# YALE QUANTUM INSTITUTE ANNUAL REPORT

## 2017

Quantum information science, hailed as one of the most exciting scientific fields of the 21st century, **now has a home** at Yale.

# CONTENTS

# Directors’ Word

Welcome to the first issue of the Yale Quantum Institute’s annual report!

Inside you will find some information about the Institute and its mission, as well as some highlights of both our programs and the research performed by YQI members this year. Since the official opening of our renovated offices at 17 Hillhouse in October 2015, the Institute has become a busy place, buzzing with activity of all sorts, and serving as a hub for scientific interchange and collaboration. We have hosted a full slate of both short-term and long-term visitors to campus, and a phenomenal series of colloquia and seminars by leading figures in quantum science and quantum information from around the globe. The Institute also sponsored many other events, from sessions on career-development and professional skills for students and postdocs, to social functions where members from all levels of the YQI community can get to know one another better.

Our support staff has also changed as we have grown. Sadly, we had to say goodbye to Stephanie Hessing, the first Institute Manager, as she and her family chose to relocate back to Europe. We were very fortunate, however, to attract Dr. Florian Carle to take up this key position. Florian has hit the ground running, not only continuing the existing efforts of the YQI and helping to launch several of our new programs, but injecting creative new ideas of his own! Joining Florian in the YQI offices is our amiable and efficient administrative assistant, Racquel Miller. This terrific team is always here on-site to help in whatever ways they can, to make the YQI as convenient as possible for both visitors and local members, and to foster an atmosphere that is conducive to the best quality science.

Today, we find ourselves at a very exciting time for quantum science and quantum information. There are now technologies which will soon lead to scalable quantum computation, and scientists can build ever more sophisticated and complex quantum machines. There is ever-increasing interest and excitement about our field, from students, the general public, governments around the world, and even the commercial sector. The pace of innovation and progress is frankly breathtaking. I believe we are now in an era where we need to merge the fields of quantum devices and quantum information theory, with plenty of technology and engineering of various kinds, to form a new discipline of quantum computer science. Here at the Yale Quantum Institute, we are poised and ready to be leaders in inaugurating this “second wave of the information age.” We hope you will join with us in this mission!

Please have a look inside this issue to learn more, and we hope to see you soon at the YQI. Here’s to another active year of learning and collaboration, and more incredible breakthroughs in quantum science ahead!

Robert Schoelkopf
Institute Director



**“One of the most surprising discoveries in physics during the last half century is the demonstration that the quantum laws do not simply limit the possibilities for human knowledge, but also enable revolutionary approaches for the storage, transmission, and processing of information.**

A. Douglas Stone
Institute Deputy Director

A. Douglas Stone (left) and Robert Schoelkopf (right)

> **Any sufficiently advanced technology is indistinguishable from magic.**
>
> Arthur C. Clarke

# About the Institute

Life as we know it would not be possible were it not for several profound scientific and technological revolutions over the last century: the Industrial Revolution with electricity, the internal combustion engine, and the telephone, and later the Digital Revolution ushered in computers, cellular phones, and the Internet. This transformative period was made possible by the understanding of the fundamental laws of the atom and of light embodied in quantum theory, developed in the first half of the 20th century. At the onset of the 21st century, we are on the brink of a new quantum revolution – and Yale is paving the way.

Our faculty members, spanning Physics, Applied Physics, Computer Science and Electrical and Mechanical Engineering, are making scientific breakthroughs that will make possible new leaps forward that we could not have been imagined only a few decades ago. The Yale Quantum Institute was formed in 2015 to advance the progress in fundamental and applied quantum science at Yale and in the broader community of researchers across the globe. Yale has particular expertise in the theoretical and experimental development of new technologies to store and process quantum information. The goal is to better understand the fundamental quantum laws of our universe, and to exploit the unique features of quantum mechanics for novel sensors, secure communications, and eventually the realization of large-scale quantum computers. We now know that by employing a kind of massive parallel processing, quantum computers, based on "quantum bits", can address problems that would otherwise remain forever beyond the reach of our current, conventional computers. These problems include basic algorithms underlying secure communication on the internet, as well as quantum simulations of new materials, complex optimization problems, and improved machine learning. As with conventional computers, the true scope of their utility will probably only be discovered once they are built.

Beginning with pioneering work on macroscopic quantum coherence in the 80's to the realization of today's quantum information processors, Yale professors are renowned for their leadership of the Quantum Revolution. In the past fifteen years, under the leadership of Devoret, Schoelkopf and Girvin, the Yale team of more than fifty researchers has been proud to demonstrate several milestones in quantum computing, including the development of the first solid state quantum information processors, based on superconducting electronics. Together, with all of the members of YQI, we are pursuing the collective goal of turning quantum physics into practical technologies and advancing our fundamental understanding of quantum science and engineering. We welcome researchers from around the world to visit and participate in this intellectual adventure.

**1998**

Robert Schoelkopf appointed to Yale Faculty in Applied Physics and is awarded Packard Foundation Fellowship to develop new types of high frequency superconducting electronics for controlling quantum circuits.

**2001 - 2002**

Distinguished faculty members Michel Devoret and Steve Girvin are recruited at Yale, bringing futher expertise in the quantum behavior of electronic circuits with superconducting elements. The first long-lived superconducting quantum bits (qubits) are demonstrated.

**2005**

Dave DeMille and his research group develop a technique to produce ultracold polar molecules and propose to use them as qubits for quantum computation.

**2009**

The Devoret, Girvin and Schoelkopf groups invent a new superconducting qubit, the method to read it out efficiently, and the quantum "bus" that entangles two of them, leading to the realization of the first solid-state quantum processor running an algorithm.

**2014**

Hong Tang and Liang Jiang's research groups develop a chip-scale device that uses the wave-particle duality of single photons to sense the presence of an object without interacting with it, useful in spectroscopic studies of photosensitive materials.

**2015**

Official launch of the Yale Quantum Institute by President Peter Salovey in newly renovated conference and offices in 17 Hillhouse Ave.

**2016**

YQI researchers explore new paradigm for quantum computing based on "Schrodinger Cat" states of light (photons). They are first to demonstrate effective error correction with such photon qubits, a critical step towards computation with logical qubits.

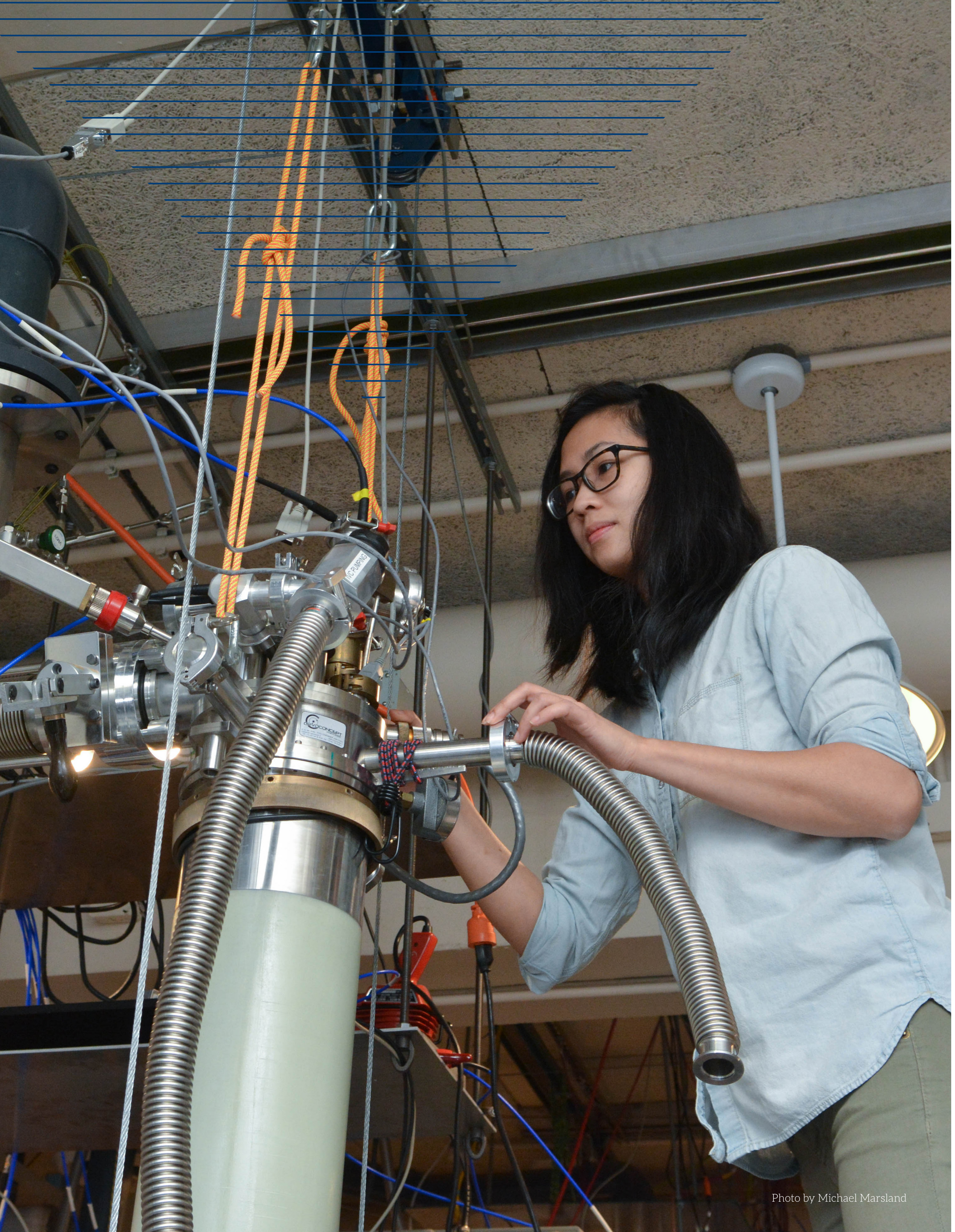


Photo by Michael Marsland



# Vision, Mission, and Field Definition

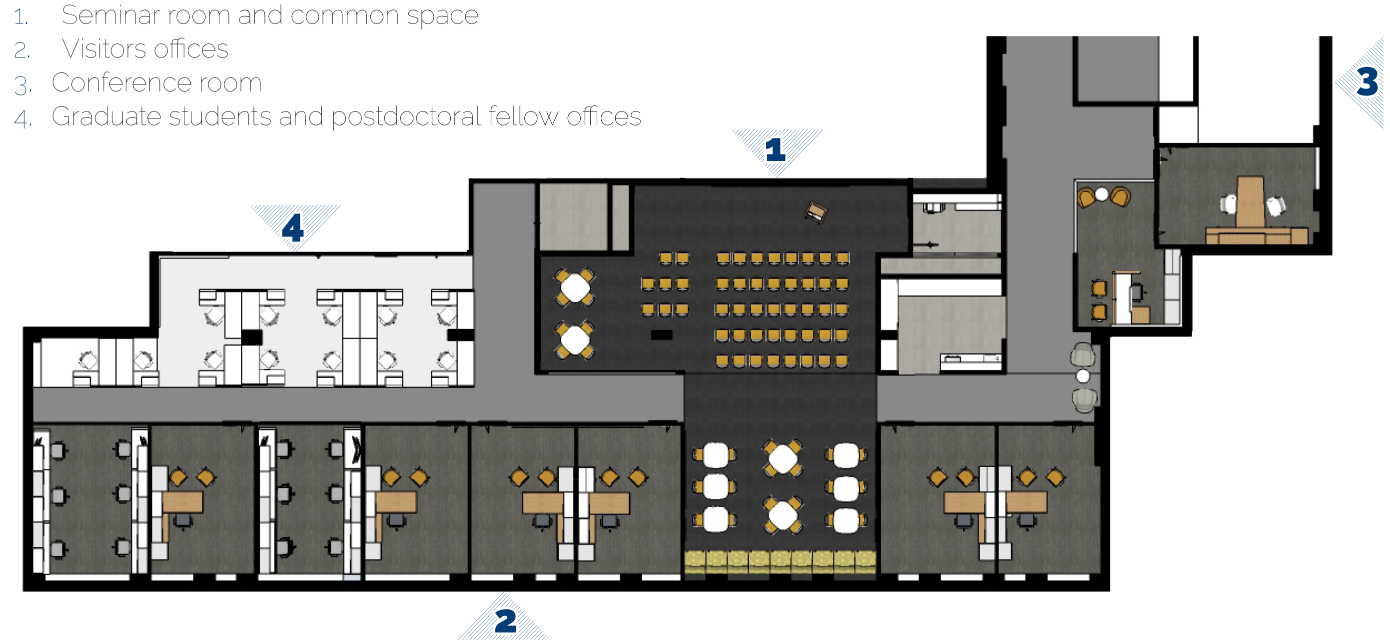
The Yale Quantum Institute was founded to enhance Yale's leadership in the field of quantum science and technology. It serves as a forum to bring together experimental and theoretical researchers at Yale in the field of quantum information physics, quantum control, quantum measurement, and quantum many-body physics. The Institute also runs an active visitors program to bring in quantum information scientists from leading institutions worldwide, and hosts conferences and workshops in sub-fields relating to its core mission.

The past two decades have seen breakthroughs in both the theory and the practice of quantum science. The properties of superposition and entanglement, once thought of as paradoxical and counterintuitive, are now understood instead as unique resources. At the same time, progress in the laboratory now allows unprecedented control over individual quantum objects, whether they are naturally-occurring microscopic systems like atoms, or macroscopic, man-made systems whose properties are engineered.

These advances may soon enable us to perform otherwise intractable computations, ensure privacy in communications, better understand and design novel states of matter and develop new types of sensors and measurement devices. Today, a new discipline is emerging which combines physics, electrical engineering, mathematics, and computer science to further the basic understanding of the quantum world, and to develop novel information processing devices and other quantum-enabled measurement and sensing technologies.

The Quantum Institute facilitates research and teaching of quantum science on the Yale campus, and performs outreach in the form of seminars, workshops, and hosting of world leading scientists from around the world.

1. Seminar room and common space
2. Visitors offices
3. Conference room
4. Graduate students and postdoctoral fellow offices



# Doubling Down on Schrödinger's Cat

## News

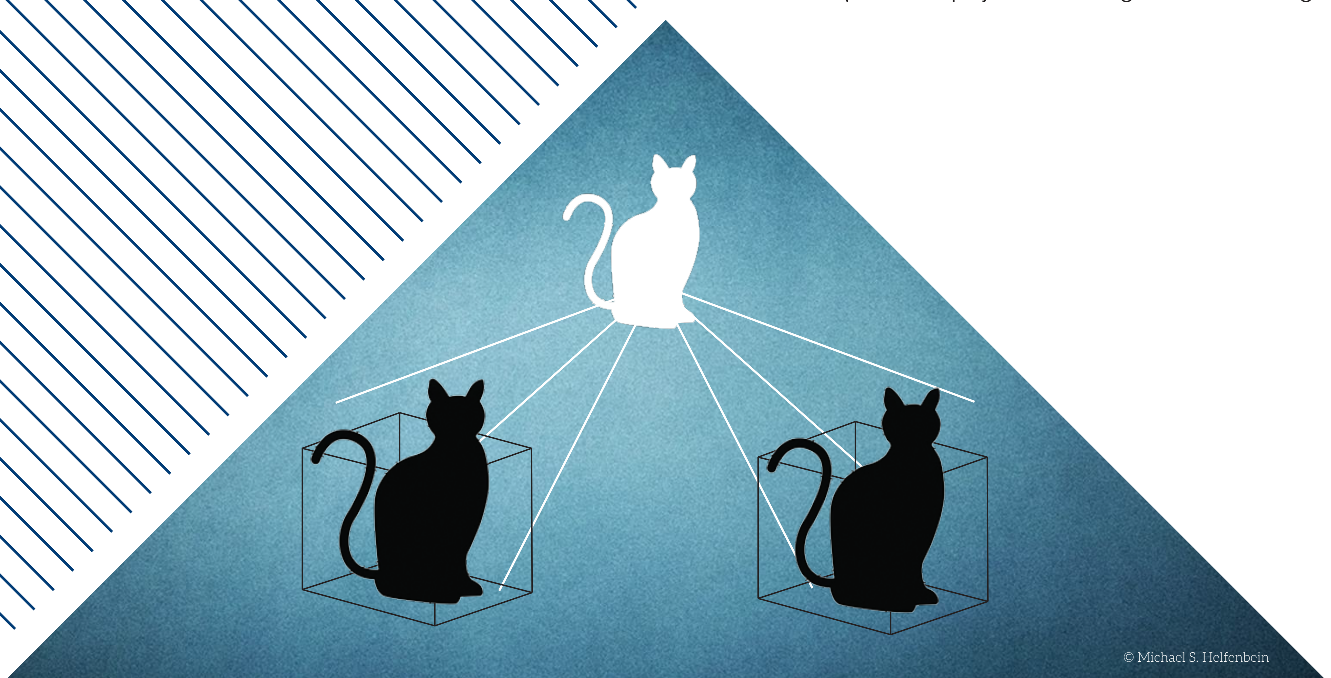
> **This cat is big and smart. It doesn't stay in one box because the quantum state is shared between the two cavities and cannot be described separately.**
>
> Chen Wang

Yale physicists have given Schrödinger's famous cat a second box to play in, and the result may help further the quest for reliable quantum computing.

Schrödinger's cat is a well-known paradox that applies the concept of superposition in quantum physics to objects encountered in everyday life. The idea is that a cat is placed in a sealed box with a radioactive source and a poison that will be triggered if an atom of the radioactive substance decays. Quantum physics suggests that the cat is both alive and dead (a superposition of states), until someone opens the box and, in doing so, changes the quantum state.

This hypothetical experiment, envisioned by one of the founding fathers of quantum mechanics in 1935, has found vivid analogies in laboratories in recent years. Scientists can now place a wave-packet of light composed of hundreds of particles simultaneously in two distinctly different states. Each state corresponds to an ordinary (classical) form of light abundant in nature.

A team of Yale scientists created a more exotic type of Schrödinger's cat-like state that has been proposed for experiments for more than 20 years. This cat lives or dies in two boxes at once, which is a marriage of the idea of Schrödinger's cat and another central concept of quantum physics: entanglement. Entanglement allows a local observation to change the state of a distant object instantaneously. Einstein once called it "spooky action at a distance," and in this case it allows a cat state to be distributed in different spatial modes.




The Yale team built a device consisting of two, 3D microwave cavities and an additional monitoring port — all connected by a superconducting, artificial atom. The "cat" is made of confined microwave light in both cavities.

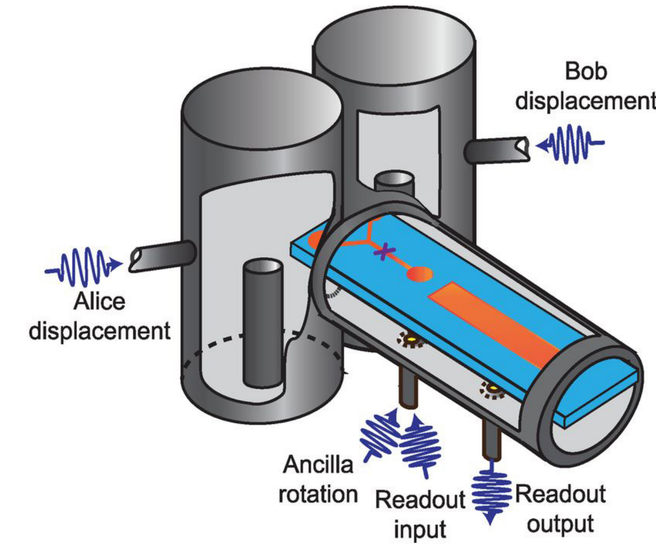
"This cat is big and smart. It doesn't stay in one box because the quantum state is shared between the two cavities and cannot be described separately," said Chen Wang, a postdoctoral associate at Yale and first author of a study in the journal *Science*, describing the research. "One can also take an alternative view, where we have two small and simple Schrodinger's cats, one in each box, that are entangled."

The research also has potential applications in quantum computation. A quantum computer would be able to solve certain problems much faster than classical computers by exploiting superposition and entanglement. Yet one of the main problems in developing a reliable quantum computer is how to correct for errors without disturbing the information.

"It turns out 'cat' states are a very effective approach to storing quantum information redundantly, for implementation of quantum error correction. Generating a cat in two boxes is the first step towards logical operation between two quantum bits in an error-correctible manner," said co-author Robert Schoelkopf, Sterling Professor of Applied Physics and Physics, and director of the Yale Quantum Institute.

Schoelkopf and his frequent collaborators, Michel Devoret and Steve Girvin, have pioneered the field of circuit quantum electrodynamics (cQED), providing one of the most widely used frameworks for quantum computation research. Devoret, Yale's F.W. Beinecke Professor of Physics, and Girvin, Yale's Eugene Higgins Professor of Physics and Applied Physics, are co-authors of the paper.

The research builds upon more than a decade of development in cQED architecture. The Yale team designed a variety of new features, including cylindrical 3D cavities with record quantum information storage time of more than 1 millisecond in superconducting circuits, and a measurement system that monitors certain aspects of a quantum state in a precise, non-destructive way.




A 3D view of the device consisting of two coaxial cavities (Alice and Bob), a Y-shaped transmon with a single Josephson junction (marked by ×), and a stripline readout resonator. All components are housed inside a single piece of bulk high-purity aluminum, with artificial windows drawn for illustration purposes.

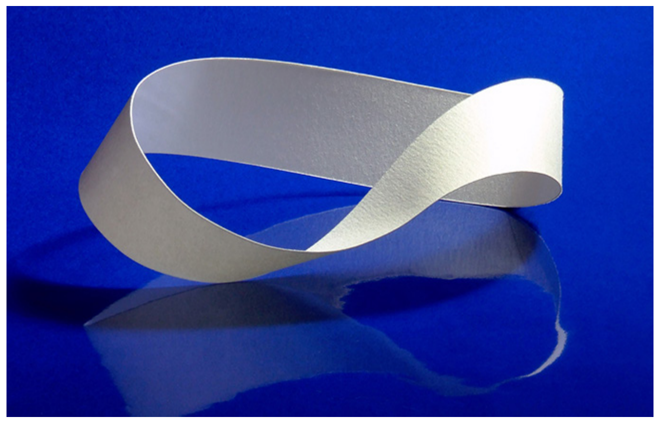
"We have combined quite a lot of recent technologies here," Wang said.

Additional co-authors from the Yale Departments of Applied Physics and Physics include assistant professor Liang Jiang; senior research scientist Luigi Frunzio; postdoctoral associates Reinier Heeres and Nissim Ofek; graduate students Yvonne Gao, Philip Reinhold, Kevin Chou, Christopher Axline, Matthew Reagor, Jacob Blumoff, and Katrina Sliwa; and Mazyar Mirrahimi.

The U.S. Army Research Office and the Multidisciplinary University Research Initiatives program of the Air Force Office of Scientific Research supported the research.

Jim Shelton, Yale News

# Building a Moebius Strip of Good Vibrations



Yale physicists have created something similar to a Moebius strip of moving energy between two vibrating objects, opening the door to novel forms of control over waves in acoustics, laser optics, and quantum mechanics.

The discovery also demonstrates that a century-old physics theorem offers much greater freedom than had long been believed. The findings are published online July 25 in the journal Nature.

Yale's experiment is deceptively simple in concept. The researchers set up a pair of connected, vibrating springs and studied the acoustic waves that traveled between them as they manipulated the shape of the springs. Vibrations — as well as other types of energy waves — are able to move, or oscillate, at different frequencies. In this instance, the springs vibrate at frequencies that merge, similar to a Moebius strip that folds in on itself.

The precise spot where the vibrations merge is called an "exceptional point."

"It's like a guitar string," said Jack Harris, a Yale associate professor of physics and applied physics, and the study's principal investigator. "When you pluck it, it may vibrate in the horizontal plane or the vertical plane. As it vibrates, we turn the tuning peg in a way that reliably converts the horizontal motion into vertical motion, regardless of the details of how the peg is turned."

Unlike a guitar, however, the experiment required an intricate laser system to precisely control the vibrations, and a cryogenic refrigeration chamber in which the vibrations could be isolated from any unwanted disturbance.

The Yale experiment is significant for two reasons, the researchers said. First, it suggests a very dependable way to control wave signals. Second, it demonstrates an important — and surprising — extension to a long-established theorem of physics, the adiabatic theorem.

The adiabatic theorem says that waves will readily adapt to changing conditions if those changes take place slowly. As a result, if the conditions are gradually returned to their initial configuration, any waves in the system should likewise return to their initial state of vibration. In the Yale experiment, this does not happen; in fact, the waves can be manipulated into a new state.

"This is a very robust and general way to control waves and vibrations that was predicted theoretically in the last decade, but which had never been demonstrated before," Harris said. "We've only scratched the surface here."

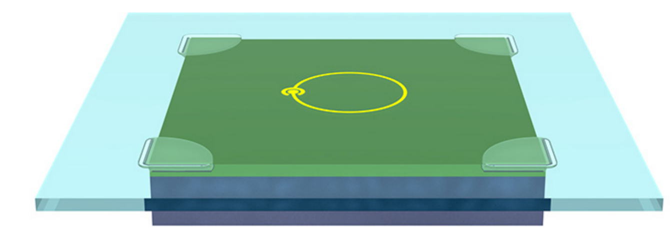
The first author of the paper is Yale postdoctoral associate Haitan Xu. Additional co-authors are Yale graduate students Luyao Jiang and David Mason.

In the same edition of Nature, a team from the Vienna University of Technology also presented research on a system for wave control via exceptional points.

Jim Shelton, Yale News



# Acoustic Resonator Device Paves the Way for Better Communication



Yale researchers have developed a high-frequency version of a device known as an acoustic resonator that could advance the field of quantum computing and information processing.

Hong Tang, Yale's Llewellyn West Jones Jr. Professor of Electrical Engineering & Physics, and his research team, accomplish this with what's also known as a piezo-optomechanical device. It achieves what is known as "strong coupling" between two systems: a superconducting microwave cavity and a bulk acoustic resonator system. The results appear in the journal Physical Review Letters.

With strong coupling, the device achieves an exchange of energy and information between the microwave and mechanical resonator systems at a rate that exceeds the dissipation — or diminishing energy — of each of the individual systems. That way, information doesn't get lost.

A unique feature of the system is that it operates at the very high frequency of 10 gigahertz. An advantage of a high-frequency system is that it allows for a high signal-processing speed, noted Xu Han, a Ph.D. student in Tang's lab and lead author of the study. "For example, you can convey the same amount of information or message in a shorter time," Han said.

Another advantage is that the high frequency makes it easier to observe quantum phenomena in experiments. In lower frequency devices, the system has to be cooled to extreme temperatures to overcome thermal noise, which comes from random vibrations from the environment that scramble the signal.

One of the potential applications, Han said, is information storage. "If you have a good coupling and exchange between the systems, then you can store information from the microwave domain in the mechanical domain," he said.

Although the experiments weren't conducted under quantum conditions, the researchers note that the high-frequency piezo-electromechanical device is compatible with superconducting qubits — the unit of information analogous to digital bits in conventional computing. That potentially could mean an important step towards hybrid quantum systems, which bridge the world between classical and quantum mechanics, they said.

Han said he is currently building on the technology to develop a device that uses the mechanical system to convert information from the microwave domain to the optical.

"If you want to transmit the information signal, you have to use optics, because optical fiber has very low loss over a long distance," he said.

Chang-Ling Zou, a postdoctoral scholar in Tang's lab, co-authored the paper.

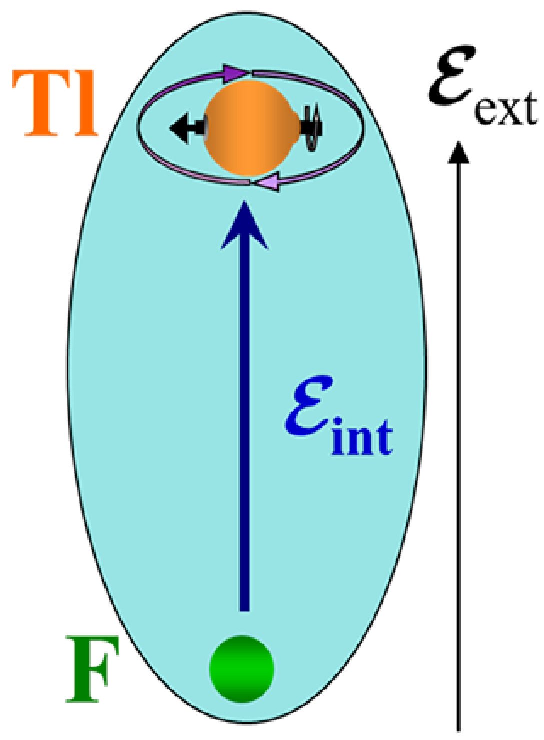
William Weir, Yale News

# Yale Leads Research Collaboration to Explore Origins of the Universe

Yale physics professor David DeMille has launched a pioneering investigation into the origins of the universe with support from the John Templeton Foundation and the Heising-Simons Foundation. DeMille plans to build a novel apparatus to sense the existence of never-before-seen subatomic particles thought to have a determining role in the formation of matter. Proving their existence — or absence — will provide a window into the earliest moments following the Big Bang.

DeMille will undertake the project in partnership with collaborators David Kawall of the University of Massachusetts, Tanya Zelevinsky of Columbia University, and Steve Lamoreaux of Yale. The grants from the John Templeton Foundation and the Heising-Simons Foundation, totaling $3 million, will support project staff and laboratory equipment.

"Our approach is a radical departure from the large particle accelerators that generally come to mind when you look for exotic particles," DeMille said. "Building on work that has been done at Yale, we will conduct a new type of experiment to probe for new particles and forces responsible for the predominance of matter over antimatter in the universe. We are very grateful to the Templeton and Heising-Simons foundations for their support, which was critical for our team to launch this work."




A deformation in the shape of a nucleus along the direction of its spin axis can arise only due to the presence of new, exotic particles. To search for such a deformation, thallium (Tl) nuclei are exposed to the strong electric field inside a polar molecule (thallium fluoride, TlF) that has been polarized by an external electric field. The deformation leads to a torque on the nucleus, which causes its axis to rotate around the electric field, in the same way that the axis of a gyroscope rotates around the direction of gravity.

## Addressing a fundamental mystery in physics

DeMille's research partnership seeks to answer a persistent question in physics known as the matter-antimatter asymmetry: Why is the universe made entirely of matter, when an equal number of matter particles and antimatter particles were created just after the Big Bang? Astronomical observations show that the matter and antimatter mostly annihilated each other, turning back into energy. The antimatter was eliminated, but a tiny fraction of matter was somehow left over, forming all the objects in the universe today.

The current model for all known fundamental forces and particles fails to explain how the excess matter survived. Recent mathematical theories seek to explain the matter-antimatter asymmetry by positing new, as-yet-undiscovered forces and particles, such as "supersymmetry particles." In most of these theories, the new fundamental phenomena also cause a tiny, yet detectable, deformation in the distribution of electric charge in ordinary atomic nuclei, known as a Schiff moment. The nuclear Schiff moment arises only in the presence of new particles and forces with properties needed to explain the matter-antimatter asymmetry.

## A novel way to detect new particles

Finding new subatomic particles is a notoriously difficult challenge. In the 1960s, physicists predicted the existence of the Higgs boson, an elementary particle in the Standard Model of particle physics, but it was not until 2013 that scientists at the CERN facility in Switzerland could prove its existence using the Large Hadron Collider — a facility measuring 17 miles in circumference and costing over $7.5 billion.

In contrast, DeMille's team will design and assemble an instrument, about 15 feet across, in an on-campus Yale physics laboratory. The device will be made up of roughly 100,000 custom-designed and fabricated parts; it will take a team of six postdoctoral fellows and graduate students three years to construct.

"Our device will focus a cryogenic beam of diatomic molecules through an electric field to detect a nuclear Schiff moment," DeMille said. "This technique will yield a 100-fold increase in sensitivity over the current state of the art, enough to say whether or not new particles with the properties posited by many theories to explain the matter-antimatter asymmetry actually exist. This determination will either validate 30 years of mainstream work in theoretical physics or send the field in another direction."

The experiment depends on a strange quirk of quantum mechanics, which posits that subatomic particles like electrons and protons must constantly spin out and reabsorb other particles — a phenomenon that DeMille and his colleagues have learned to observe in the laboratory. "I tell my students to imagine Pig Pen, the character from 'Peanuts,'" said DeMille. "Every proton is surrounded by an ever-cycling cloud of short-lived particles that pop in and out of existence. Theoretically, this cloud should include supersymmetry particles."

Direct observation of supersymmetry particles with the properties needed to explain the matter-antimatter asymmetry is beyond current technology, but DeMille believes he can record their influence on the proton itself — hence his search for the Schiff moment. "The forces associated with a supersymmetry particle should cause a small but observable deformation at the surface of the proton," he said. "This will in turn cause a similar deformation in an atomic nucleus — the Schiff moment. We are looking for a minute dent on one side of the nucleus and a corresponding bulge on the other. If we find this deformation, we will have definitive proof that new particles exist."

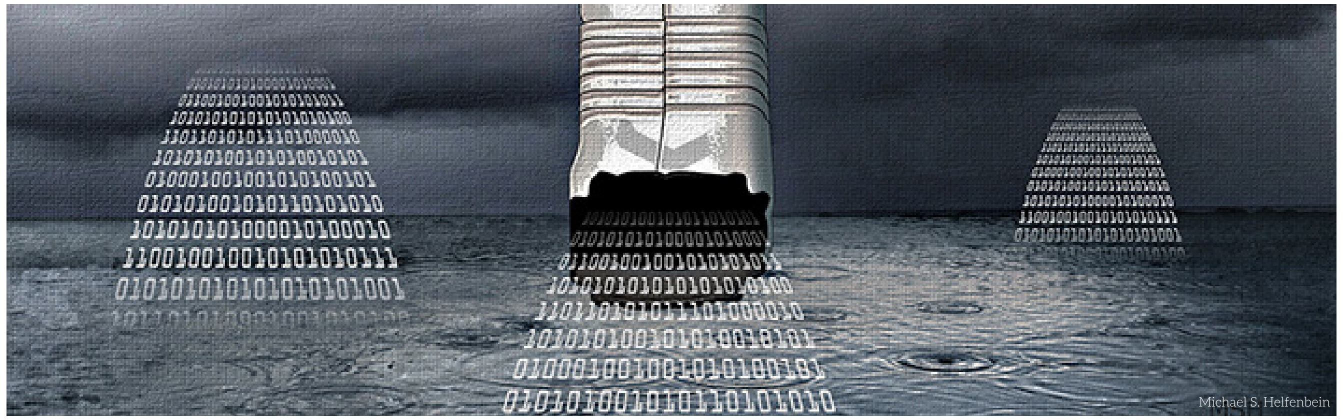
The precision of this experiment will be unprecedented, notes DeMille. For comparison, if the proton were scaled up to the size of the Earth, the dent in its surface would be 1/30th the width of a human hair.

## Revising our understanding of the universe

Steven Girvin, deputy provost for research and the Eugene Higgins Professor of Physics, has hailed this project as groundbreaking. "David DeMille, David Kawall, Tanya Zelevinsky, and Steve Lamoreaux are on the very cutting edge of physics," he said. "Their experiment promises to detect particles 10 times more massive than what one might see in the Large Hadron Collider. If they succeed, this will be an extraordinary accomplishment, and one that revises our understanding of the universe. I am personally grateful to the Heising-Simons and Templeton foundations for their decision to work together to fund the different aspects of this large and complex project."

Yale Development

# Tracking the Flow of Quantum Information



Michael S. Helfenbein

If objects in motion are like rainwater flowing through a gutter and landing in a puddle, then quantum objects in motion are like rainwater that might end up in a bunch of puddles, all at once. Figuring out where quantum objects actually go has frustrated scientists for years.

Now a Yale-led group of researchers has derived a formula for understanding where quantum objects land when they are transmitted. It's a development that offers insight for controlling open quantum systems in a variety of situations.

"The formula we derive turns out to be very useful in operating a quantum computer," said Victor Albert, first author of a study published in the journal Physical Review X. "Our result says that, in principle, we can engineer 'rain gutters' and 'gates' in a system to manipulate quantum objects, either after they land or during their actual flow."

In this case, the gutters and gates represent the idea of dissipation, a process that is usually destructive to fragile quantum properties, but that can sometimes be engineered to control and protect those properties.

The principal investigator of the research is Liang Jiang, assistant professor of applied physics and physics at Yale.

It is a fundamental principle of nature that objects will move until they reach a state of minimal energy, or grounding. But in quantum systems, there can be multiple groundings because quantum systems can exist in multiple states at the same time — what is known as superposition.

That's where the gutters and gates come in. Jiang, Albert, and their colleagues used these mechanisms to formulate the probability of quantum objects landing in one spot or the other. The formula also showed there was one situation in which superposition can never be sustained: when a quantum "droplet" in superposition has landed in one "puddle" already, but hasn't yet arrived at the other "puddle."

"In other words, such a superposition state always loses some of its quantum properties as the 'droplet' flows completely into both puddles," Albert said. "This is in some ways a negative result, but it is a bit surprising that it always holds."

Both aspects of the formula will be helpful in building quantum computers, Albert noted. As the research community continues to develop technological platforms capable of supporting such systems, Albert said, it will need to know "what is and isn't possible."

Additional co-authors of the study are Barry Bradlyn of Princeton and Martin Fraas of KU Leuven.

Jim Shelton, Yale News



# Quantum, Art, and Music

## A new series of nontechnical talks

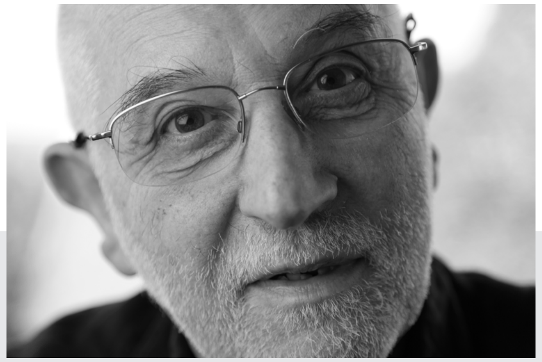
The Yale Quantum Institute launched a new series of non-technical talks in Spring 2017. The goal of these talks is to bring a new regard to quantum physics and science by having experts cast new light on often-overlooked aspects of scientific work.

The first two speakers of this series (see their bio below), Michael Berry, professor at the university of Bristol and Martha Willette Lewis, New Haven-based visual artist and Yale MFA alumna, will cover music and art respectively. By attending these lectures accessible to a large audience (made of a diverse population distributed from undergraduates to professors and staff as well as New Haven residents), we are all invited to reflect on how the contribution of science play a role in our daily life.

"Connections between physics and technological invention and aspects of human life that seem far from science are both unexpected and unexpectedly common. And rather than flowing one way - from physics to gadgets - the connections form an intricate web, linking all aspects of human culture, in a way that frustrates our convenient compartmentalizations and coarse interventions aimed at promoting technology transfer" said Berry.

"How do we visualize the complex and intangible forces which surround us? It turns out to be surprisingly difficult without employing a range of similes, resemblances, and metaphors. Unlike science, art offers ways of looking at problems that are wobbly and uncertain, neatly sidestepping the need for rigorous quantification or stabilization" said Lewis.

*This series of talks are co-sponsored by The Franke Program for Science and the Humanities, a program at Yale that aim to foster communication, mutual understanding, collaborative research and teaching among diverse scientific and humanistic disciplines.*



Harold Shapiro

### Michael Berry

Michael Berry is a mathematical physicist at the University of Bristol, England and an elected fellow of the Royale Society of London. He is known for the Berry phase, a phenomenon observed in quantum mechanics and optics. He specializes in semi classical physics (asymptotic physics, quantum chaos), applied to wave phenomena in quantum mechanics and other areas such as optics. Among numerous awards, he received the Louis-Vuitton Moët-Hennessey 'Science for Art' prize.

### Martha Willette Lewis

Martha W Lewis is an artist, curator, educator and the host of the radio program "Live Culture". Much of Martha's work explores aspects of the history of science and human knowledge, often invoking books and archives, through the means of drawing and installation. Her recent work involves drawing in three dimensions, crumpling paper and mapping its surfaces. A longtime resident of New Haven, Martha holds an MFA from Yale University, and a BFA from The Cooper Union in New York.

# Core Programs

## Curent activities in the institute

### Venue for quantum information events

The Institute is the hosting venue for all related seminars, presentations, group meetings and other events in the field of quantum information physics and science. Among other events, YQI will host the 2017 Yale Science and Engineering Forum and the Office of Naval Research Program Review and Workshop. 17 Hillhouse has an open-door policy and cordially welcomes interested students and staff from Yale or other institutions to come attend its events.

### Colloquium and Seminars Series

During the academic year, the institute is hosting a series of seminars and colloquia from national and international experts in the field of quantum information physics, quantum control, quantum measurement, and quantum many-body physics. The talks are attended by a very diverse population distributed from sophomore undergraduates interested in quantum information to professors teaching that subject at the graduate level.

### Visitor Program

The Yale Quantum Institute hosts and partially funds world leaders in quantum information science for sabbatical visits to Yale lasting from three to twelve months. These visiting scientists in residence, will be granted a large private office where they can focus on their research in close proximity to YQI's professors and students at the prestigious Hillhouse Avenue, described as the most beautiful street in America by both Mark Twain and Charles Dickens

**The institute will foster collaborations and bring world leaders in this field here to ensure that New Haven remains an intellectual hub for quantum information science, and of quantum science more generally.**



### Networking and non technical talks series

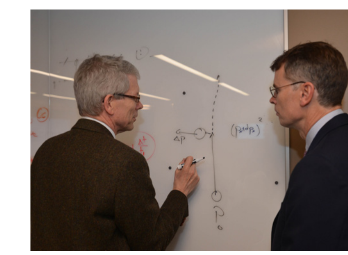
A second series of talks is curated by YQI to help students and postdocs with career development, job search and networking. This series includes a wide array of speakers (alumni, scientists, industry leaders, artists…) who all started as graduate students and will be talking about their career choices and experiences. The talks and the discussion following them is a great opportunity for attendees to build a solid network and have all their questions answered.

### Students' Happy Science Hours

Students' happy science hours offer the opportunity for students to meet with world-renowned quantum experts who come to YQI to give talks or for sabbatical. SHSH are a great way to network and have a privileged relationship with the speakers thanks to the informal setting in small groups around snacks and refreshments. The conversation, moderated by a host who changes every time depending their interests, can flow from specific questions about the speakers' work to their experience and path from graduate student to where they are today, but also to completely unrelated sciences news or events.

### Learn

The common space, most of the time set up with couches and stools for collaborative work can be turned into a 120-person lecture hall for colloquia and classes.



### Work

The institute features 380+ square feet of white boards allowing collaborate thinking, 1 conference room for meeting and conference calls and 2 offices open to all for work in small groups or requiring concentration.

### Socialize

Fortunately, all is not work! The common space is also use to socialize during special events such as thesis defense celebrations, trivia nights, students' happy hours…

# Key Factors

## IN 2016

**18** YQI FACULTY MEMBERS

**380+** SQ FT WHITEBOARD AREA

**71** GRADUATE STUDENTS

**26** POSTDOCS

**66** EVENTS HELD

**7** ASSISTANT RESEARCHERS

**112** PUBLICATIONS

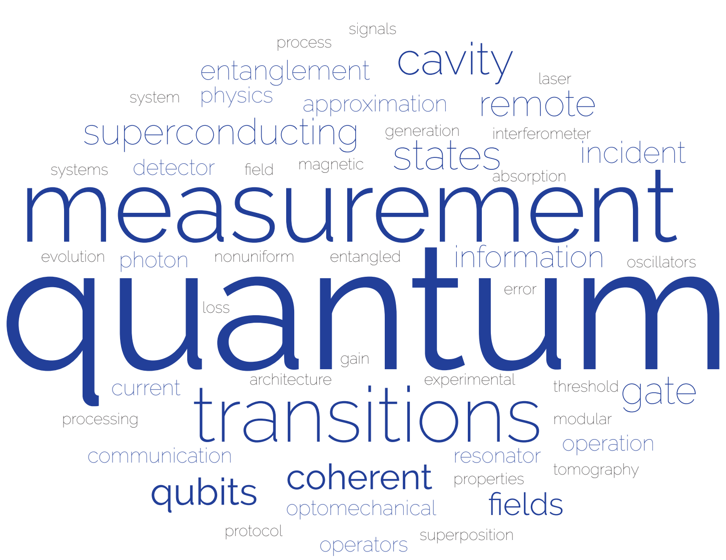
INCLUDING **15** NATURE, SCIENCE AND PHYS. REV. LETTER

**2** STAFF MEMBERS

**9705** CITATIONS

Data: Scopus

**23** VISITORS




Keyword frequency in YQI members publications



# Visitors at YQI

## JANUARY 2016 TO FEBRUARY 2017

**Alain Aspect**
Institut d'Optique Graduate School Paris, France

**Simon Benjamin**
University of Oxford, United Kingdom

**Michael Berry**
University of Bristol, United Kingdom

**Alexandre Blais**
Université de Sherbrooke, Canada

**Howard Carmichael**
University of Auckland, New Zeland

**Gianluigi Catelani**
Forschungszentrum Jülich, Germany

**Ignacio Cirac**
Max-Planck-Institut für Quantenoptik, Germany

**Aashish Clerk**
McGill University, Canada

**Kasper Duivenvoorden**
RWTH Aachen Univeristy, Germany

**Steven Flammia**
University of Sidney, Australia

**Alexander Gaeta**
Columbia University New York, United States

**Saikat Guha**
Raytheon, United-States

**Pierre Hohenberg**
New York University, United State

**Aeysha Khalique**
NUST, Pakistan

**Tobias Kippenberg**
EPFL, Switzerland

**Roman Lutchyn**
Microsoft Station Q, United States

**John Morton**
London Centre Nanotechnology, United Kingdom

**Chetan Nayak**
UC Santa Barbara, United States

**Hugues Pothier**
CEA-Saclay, France

**David Poulin**
Université de Sherbrooke, Canada

**John Preskill**
Caltech, United States

**Shruti Puri**
Université de Sherbrooke, Canada

**Roman Riwar**
Juelich, Germany

**Stefan Rotter**
TU Wien, Vienna

**Zeliang Xiang**
TU Wien, Vienna

**Leo Zhou**
Havard University, United-States

# Introducing...

## The Yale Quantum Institute Distinguished Lecturer

The Yale Quantum Institute Distinguished Lecturer recognizes a researcher whose work significantly advances quantum science, with emphasis on the areas of mesoscopic physics, nanoscience, quantum information, quantum computing and related theoretical and mathematical topics.

Annually, a YQI Distinguished Lecturer will be invited to visit the Yale Quantum Institute with a $1000 honorarium to deliver a lecture about a specific research result of great significance or a body of important work which has advanced our understanding in one or several sub-fields of quantum science.

Candidates eligible for the title of YQI Distinguished Lecturer must be within 12 years of receiving their PhD. All travel and accommodation costs will be covered by YQI in addition to the honorarium.

**2017 Selection committee**

John Clarke, UC Berkeley, Michel Devoret, Yale; John Preskill, Caltech; Douglas Stone, Yale; Amir Yacoby, Harvard

Nominate your colleagues at quantuminstitute.yale.edu

*Students and faculty cringe as Douglas Stone pushes the button to decide the fate of a Schrodinger Cat .*



# Meet the Executive Team

### Robert Schoelkopf

*Internationally recognized for his experimental work in quantum circuits, he is the founding Institute Director since 2015.*

### A. Douglas Stone

*Former chair of the Department of Applied Physics at Yale and author of "Einstein and the Quantum", he serves as Institute Deputy Director.*

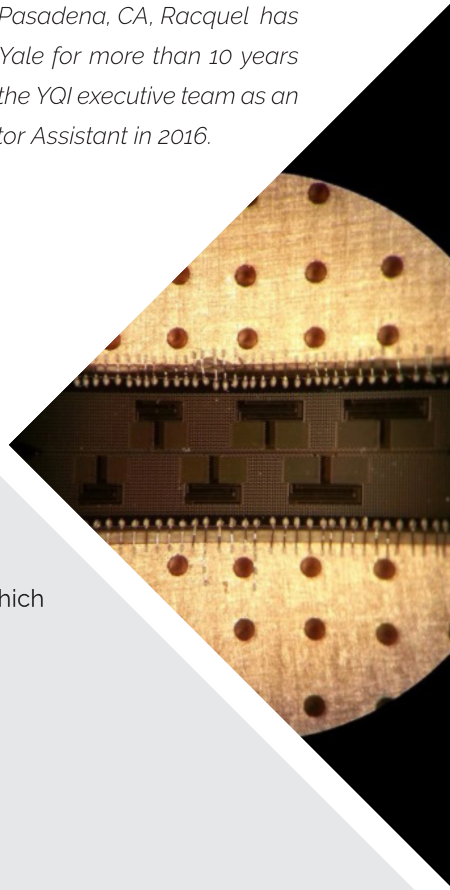
### Florian Carle

*After a PhD in Heat Transfer in France, he joined Yale as a postdoctoral associate in Mechanical Engineering before becoming YQI Manager.*

### Racquel Miller

*A native of Pasadena, CA, Racquel has worked at Yale for more than 10 years and joined the YQI executive team as an Administrator Assistant in 2016.*

Engage with us on Twitter @Yale_QI



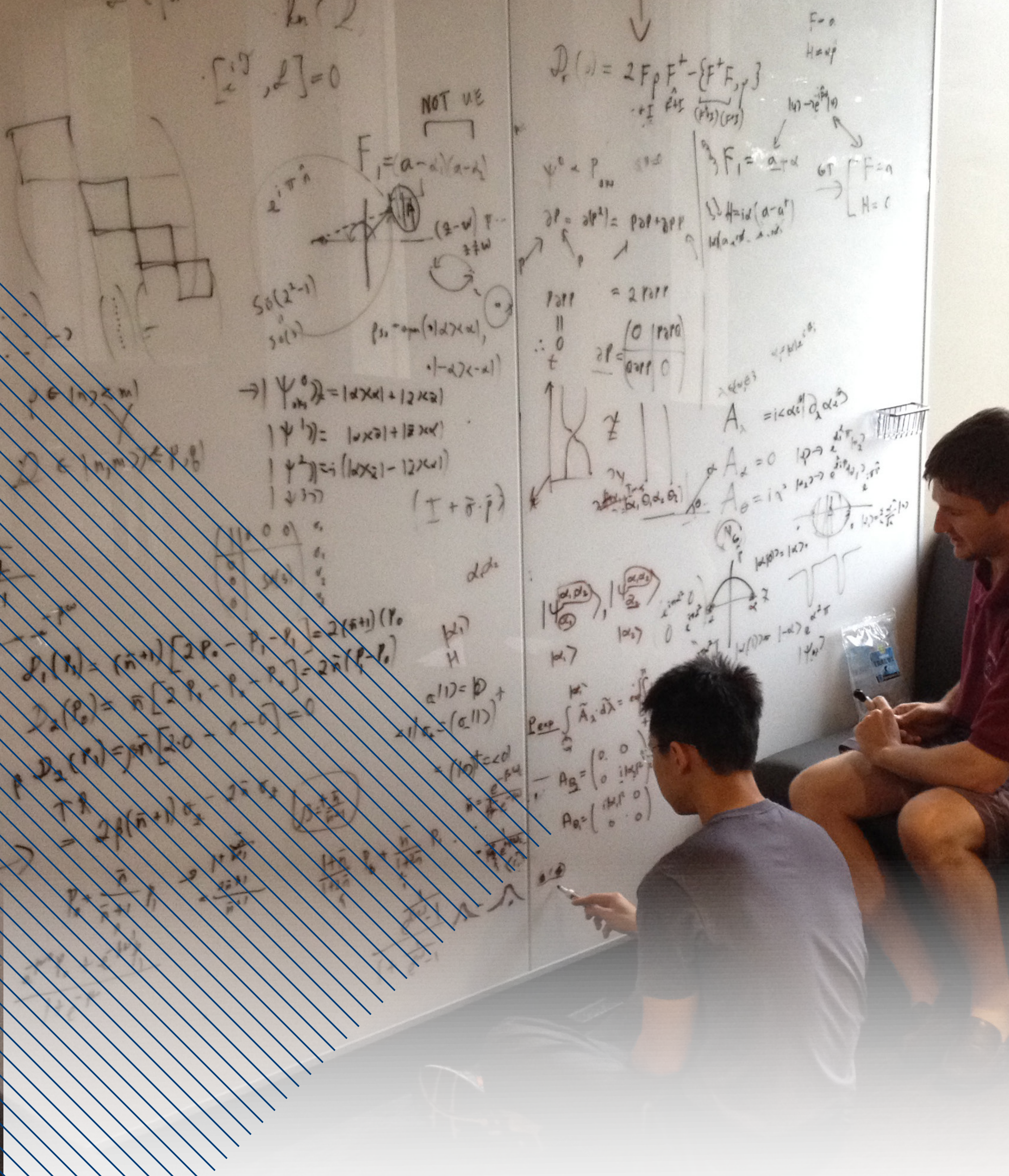
## Thank You

The Yale Quantum Institute would like to acknowledge the support of these organizations which have helped the institute become a world leaders in quantum science.

Yale Office of the Provost

Yale Office of Development

Franke Program for Science and the Humanities



quantuminstitute.yale.edu