SAN FRANCISCO BAY AREA
NANOTECHNOLOGY COUNCIL

Quantum Computing

Devices, Challenges and Applications

Thursday, Nov 12 from 8:30 am – 3.30 pm

Registration Starts 8.30 am

IEEE SFBA 2020 Chair Introduction - Dr. Vasuda Bhatia – 8.45 am

Quantum Computing Conference Chair Introduction - Dr. Geetha Dholakia – 8.55 am

Abstracts and Speaker Bios

Dr. Tim Phung

IBM, *Research Staff Member*

Challenges towards developing low loss superconducting qubit devices

Superconducting qubits are considered a promising hardware platform for constructing future quantum computing systems. Over the last several decades, the field has advanced from initial demonstrations of quantum dynamics in superconducting devices to the design and development of large-scale multi-qubit chips. A critical experimental challenge towards realization of such superconducting quantum processors is the fabrication of low loss superconducting qubit devices, which can ultimately limit the fidelity of operations on the quantum processor. In this talk, I will describe the materials and device aspects of this challenge.

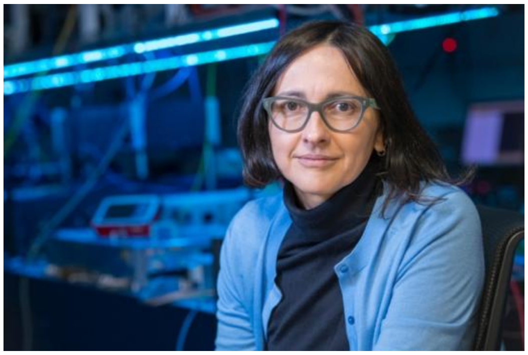
Bio:

Timothy Phung graduated from UC Berkeley with a BA in Physics in 2006 and received a Ph.D. in Electrical Engineering from Stanford University in 2014, with a thesis on magnetic domain wall dynamics in magnetic nanowires. He joined IBM Research - Almaden as a Research Staff Member in 2014, where he worked on spin transfer torque MRAM and spin orbit torque materials and devices. His current research interests includes the design and development of superconducting qubit devices.

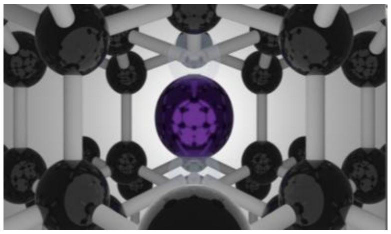
Prof. Jelena Vuckovic

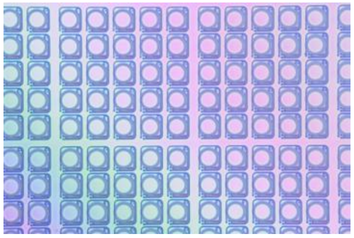
Stanford University, *Professor of Electrical Engineering and Applied Physics*

Connecting and scaling semiconductor quantum systems



At the core of most quantum technologies, including quantum networks, quantum computers and quantum simulators, is the development of homogeneous, long lived qubits with excellent optical interfaces, and the development of high efficiency and robust optical interconnects for such qubits. To achieve this goal, we have been studying color centers in diamond (SiV, SnV) and silicon carbide (VSi in 4H SiC), in combination with novel fabrication techniques, and relying on the powerful and fast photonics inverse design approach that we have developed. We illustrate this with a number of demonstrated devices, including efficient quantum emitter-photon interfaces for color centers in diamond and in SiC.





Bio:

Jelena Vuckovic is a Jensen Huang Professor in Global Leadership in the School of Engineering, a Professor of Electrical Engineering and by courtesy of Applied Physics at Stanford, where she leads the Nanoscale and Quantum Photonics Lab. She is also a director of Q-FARM, Stanford-SLAC Quantum Science and Engineering Initiative, and is affiliated with Ginzton Lab, PULSE Institute, SIMES Institute, Stanford Photonics Research Center (SPRC), SystemX Alliance, Bio-X, and Wu-Tsai Neurosciences Institute at Stanford.

Upon receiving her PhD degree from the California Institute of Technology (Caltech) in 2002, she worked as a postdoctoral scholar at Stanford. In 2003, she joined the Stanford Electrical Engineering Faculty, first as an assistant professor (until 2008), then an associate professor (2008-2013), and as a professor of electrical engineering (since 2013). She has also held visiting positions at the Max Planck Institute for Quantum Optics (MPQ) in Munich, Germany (2019), at the Institute for Advanced Studies of the Technical University in Munich, Germany (2013-2018), and Institute for Physics of the Humboldt University in Berlin, Germany (2010-2013).

Vuckovic has received many awards including the James Gordon Memorial Speakership from the OSA (2020), the IET A. F. Harvey Engineering Research Prize (2019), Distinguished Scholar of the Max Planck Institute for Quantum Optics - MPQ (2019), Hans Fischer Senior Fellowship from the Institute for Advanced Studies in Munich (2013), Humboldt Prize (2010), Marko V. Jaric award for outstanding achievements in physics (2012), DARPA Young Faculty Award (2008), Chambers Faculty Scholarship at Stanford (2008), Presidential Early Career Award for Scientists and Engineers (PECASE in 2007), Office of Naval Research Young Investigator Award (2006), Okawa Foundation Research Grant (2006), and Frederic E. Terman Fellowship at Stanford (2003). She is a Fellow of the American Physical Society (APS), of the Optical Society of America (OSA), and IEEE.

Vuckovic is a member of the scientific advisory board of the Max Planck Institute for Quantum Optics - MPQ (in Munich, Germany), of the Ferdinand Braun Institute (in Berlin, Germany), an advisory board member of the National Science Foundation (NSF) - Engineering Directorate, and a board member of SystemX at Stanford. Currently, she is also an Associate Editor of ACS Photonics, and a member of the editorial advisory board of Nature Quantum Information and APL Photonics.

Prof. Dan Stamper-Kurn

***UC Berkeley**, Professor of Physics*

Quantum computation and simulation with single-atom qubits

When we think of computers these days, we think about the content of our laptops and cell phones, which are highly integrated semiconductor-based electronics. However, in order to realize quantum computers, which rely on coherent quantum mechanical evolution of computing hardware, we may have to rethink what a computer looks like. I will discuss some of the plans of the newly formed Challenge Institute for Quantum Computation, which was established by the National Science Foundation as part of their Quantum Leap Challenge Institute program. I will then summarize some modern efforts to realize quantum computation, and the related goal of quantum simulation, using ultracold neutral atoms that are trapped optically within ultra-high vacuum chambers. Will ultracold atoms find their way into the quantum computing laptops and cell phones of the future?

Bio:

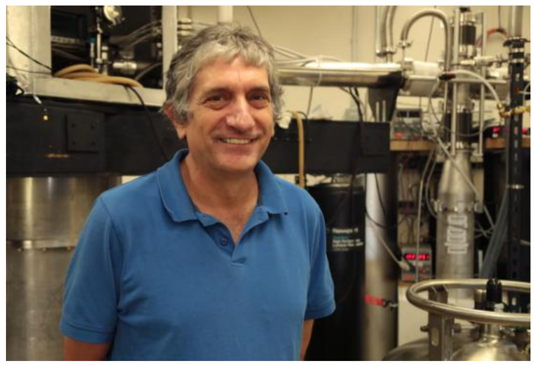
Dan Stamper-Kurn received his undergraduate degree in Physics from UC Berkeley in 1992. Following a research assistantship at the Lawrence Berkeley National Laboratory, Dan pursued doctoral studies at MIT, the first studies of Bose-Einstein condensation in an atomic gas in the group of Prof. Wolfgang Ketterle, work for which Ketterle received the Nobel Prize in Physics in 2001.

Thereafter, Dan developed quantum optics experiments with single trapped neutral atoms as a Millikan Postdoctoral Fellow with Prof. H. Jeff Kimble at Caltech. In 2001, Prof. Stamper-Kurn joined the Physics faculty at UC Berkeley where he teaches courses in theoretical and experimental physics and conducts research in quantum optics, materials science, and precision metrology using ultracold atoms. He is the recipient of Fellowships from the Packard Foundation, the Sloan Foundations and the Miller Institute, of the Presidential Early Career Award in Science and Engineering, and of the Carl Friedrich von Siemens Research Award of the Alexander von Humboldt Foundation. Prof. Stamper-Kurn is an elected fellow of the American Physical Society and the Optical Society (OSA). He holds an endowed research chair and an adjunct appointment in the Materials Sciences Division of the Lawrence Berkeley National Laboratory. Most recently, Stamper-Kurn directs the Challenge Institute for Quantum Computation, which was established as part of the NSF Quantum Leap Challenge Institute program.

Prof. John Martinis

Google, *Research Scientist*
UC Santa Barbara, *Professor of Physics*

Quantum supremacy using a programmable superconducting processor



The promise of quantum computers is that certain computational tasks might be executed exponentially faster on a quantum processor than on a classical processor. A fundamental challenge is to build a high-fidelity processor capable of running quantum algorithms in an exponentially large computational space. Here we report the use of a processor with programmable superconducting qubits to create quantum states on 53 qubits, corresponding to a computational state-space of dimension 2^53 (about 10^16). Measurements from repeated experiments sample the resulting probability distribution, which we verify using classical simulations. Our Sycamore processor takes about 200 seconds to sample one instance of a quantum circuit a million times—our benchmarks currently indicate that the equivalent task for a state-of-the-art classical supercomputer would take approximately 10,000 years. This dramatic increase in speed compared to all known classical algorithms is an experimental realization of quantum supremacy for this specific computational task, heralding a much-anticipated computing paradigm.

Bio:

John Martinis did pioneering experiments in superconducting qubits in the mid 1980's for his PhD thesis. He has worked on a variety of low temperature device physics during his career, focusing on quantum computation since the late 1990s. He was awarded the London Prize in Low temperature physics in 2014 for his work in this field. From 2014 to 2020 he worked at Google to build a useful quantum computer, culminating in a quantum supremacy experiment in 2019.

Dr. Eleanor Rieffel

NASA Ames, *Senior Research Scientist Lead, Quantum Artificial Intelligence Laboratory*

How to Compute with Schrödinger's Cat: An Introduction to Quantum Computing

The success of the abstract model of computation, in terms of bits, logical operations, algorithms, and programming language constructs makes it easy to forget that computation is a physical process. Our cherished notions of computation and information are grounded in classical mechanics, but the physics of our universe is quantum. A natural question to ask is how computation would change if we adopted a quantum mechanical, instead of a classical mechanical, model of computation. In the early 80s, Richard Feynman, Yuri Manin, and others recognized that certain quantum effect could not be simulated efficiently on conventional computers. This observation led researchers to speculate that perhaps such quantum effect could be used to speed up computation more generally. Slowly, a new picture of computation arose, one that gave rise to a variety of faster algorithms, novel cryptographic mechanisms, and alternative methods of communication. In the first part of the talk, I will introduce key concepts underlying quantum computing and correct misconceptions. In the second part of the talk, I will discuss research being done by NASA's QuAIL group on quantum algorithms, quantum supremacy, elucidating quantum resources for computation, quantum programming and compilation, quantum-inspired classical algorithms, and assessing future applications of quantum computing, all within the broader context of the rapidly evolving field.

Bio:

Eleanor G. Rieffel leads the Quantum Artificial Intelligence Laboratory at the NASA Ames Research Center, and is a 2020 NASA Ames Associate Fellow. She joined NASA Ames Research Center in 2012 to work on the expanding quantum computing effort. Previously, she performed research in diverse fields at FXPAL, including quantum computation, applied cryptography, image-based geometric reconstruction of 3D scenes, bioinformatics, video surveillance, and automated control code generation for modular robotics. Her research interests include quantum heuristics, evaluation and utilization of near-term quantum hardware, fundamental resources for quantum computation, quantum error mitigation, and applications for quantum computing. She received her Ph.D. in mathematics from the University of California, Los Angeles. She is best known for her 2011 book Quantum Computing: A Gentle Introduction with coauthor Wolfgang Polak and published by MIT press.

Thanks to our Sponsors: EAG LABORATORIES intel