.
- “Control in magnetic resonance”, Meeting on Control of Quantum Systems, Caltech, August 2005.
- “Broadband control in solid state NMR”, University of Aarhus, Denmark, April 2005.
- “Fundamental limits on control of open quantum systems”, Physics Research Colloquium, Caltech, February 2005
- “Relaxation optimized coherent spectroscopy”, Meeting on Control of Quantum Systems, University of Michigan, July 2004.
- “Optimal control in magnetic resonance”, University of California, Berkeley, May 2004.
- “Optimal control of spin dynamics in the presence of relaxation”, Experimental Nuclear Magnetic Resonance Conference, April 2004.
- “ Optimal control in magnetic resonance”, University of Aarhus, Denmark, September 2004.
- “Optimal control in magnetic resonance”, Meeting on Control of Quantum Systems, Caltech, August 2004.
- “Relaxation optimized coherent spectroscopy”, Meeting on Control of Quantum Systems, University of Michigan, July 2004.
- “Optimal control in magnetic resonance”, University of California, Berkeley, May 2004.
- “Optimal control of spin dynamics in the presence of relaxation”, Experimental Nuclear Magnetic Resonance Conference, April 2004.
- “Optimal control in spin systems”, University of California Berkeley, March 2004.

- “Relaxation optimized NMR spectroscopy”, Magnet Lab, MIT, December 2003.
- “Optimal control of coupled spin dynamics”, Caltech, December 2003.
- “Control of quantum systems in presence of dissipation”, Weizmann Institute of Science, Israel, May 2003.
- “Control of quantum systems in the presence of relaxation”, Army research office meeting on quantum control, MIT, Cambridge, October 2002.
- “Optimal control of dissipative quantum dynamics”, Quantum information processing seminar, MIT, Cambridge, September 2002.
- “Time optimal control of spin networks”, MIT, Cambridge, MA, February 2002.
- “Subriemannian geometry and control of spin networks”, SIAM meeting, San Diego, California, July 2001.
- “Optimal control of spin networks”, University of Pennsylvania, Philadelphia, April 2001.
- “Optimal control of quantum systems”, University of Maryland, College Park, Maryland, March 2001.
- “Time optimal control of quantum networks”, Max Planck Institute of Quantum Optics, Germany, November 2000.
- “Optimal control of spin systems”, Princeton University, Princeton, New Jersey, August 2000.
- “Time optimal control of quantum systems”, Caltech, Pasadena, July 2000.
- “Optimal control problems in NMR spectroscopy”, Technical University of Munich, Germany, December 1999.

Collaborators: Professor S. J. Glaser, Institut fuer Organische Chemie and Biochemie II technische Universitaet Muenchen, Germany.

Professor Niels Nielsen, University of Aarhus, Denmark.

Professor Gerhard Wagner, Department of Biological Chemistry and Molecular Pharmacology, Harvard Medical School.

Professor Roger W. Brockett, Division of Engineering and Applied Sciences, Harvard University.

Professor David Tannor, Department of Chemical Physics, Weizmann Institute of Science.