CURRICULUM VITAE

Irfan Siddiqi

University of California, Berkeley
Physics Department, 366 LeConte Hall
Berkeley, CA 94720-7300

e-mail: irfan_siddiqi@berkeley.edu
Tel: (510) 642-5620
Fax: (510) 643-8497

PERSONAL

Date of Birth: March 4th, 1976
Citizenship: United States
Marital Status: Married, two children

EDUCATION

Yale University, **Ph.D.** in Applied Physics (2002)
M.Phil. in Applied Physics, (2000)
M.S. in Applied Physics, (1998)
Harvard University, **A.B.** *cum laude* in Chemistry & Physics (3 yrs, 1997)
Bronx High School of Science, graduated with honors (1994)

SCIENTIFIC HIGHLIGHTS

Quantum Amplifiers: We have developed a new amplifier based on dynamical switching near a Hopf bifurcation in a purely AC driven nonlinear system with no excess dissipation. In this system, dissipation is only present at the input of the following amplification stage, thus making it ideally suited for quantum measurements which require low back-action. We have successfully implemented this amplification principle in a solid-state system – the microwave driven Josephson junction. We are now using the Josephson bifurcation amplifier, with its quasiparticle-free operation, as a readout for quantum systems, in particular superconducting qubits.

Variable T_C Hot-Electron Mixers: Superconducting hot-electron bolometers used in astronomy for heterodyne detection at THz frequencies are currently limited in sensitivity by fluctuations in electron temperature. A reduction in critical temperature (T_C) increases sensitivity but also increases the susceptibility to saturation from background photons. Using various superconductors, we have verified the reduction in thermal fluctuation noise achieved by lowering T_C, and have characterized the different saturation effects which limit mixer sensitivity. Using a bilayer material system (Nb-Au) which uses the superconductor-normal metal proximity effect to tune T_C, we have demonstrated devices which should achieve an optimum balance between sensitivity and saturation.

RESEARCH POSITIONS

Assistant Professor (on leave 2005) July 1, 2005-Present
Physics Department, UC Berkeley

Postdoctoral Associate March 2002-June 2006
Applied Physics Dept., Yale University New Haven, CT
Research topic: Microwave measurements on mesoscopic systems with emphasis on superconducting charge-phase qubits and novel Josephson effect devices.
Supervisor: Prof. Michel Devoret

Graduate Researcher September 1997-February 2002 Applied Physics Dept., Yale University New Haven, CT
Dissertation topic: "Critical Temperature Dependence of High Frequency Electron Dynamics in Superconducting Hot-Electron Bolometer Mixers."
Graduate Advisor: Prof. Daniel Prober

Research Assistant September 1995-June 1997
Physics Dept., Harvard University Cambridge, MA
Undergraduate thesis topic: "Absolute Quantum Efficiency Measurements of a Prototype Ultra-Cold Neutron in Liquid Helium Detection System."
Undergraduate Advisor: Prof. John Doyle

Research Intern Summer 1996
HYPRES Inc. Elmsford, NY
Advisors: Dr. Raymond Robertazzi & Dr. David Osterman

Research Assistant Summer 1994&1995
Astrophysics Dept., Columbia University New York, NY
Advisor: Prof. Joseph Patterson

Research Intern Summer 1992-December 1993
Materials Science Dept., Polytechnic University Brooklyn, NY
Advisor: Prof. Harold Margolin

TEACHING EXPERIENCE

Instructor Fall 2006
Physics H7B
UC Berkeley (Honors Electricity and Magnetism)

Teaching Fellow level II Fall 1998, 1999, 2000& 2001
Engineering & Applied Science 506a/Physics 439a
Yale University (Basic Quantum Mechanics)

Teaching Fellow level II Spring 1998&1999
Engineering & Applied Science 110b
Yale University (Perspectives on Technology)

Teaching Fellow level I Fall 1999
Engineering & Applied Science 650a
Yale University (Instrumentation & Product Design)

OTHER EXPERIENCE

Cleanroom Committee Chairman February 2000-August 2000
Yale Center for Microelectronic Materials and Structures
Committee Member 1998-Present

Fellowships

NASA Graduate Student Researchers Program, 1997-2000
Edward Barlow Fellowship, Yale University, 1997-1998
Q Entry Scholarship, Harvard University, 1997
Harvard Scholarship for Academic Excellence, 1997
New York Governor's Award and Scholarship 1994-1996

Honors

The UC Berkeley Hellman Faculty Fund (2007)
The Office of Naval Research, Young Investigator Award (2007)
The George E. Valley Prize, American Physical Society (2006)
The Harding Bliss Prize, Yale University (2002)
The Harvard Foundation for Intercultural and Race Relations Citation (1997)
Perkins Prize, Lowell House Harvard University (1997)
New York Academy of Sciences: NYC School Technology Expo *First Place* (1994)
New York State Science Talent Search *Highest Honor,* (1994)
Rensselaer Polytechnic Institute Medal, Outstanding Achievement in Math and Sci. (1994)
American Mathematics Competitions Certificate of Achievement (1994)
National Honor Society (1994)
Nat. Consortium for Specialized Schools of Math, Sci. and Tech. *National Scholar* (1994)
Columbia Engineering Alumni Association Award (1994)
Nynex Award (1994)
Columbia University Science Honors Program (1993-1994)
New York Mathematics Fair *Gold Medal* (1993)
Who's Who in American High School Students (1992-1994)
New York Academy of Sciences: NYC School Technology Expo *Second Place* (1993)
Lehigh University Materials Camp, Lehigh University (1992)
New York Academy of Sciences: NYC School Technology Expo *Second Place* (1990)

Refereed Journal Publications

1. "Entangled Solid-State Circuits"
   I. Siddiqi and J. Clarke
   Science **313**, 1400 (2006).

2. "Dispersive Measurements of Superconducting Qubit Coherence with a Fast, Latching Readout"
   I. Siddiqi, R. Vijay, M. Metcalfe, E. Boaknin, L. Frunzio, and M.H. Devoret
   Phys. Rev. B **73**, 054510 (2006).

3. "An RF-Driven Josephson Bifurcation Amplifier for Quantum Measurements"
   I. Siddiqi, R. Vijay, F. Pierre, C.M. Wilson, M. Metcalfe, C. Rigetti, L. Frunzio, and M.H. Devoret, Phys. Rev. Lett. **93**, 207002 (2004).

4. "Direct Observation of Dynamical Switching between Two Driven Oscillation States of a Josephson Junction.
   I. Siddiqi, R. Vijay, F. Pierre, C.M. Wilson, L. Frunzio, M. Metcalfe, C. Rigetti, R.J. Schoelkopf, and M.H. Devoret, Phys. Rev. Lett. **94**, 027005 (2005).

5. "Nb-Au Bilayer Hot-Electron Bolometers for Low-Noise THz Heterodyne Detection"
   I. Siddiqi and D.E. Prober, Appl. Phys. Lett. **84**, 1404 (2004).

6. "Primary Electronic Thermometry using the Shot Noise of a Tunnel Junction"
   L. Spietz, K. Lehnert, **I. Siddiqi**, and R.J. Schoelkopf, Science 300, 1929 (2003).

7. "Heterodyne Mixing in Aluminum Superconducting Hot-Electron Bolometer Mixers"
   I. Siddiqi, A. Verevkin, R. Jahn, D.E. Prober, A. Skalare,W.R. McGrath, P.M. Echter nach and H.G. LeDuc, J. Appl. Phys. **91**, 4646 (2002).

8. "Noise and Conversion Efficiency in Aluminum Superconducting Hot Electron Bolome ter Mixers"
   I. Siddiqi, A. Verevkin, D.E. Prober, A. Skalare, W.R. McGrath, P.M. Echternach and H.G. LeDuc, IEEE Trans. Appl. Supercond. **11**, 958 (2001).

9. "Aluminum Hot-Electron Bolometer Mixers at Submillimeter Wavelengths"
   A. Skalare, W.R. McGrath, P.M. Echternach, H.G. LeDuc, **I. Siddiqi**, A Verevkin, and D.E. Prober, IEEE Trans. Appl. Supercond. **11**, 641 (2001).

10. "Flux Trapping Experiments in Single Flux Quantum Shift Registers"
    R. Robertazzi, **I. Siddiqi**, and O. Mukhanov, IEEE Trans. Appl. Supercond. **7**, 3164 (1997).

Published Conference Proceedings

1. "The Josephson Bifurcation Amplifier for Quantum Measurements"
   I. Siddiqi, R. Vijay, F. Pierre, C.M. Wilson, L. Frunzio, M. Metcalfe, C. Rigetti, and M.H. Devoret
   In *Quantum Computation in Solid State Systems*, B. Ruggiero, P. Delsing, C. Granata, Y. Pashkin, and P. Silvertrini (eds.). Springer, Vol. XVI, 337 pp., ISBN 0-387-26332-2 (2006).

2. "Reduced-Tc Nb Superconducting Hot-Electron Bolometer Mixers"
   I. Siddiqi, D.E. Prober, B. Bumble, and H.G. LeDuc
   Proceedings of the 12th International Symposium on Space Terahertz Technology, San Diego, CA, February 2001, pp. 36-41.

3. "Aluminum Sub-Micron Superconducting Hot-Electron Bolometer Mixers"
   I. Siddiqi, A. Verevkin, D.E. Prober, A. Skalare, B.S. Karasik, W.R. McGrath, P.M. Echternach, and H.G. LeDuc
   Proceedings of the 11th International Symposium on Space Terahertz Technology, Ann Arbor, MI, May 2000, pp. 82-94.

4. "Diffusion-Cooled Aluminum Hot-Electron Bolometer Mixers at Submillimeter Wave lengths"
   A. Skalare, W.R. McGrath, P.M. Echternach, H.G. LeDuc, **I. Siddiqi**, A. Verevkin, and D.E. Prober
   Proceedings of the 11th International Symposium on Space Terahertz Technology, Ann Arbor, MI, May 2000, pp. 501-512.

Invited Talks

"Amplifying Quantum Signals with the Josephson Bifurcation Amplifier (JBA)"
IV International workshop on Macroscopic Quantum Coherence and Computing
Palazzo Serra di Cassano, Via Monte di Dio 14, Napoli, Italy 7-10 June, 2004

"Using a Dynamical Bifurcation to Readout a Quantum Bit"
Gordon Research Conference on Quantum Information Science, February 2005.

"Amplifying Quantum Signals with the Josephson Bifurcation Amplifier (JBA)"
2005 March Meeting, Los Angeles CA.

"**Metastable State of the Josephson Junction"**
Boulder Summer School, July 2005.

"**Bifurcation Readout for Superconducting Qubits"**
Boulder Summer School, July 2005.

"**Non-linear Dispersive Measurements of the Quantronium Qubit**"
GDEST EU-US Workshop on "Quantum Information and Coherence"
Munich, 7 – 9 December 2005.

"**Non-linear Dispersive Measurements of the Quantronium Qubit**"
Gordon Research Conference on Superconductivity, January 2006.

"**Information Flow in the Readout of a Superconducting Qubit**"
Quantum Computing and Many Body Systems, February 2005.

"Quantum Activation in the Josephson Bifurcation Amplifier"
International Workshop on Nanoscale Superconductivity and Magnetism – MESO '06, Chernogolovka, June 2006.

"Quantronium: A Superconducting Wheatstone Bridge"
Applied Superconductivity Conference, August 2006.

Seminars/Colloquia

"THE JOSEPHSON BIFURCATION AMPLIFIER: A new readout for superconducting qubits"
-Michigan State University, Institute for Quantum Sciences Seminar, April 21, 2004.

"BIFURCATION AMPLIFICATION IN AN RF-DRIVEN JOSEPHSON JUNCTION: A new readout for superconducting qubits"
-NIST, Electronics and Electrical Engineering Laboratory, January 15, 2004.
-Caltech, Physics Seminar, February 17, 2004.

"**AMPLIFYING QUANTUM SIGNALS WITH THE JOSEPHSON BIFURCATION AMPLIFIER"**
-City College, City University of New York, Physics Seminar, October 29, 2004.

"**COMMUNICATING WITH THE QUANTUM WORLD USING A CLASSIC DYNAMICAL BIFURCATION"**
-University of Washington, Seattle, Physics Colloquium, December 6, 2004.

"**USING A DYNAMICAL BIFURCATION TO READOUT A QUANTUM BIT"**
- University of South Carolina, Nanocenter, Physics Colloquium, January 13, 2005.
- Northeastern University, Physics Colloquium, January 18, 2005.
- Massachusetts Institute of Technology, Physics Seminar, January 20, 2005.
- Boston College, Physics Colloquium, February 2, 2004.
- University of Chicago, James Franck Institute, February 15, 2005.
- Harvard University, March 11, 2005.
- Georgia Institute of Technology, February 21, 2005.
- UC Berkeley, April 4, 2005.

"OBSERVATION OF THE DYNAMICAL CASIMIR EFFECT IN THE JOSEPHSON BIFURCATION AMPLIFIER"
Quantronics Group, CEA, Saclay, June 2006.

"USING A DYNAMICAL BIFURCATION TO READOUT A QUANTUM BIT"
Louis Neel Laboratory, CNRS, Grenoble, June 2006.

Conferences Presentations

American Physical Society March Meeting, Baltimore, Maryland	March 2006
Applied Superconductivity Conference, Jacksonville, FL	October 2004
Macroscopic Quantum Coherence and Computing, Naples, Italy	June 2004
American Physical Society March Meeting, Montreal, Canada	March 2004
Army Research Office Program Review, Nashville, TN	August 2003
U.S.-Australia Workshop on Solid State and Optical Approaches to Quantum Information Science, Sydney, Australia	January 2003
Army Research Office Program Review, Nashville, TN	August 2002
Applied Superconductivity Conference, Houston, TX	August 2002
NATO-ASI "New Trends in Mesoscopic Physics", Erice, Italy	July 2002
13th Int'l Symposium on Space Terahertz Technology, Cambridge, MA	March 2002
American Physical Society March Meeting, Indianapolis, IN	March 2002
9th Int'l Conference on Terahertz Electronics, Charlottesville, VA	October 2001
American Physical Society March Meeting, Seattle, WA	March 2001
12th Int'l Symposium on Space Terahertz Technology, San Diego, CA	February 2001
Applied Superconductivity Conference, Virginia Beach, VA	September 2000
Space Astrophysics Detectors and Detector Technologies, Baltimore, MD	June 2000
11th Int'l Symposium on Space Terahertz Technology, Ann Arbor, MI	May 2000
American Physical Society March Meeting, Minneapolis, MN	March 2000

Research Description

Yale University Postdoctoral Research: We are currently developing novel amplifiers based on the transition between different driven oscillation states in the vicinity of a Hopf bifurcation in a Josephson junction. These oscillation states differ in their oscillation phase, and therefore can be readily detected using microwave reflection measurements. Precise characterization and control of the Josephson non-linearity is achieved by shunted the junction with a lithographic capacitor to tune the plasma oscillation frequency. In this amplification scheme, no on-chip resistors are needed and the only dissipative element is load impedance of the circuitry used to detect the bifurcation amplifier signal. There is therefore no loss of information to parasitic dissipation. Also the only back-action in this amplifier is due to phase fluctuations in the readout junction induced by thermal noise in the load at the output of the bifurcation amplifier, thus yielding an ultra-low input noise temperature. No quasiparticles are generated in the dynamical transition as the junction never switches into the voltage state, reducing quasiparticle poisoning and permitting fast operation. Such amplifiers, when

properly optimized, should have comparable sensitivity to SQUIDs but with minimal back-action and quasiparticle-free operation. We have fabricated and performed microwave tests on Josephson bifurcation amplifiers, and have shown that they perform in accordance with simple theoretical predictions. We are currently integrating these amplifiers with superconducting qubits to perform stringent tests of quantum mechanics such as the violation of Bell's inequalities.

Yale University Graduate Research (*http://www.yale.edu/proberlab/*): Ultra-sensitive, thin-film superconducting hot-electron bolometer (HEB) terahertz mixers are ideal for remote-sensing applications in radio-astronomy, upper atmospheric chemistry, and planetary science. The focus of my research was to improve the performance of HEB mixers by using superconductors with a lower critical temperature than Nb (T_C=5-6K). I worked on both the e-beam fabrication and microwave (40 GHz) testing of these devices at subkelvin temperatures. In our experiments, we took two different approaches to produce lower T_C mixers. First, by applying a magnetic field, the T_C of Nb HEBs was varied in a continuous fashion. Second, we studied Al and Nb-Au (superconductor-normal metal bilayer) mixers which have T_c < 2K. We demonstrated that mixer sensitivity increases linearly by lowering T_C due to a decrease in thermal fluctuation noise. We also characterized saturation at the input and output ports of the mixer due to incident broadband noise. In the course of these measurements, we observed novel phenomena in these superconducting nanobridges that arise from proximity effects that place size limitations, and therefore bandwidth limitations on nanostructure devices. The Nb-Au bilayer HEBs fabricated at Yale are planned for use in focal plane arrays on the Heinrich Hertz telescope and on AST/RO at the South Pole in collaboration with the University of Arizona. HEBs are also planned for use on the NASA/DLR Stratospheric Observatory for Infrared Astronomy (SOFIA) (*http://sofia.arc.nasa.gov/*) and on the Herschel Far Infrared and Submillimeter Telescope (FIRST) (*http://sci.esa.int/first/*) satellite.

Harvard University (*http://www.doylegroup.harvard.edu/*): The ultra-cold neutron (UCN) experiment is aimed at exploring fundamental neutron physics, such as the free neutron beta-decay lifetime, by magnetically trapping UCNs in liquid helium and detecting the ultraviolet radiation emitted by the helium upon absorption of beta particles from the neutron decay. The ultraviolet emission is converted to the visible by way of scintillators such as tetraphenyl butadiene. My work focused on simulating the detection experiment by using the decay products of a ^{210}Po source in liquid helium to induce scintillations. Collaborators include NIST, HMI (Berlin), and Los Alamos National Lab.

HYPRES (*http://hypres.hypres.com/*): I investigated various aspects of the fabrication and testing of digital rapid single flux quantum (RSFQ) superconducting circuits. In particular, I tested the effect of ground plane holes on flux trapping in SFQ shift registers. Also, new fabrication techniques for thermopile infrared detectors were developed.

Columbia University (*http://cba.phys.columbia.edu/jop/*): My work here involved the study of light emission from cataclysmic variable stars. I used different mathematical techniques and wrote computer programs to analyze the quasi-periodic and flickering behavior of AL COM, V603 AQL, and other dwarf novae.

Polytechnic University (*http://mechanical.poly.edu/*): I conducted independent research aimed at improving the wetting and mechanical properties of 60/40 Sn-Pb solder. A new alloy consisting of Sn-Pb-Ti-Cu-Ni that had a ~20% increase in copper wettability and a ~100% increase in shear strength was developed.

References

Professor Michel H. Devoret (Postdoctoral Advisor)
Department of Applied Physics, Yale University
PO Box 208284
New Haven, CT 06520-8284
Tel: 203-432-4277
michel.devoret@yale.edu

Professor Daniel E. Prober (Graduate Advisor)
Department of Applied Physics (Chairman), Yale University
PO Box 208284
New Haven, CT 06520-8284
Tel: 203-432-4280
daniel.prober@yale.edu

Professor Robert Schoelkopf
Department of Applied Physics, Yale University
PO Box 208284
New Haven, CT 06520-8284
Tel: 203-432-4289
robert.schoelkopf@yale.edu

Professor Emeritus Werner P. Wolf (Teaching)
Department of Applied Physics, Yale University
PO Box 208284
New Haven, CT 06520-8284
Tel: 203-432-2210
werner.wolf@yale.edu

Dr. Daniel Esteve
Director of Research, Quantronics group
SPEC-CEA Saclay
91191 Gif-sur-Yvette FRANCE
Tel: (33)+(0)169085529
(33)+(0)169087341
Fax: (33)+(0)169087442
esteve@drecam.saclay.cea.fr

Dr. Elie K. Track
Visiting Professor
Department of Physics, Fairfield University
1073 North Benson Road
Fairfield, CT 06824
Tel: (203) 254-4000 Ext. 2192
etrack@mail.fairfield.edu

Dr. John Martinis
National Institute of Standards and Technology (NIST)
Electromagnetic Technology Division
325 Broadway, MC 814.00
Boulder, Colorado 80305-3328
Tel: 303-497-3597
john.martinis@nist.gov