Unitary Foundation

Annual Report
2024

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Striving towards **evolution**

Unitary Fund got started in June 2018 with a blogpost, $6k, and a microgrant program. At the time, the quantum industry was just emerging. I wrote:

> *"Quantum computing also remains a place where small teams and open research projects can make a big difference… My thesis for what's happening here is that we are codifying, in open source software, the mathematics of quantum computing that have been developed over the last few decades. This makes the field more accessible and interactive. It allows us to progress faster, together. It is much more effective to stand on the shoulders of giants when you can import them as an API."*

I still believe this. And I believe it even more for what has happened in quantum technology as a whole sector over the last 6.5 years.

The Unitary Fund experiment has supported the truth of this statement and itself has grown so much. We gave our 100th microgrant last year! I am grateful and encouraged by the many of you who have made this happen so successfully: our supporters, team, advisors, microgrants, community and many others..

With this help, we have expanded beyond our core microgrant program. We now:

- staff an in-house technical team working on public goods in quantum tech
- develop mitiq: the main cross-platform open source error-mitigating compiler
- run metriq: an open source platform for quantum tech benchmarks
- run unitaryHACK bounty programs, a community discord, and the major global quantum developer survey
- publish research on quantum compilation, benchmarking, and foundations

We are now more than a micro-grant fund. All of these programs accelerate our drive to build the open foundation for the quantum technology ecosystem.

To better represent our growth, we are re-branding as Unitary Foundation: https://unitary.foundation. Though we have a new name, our mission remains the same:

Unitary Foundation: creating a quantum technology ecosystem that benefits the most people.

William Zeng, PhD

Together, **we thrive**

Unitary Foundation would like to thank the following supporters for their commitment to open source quantum technology. Our community development work and research are made possible through the generosity and partnership of these foundations, companies and individuals. We are excited to work with all of them to grow the open quantum ecosystem around the world.

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QuTiP Quantum Toolbox in Python — 10 years on!

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The Fund

"Thank you Unitary Fund for **supporting and building** the open source quantum community!"
- *Spencer Churchill*

"As a young student from a low income country I had no means to work on academic projects since they were always unpaid. But with the help of Unitary Fund's grant during COVID, I was able to work on my first proper theoretical project. This project was the first step towards building my **foundations in theoretical research** and I believe I wouldn't have worked on any other research projects without it." - *Muhammad Usman Farooq*

"I would like to express my sincere gratitude to UF for their invaluable support. I truly appreciative of UF's commitment to **fostering innovation and collaboration** in the field of quantum computing." - *Dafne Carolina Arias Perdomo*

"I am so thankful for this opportunity and truly appreciate your **commitment to open quantum science!**" - *Mattias Fitzpatrick*

Empowering **evolution**

Microgrants

The Fund gives **no-strings attached micrograants** to explorers building the open source foundation for quantum technology.

This year Unitary Fund distributed its 100th grant to open source and community-minded projects across quantum technology.

As reported by our alumni, **87%** of micrograants resulted in additional resources to the micrograntee, including additional financial funding, hardware access, new collaborators or contributors, or new professional networks.

IMPACT	BY THE NUMBERS
31	countries with supported micrograants
420+	papers citing micrograant funded research
40+	new libraries
400+	contributors & maintainers
18.2K+	commits (excluding QuTiP)
3	new startups
1	new non-profit
$356K	awarded in micrograants < the cost of funding two US PhD students

87% of micrograants also resulted in career advancements, whether within academia or industry, or by facilitating a career change. Since the program's inception, **51%+** of micrograants have also gone to individuals belonging to a historically underrepresented group in STEM.

2024 Grants Advisory Board

A special thank you to our 2024 Grants Advisory Board

- **Amira Abbas**, University of Amsterdam
- **Shahnawaz Ahmed**, Embdl
- **Tomas Babej**, ProteinQure
- **Ntwali Bashige**
- **Amy Brown**, Rigetti
- **Stephen DiAdamo**, Qoro
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- **Dylan Sim**, PsiQuantum
- **Michał Stęchły**, PsiQuantum
- **Christa Zoufal**, IBM

2024 Microgrant projects

Frameworks + Libraries + Toolkits

- **MQT Qudits,** Kevin Mato: A quantum open-source software framework for mixed-dimensional quantum computing. *#python #gpu #simulator #hpc*
- **Lie algebraic properties of quantum circuits,** Oxana Shaya and Konstantin Golovkin: An implementation of functionalities that help with the understanding of the Lie algebra of a quantum circuit. *#machine learning #algebra*
- **Comprehensive Quantum Tomography Library,** Hana KimLee: A Julia library that includes standard algorithms such as state/process tomography and randomized benchmarking, as well as more sophisticated machine learning algorithm. *#julia #algorithms*
- **Python CVXQuad,** Aidan Sims: A project translating the CVXQuad library to Python and integrating it with the existing Toqito library. *#python #toqito*
- **Documentation for QuantumToolbox.jl,** Alberto Mercurio, Yi-Te Huang and Luca Gravina: A state-of-the-art Julia package designed for quantum physics simulations. *#python #simulator #quantum #julia*
- **Graphix Workshop,** Maxime Garnier and Thierry Martinez: To further develop Graphix during a 2025 workshop. *#follow-up grant #workshop #measurement-based qc*

Error Correction + Error Mitigation

- **Topological Quantum Error Correction (TQEC),** Sam Burdick: An expansion of an existing open-source TQEC service. *#error correction*
- **An entanglement toolbox for t-doped stabilizer states beyond the classical simulability barrier,** Andi Gu, Lorenzo Leone, and Salvatore F.E. Oliviero: A toolbox to equip researchers with theoretical tools and a Python framework to study t-doped states' entanglement efficiently #error correction. *#simulator #python*
- **Integration of Zero-Noise Extrapolation from Mitiq into OpenQAOA,** Marco Venere, Adriano Lusso, Alberto Maldonado and Victor Onofre: An integration of Mitiq into OpenQAOA to allow error mitigation techniques to take place during the execution of the QAOA algorithm. *#mitiq #error mitigation #qaoa*
- **Hypergraph MWPF Decoder for QEC,** Yue Wu: A new decoder that can decode arbitrary qLDPC codes and establish a programming framework that allows one to implement graph-based decoders easily. *#error correction*

- **Error-agnostic shadow estimation,** Markus Heinrich, Jonas Helsen and Ingo Roth: A project that aims to show that logarithmic-depth random circuits are sufficient to estimate expectation values of a large class of global observables. *#error mitigation #python*
- **Overhead and Performance Analysis for Mitiq's Quantum Error Mitigation Implementations,** Ella Carlander and Ruhee Nirodi: A tool that can characterize overhead for different QEM methods and compare them. *#mitiq #error mitigation*
- **QuantumACES.jl,** Evan Hockings: An open-source Julia package for designing, optimizing, and simulating scalable Pauli noise characterization experiments for stabilizer circuits. *#julia #benchmarking #error correction*
- **Generating hardware-tailored logical Clifford gates for stabilizer codes using Gurobi,** Eric Kuehnke and Daniel Miller: A project to further develop the generation of hardware-tailored logical Clifford gates for stabilizer codes using Gurobi. *#error correction*

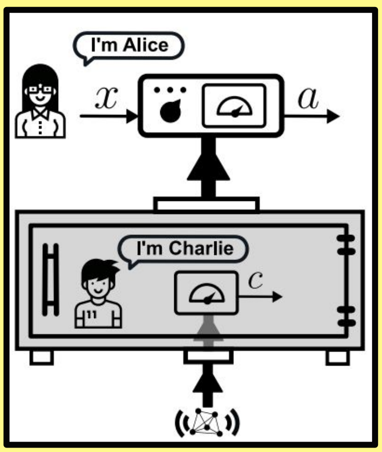
Education + Public Outreach

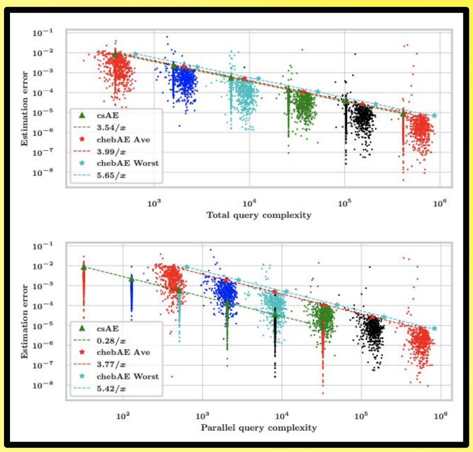
- **<Quantum|Chamitas>,** Dafne Carolina Arias Perdomo: A pioneering initiative focusing on accessible, high-quality quantum education in both Venezuela and France for girls in STEM. *#education*
- **Qubit-Pulse: An educational qubit pulse engineering game,** Mattias Fitzpatrick: A pulse simulator game that takes in drive amplitudes as a function of time and produces the qubit state in the Bloch sphere to allow users to simulate different Hamiltonians and controls. *#education #games #simulator*
- **Global Expansion of QCoder,** Kein Yukiyoshi, Adam Siegel and Tyson Jones: An initiative to further develop a quantum programming contest platform. *#games #education*
- **GQuantum Education,** Dorcas Attuabea Addo, Henry Martin and Peter Nimbe: A quantum education initiative based in Ghana. *#education*
- **Quantum Arcade,** Timothy King and Ella Meyer: A project creating a landing page and curating existing quantum games as well as developing resources for new games to help teach quantum computing globally. *#games #education*
- **Quantum Picturalism Website,** Abbey Pint and Thomas Cervoni: Quantum Picturalism empowers teachers and learners of all ages by making quantum math accessible and inclusive. *#education*

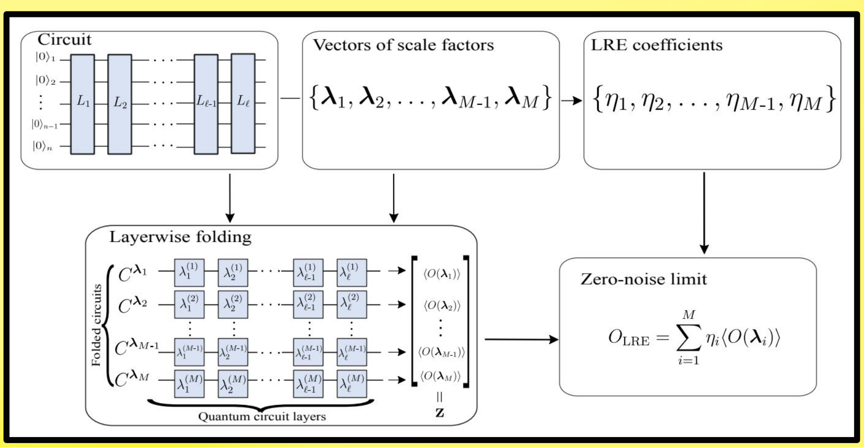
Interested in applying with your project? Learn more here!

The Lab

Imagining the future,
driving **innovation**







Committed Strategic **Partners**

UF is proud to have received support for many of our research initiatives from both private and governmental funders. We thank these agencies and institutions for their continued support of open source development of quantum tools.

POSE Phase II: "Mitiq OSE: Increasing and sustaining the open-source ecosystem for cross-platform quantum error mitigation".

Wellcome Leap Q4Bio: A quantum application for protein cavity hydration (AQUA)
- → Partners: Pasqal, Qubit Pharmaceuticals

DoE ASCR: "Tough Errors Are no Match (TEAM): Optimizing the quantum compiler for noise resilience"
DoE ASCR: "Scalable, Modular, Adaptable, Reconfigurable, error-Targeted approaches to quantum stack design (SMART Stack)"
- → Partners: Johns Hopkins University Applied Physics Laboratory, Lawrence Livermore National Laboratory, Infleqtion, University of Chicago, University of Michigan

EU Horizon Europe "Quantum Glass-based Photonic Integrated Circuits (QLASS)"
- → Partners: Politecnico di Milano (POLIMI), Fondazione Politecnico di Milano (FPM), Pixel Photonics, Sapienza Università di Roma (SUR), Ephos, CNRS-Institut Charles Gerhardt Montpellier (CNRS-ICGM), Université de Montpellier (UM), Schott AG (SCHOTT)

Public goods in quantum tech

The Lab creates and maintains public goods for quantum sciences and technology.

QOSS Survey

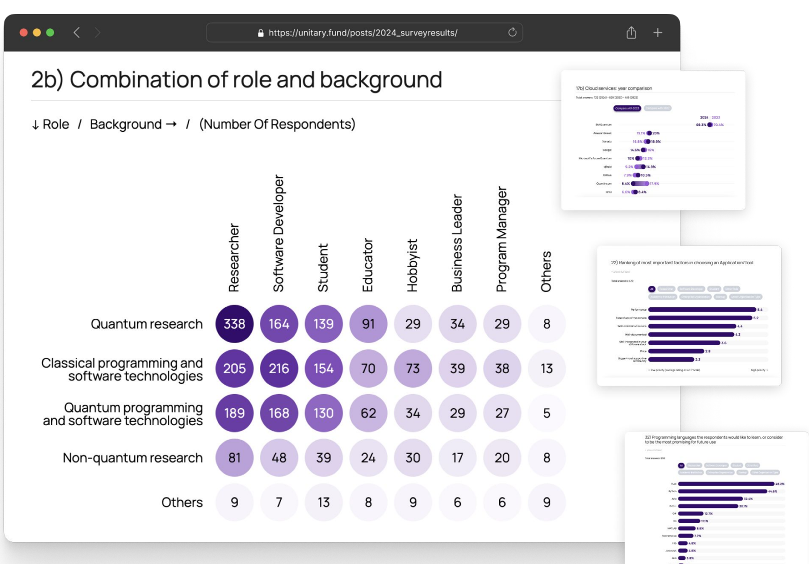
The more we understand about the needs and backgrounds of the quantum computing community, the more we can ensure the field's products and services are built to address their current and future needs.

Each year, the QOSS Survey delivers a bottom up view of who we are, what we are working with, what we need, and how that is evolving.

With over 1,100 respondents from more than 50 countries, including developers, researchers, students, maintainers, business leaders and educators, the findings provide data points that can assist all players in the quantum ecosystem in their own roadmaps and development.

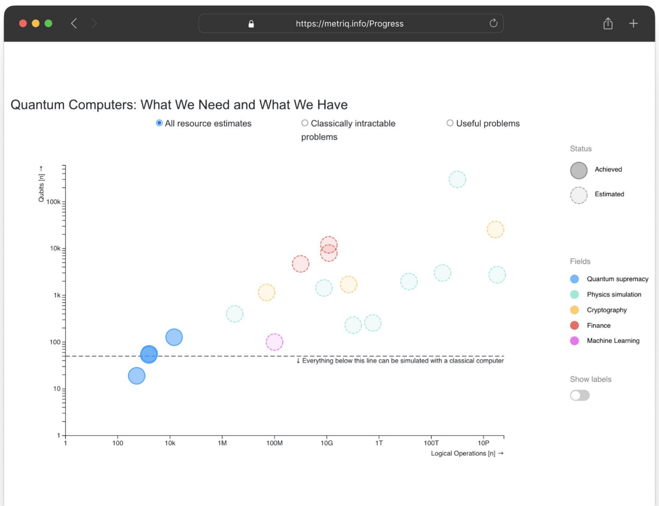
Topics covered include Demographics, Experience, Cloud Services, Full-Stack Development Platforms, Compilers and Simulators, Software for Applications and Tools, User Experience, OSS Development and Research, and Community

The survey can be accessed at this link, and the anonymized data set is available on the Unitary Foundation Github.



Metriq

Our open source benchmarking project is empowering the global community to better understand state of the field, how the science is progressing, and what we need in the future.



Metriq Gym

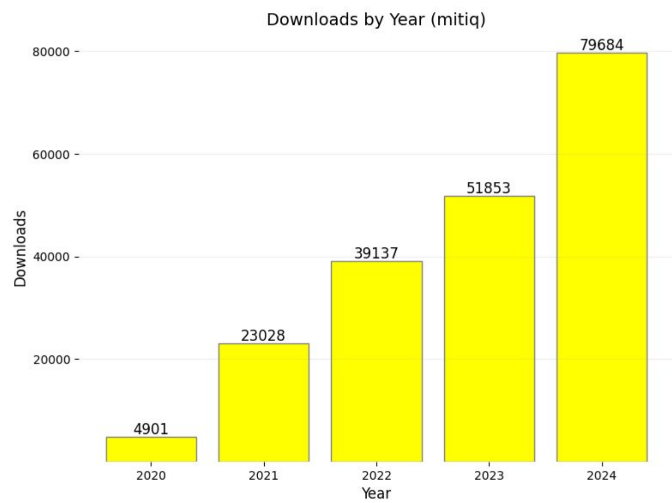
One of the main issues facing quantum benchmarking is the lack of availability of software necessary to run and reproduce verified benchmark results. To help address this issue we have premiered Metriq Gym, a software for standard benchmark script implementations, along with benchmark schema definitions, and results certified by our team.

The Open Quantum Benchmark Committee

In 2024, we were thrilled to inaugurate the Benchmark Committee, welcoming expert practitioners and researchers from around the world with focuses in hardware, compilation, simulation, applications, and error correction and mitigation, to provide the field with a comprehensive and reliable framework for evaluating quantum computing systems, and empower researchers and developers with the tools they need to navigate this complex landscape. The committee is advises the Metriq team on the development of benchmarks implemented in Metriq Gym, and hail from Leibniz Supercomputing Centre; University of Milano-Bicocca; Lawrence Berkeley National Laboratory; Pasqal; THALES; NVIDIA; IBM Quantum; University of British Columbia; Oak Ridge National Laboratory; qBraid; European Center for Quantum Sciences; and Amazon Braket.

Mitiq

Mitiq is an open-source cross platform compiler that makes your programs robust to the error in current quantum computers. We want to thank the National Science Foundation's POSE program for their generous support in helping us develop the open source ecosystem around Mitiq to ensure it remains sustainable, and grows in a way that best serves its user base and contributors.



200k Downloads

75 Contributors

163 Forks

368 Stars

121 Paper Citations

Mitiq Ecosystem Case Study: Open source tools as educational opportunity

The Mitiq team worked with a group of graduate students at the University of Washington over ten weeks on UW's Accelerating Quantum-Enabled Technologies (AQET) capstone course. The students, Ruhee Nirodi, Ella Carlander, and Alexandros Peltekis, created a benchmarking pipeline and GUI using the Mitiq library, with the goal of providing users a streamlined tool to compare overhead requirements and the effectiveness of various quantum error mitigation methods in Mitiq. The project culminated in a presentation of their work to the open source community as part of Unitary Fund's Quantum Wednesdays, as well as a poster presentation at University of Washington. The presentation can be accessed here. The students then applied for and received a microgrant to continue their work analyzing Mitiq's QEM implementations.

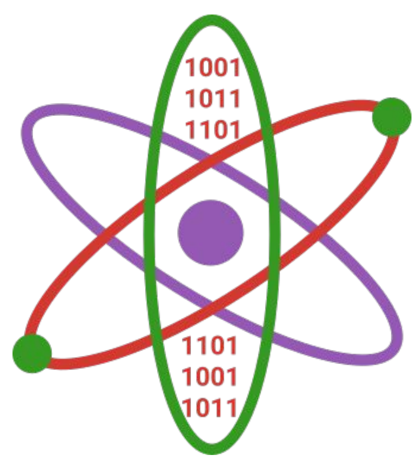
2024 Mitiq Workshop

This year, we also held our very first in person workshop for Mitiq. To make the most of this opportunity we partnered with the University of Massachusetts, Amherst's QNumerics Summer School, along with co-organizers University of Maryland, Flatiron Institute, QuEra Inc., MIT, Perimeter Institute Quantum Intelligence Lab.

Over 40 students joined for the workshop, most at the graduate or postdoc level, with a few advanced undergraduates and other motivated community members. The program focused on practical, experiential learning with an emphasis on programming skills and open source tooling. This focus, combined with an openness in accepting applicants with various backgrounds and career stages, made it a natural fit for hosting the Mitiq workshop.

We were able to engage with the group around quantum error mitigation (QEM) core concepts and techniques, Mitiq's structure and interface, and a deep dive into the techniques of Zero Noise Extrapolation (ZNE) and Digital Dynamical Decoupling (DDD). We then challenged the students to complete a guided Jupyter notebook activity applying ZNE and DDD to standard benchmarking problems on simulated noisy backends.

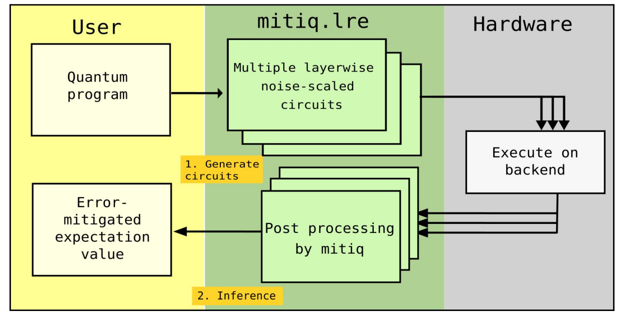
The workshop concluded in the evening with an informal Mitiq coding session. Throughout the workshop the participants asked thoughtful questions and gave insightful feedback, which will we will use to inform future Mitiq development and outreach.



Unitary Foundation CTO Nathan Shammah also presented on the quantum open technology ecosystem and Unitary Fund's activities to grow and support it. UF Technical Staff Member Misty Wahl presented a survey of hybrid quantum error mitigation, including her recent work "Zero noise extrapolation on logical qubits by scaling the error correction code distance".

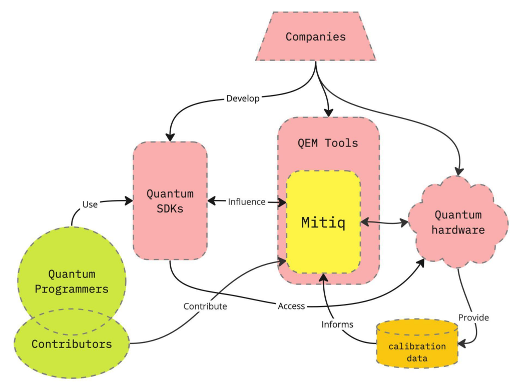
Open Source Fellow

This year we were thrilled to bring Purva Thakre as our Open Source fellow working to develop new techniques available on Mitiq. Purva focused on building new capabilities within Mitiq, specifically the introduction of a new QEM technique: Layerwise Richardson Extrapolation. LRE is a technique that creates multiple noise-scaled variations of the input circuit such that the noiseless expectation value is extrapolated from the execution of each noisy circuit.



Mitiq Ecosystem: NSF I-Corp Training

This year, as part of an I-Corp training program through the National Science Foundation's POSE program, we conducted over 50 interviews of stakeholders, current and potential users, contributors, and other people across the ecosystem to help shape the long term growth of the open source tool.



Ambassador Program

After originally becoming involved with Unitary Fund through his contributions to Mitiq, and in recognition of his ongoing contributions to Mitiq and its ecosystem, we were thrilled to name Brian Goldsmtih to our ambassadors program for 2024.

Join the Mitiq community

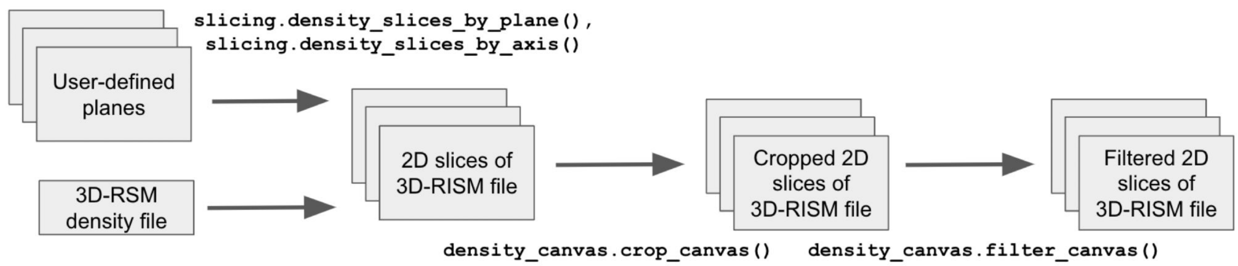
Whether you're a researcher, educator, or software engineer, or quantum tinkerer, there's a place for you in the Mitiq community.

- Check out the mitiq GitHub repository and contribute by opening issues, asking questions, or making a pull request. If you have a QEM technique you'd like to use, let us know! Feature requests are always appreciated, and encouraged.
- Join our Discord community to connect with me and all the other wonderful Mitiq developers and quantum enthusiasts.
- Sign up to receive the Mitiq Newsletter to stay up to date with the latest happenings.
- Read our recent 5-year retrospective on Mitiq

Additional Research & Ecosystem Tooling

Aquapointer

We were thrilled to be a part of a funded consortium under Q4Bio, a program by Wellcome Leap to explore quantum advantage for biology applications. In collaboration with **Pasqal** and **Qubit Pharmaceuticals**, we published Aquapointer, a new open source software package that automates the pipeline of 3D-RISM density distribution to water molecule locations.



QLASS

Alongside Politecnico di Milano, Fondazione Politecnico di Milano, University of Montpellier, CNRS, University of Rome La Sapienza, Ephos, Pixel Photonics, and Schott AG,

we have joined the QLASS consortium to develop algorithms to run on the specific quantum photonics hardware, designing an end-to-end compilation stack, optimizing the process from the algorithmic level down to the compilation, simulation and error mitigation tasks. On the hardware side, QLASS focuses on developing novel 2D and 3D photonics chips in glass. On the algorithmic side, it tackles the lithium ion battery problem with a quantum chemistry approach. QLASS is funded by the European Union Horizon Program.

Qrack & PyQrack

Qrack is a comprehensive, novel, GPU accelerated framework for simulating quantum processors. Qrack and PyQrack are developed and maintained by Technical Team member Dan Strano. The project has seen over 1.25M downloads. In 2024, it became the first supported back end to provide a physical noise model for the (Xanadu) PennyLane Catalyst “quantum just-in-time” (QJIT) compiler for quantum machine learning (see below for details). This noise model, and much of the frontier functionality in Qrack, is based on “weak simulation condition” rather than “strong,” such that it can support about or exactly twice as many virtual qubits in noisy simulations as density-matrix-based techniques, though requiring proportionally more time to simulate (linear in measurement shot count). Based on investigation into “patch” and “elided” circuits used since Google’s first 2019 Sycamore “quantum supremacy” experiment, Qrack now has competitive “automatic elision” for approximate simulation of large quantum circuits.

Catalyst

In 2024, we collaborated with Xanadu on the PennyLane Catalyst project.

We integrated our Qrack simulator as a supported device, introducing novel simulation optimizations–including hybrid stabilizer simulation–to Catalyst. Additionally, we incorporated Mitiq’s quantum error mitigation techniques, enhancing Zero-Noise Extrapolation (ZNE) within the quantum just-in-time (JIT) compiler. This integration improves error mitigation in specific noise scenarios while maintaining the optimization that Catalyst guarantees for quantum-classical workflows.

Beyond technical contributions, the teams exchanged knowledge: sharing expertise in GPU-accelerated quantum simulation and error mitigation, while gaining valuable insights into the MLIR compiler framework and JIT compilation. This collaboration exemplifies synergy within the quantum open-source ecosystem, paving the way for future advancements in quantum computing compilers that benefit the entire community.

CATALYST BETA

Papers

Unitary Labs research with Mitiq, QuTiP and long-term projects

The Unitary Fund research GitHub repo has source code for a selection of our research projects.

- **Report for the ASCR Workshop on Basic Research Needs in Quantum Computing and Networking**, P. Lougovski, O. Parekh, J. Broz, M. Byrd, J.C. Chapman, Y. Chembo, W.A. de Jong, E. Figueroa, T.S. Humble, J. Larson, G. Quiroz, G. Ravi, N. Shammah, K.M. Svore, W. Wu, W.J. Zeng, January 7, 2024, United States, osti.gov/biblio/2001045, DOI:10.2172/2001045
  Abstract:
  Employing quantum mechanical resources in computing and networking opens the door to new computation and communication models and potential disruptive advantages over classical counterparts. However, quantifying and realizing such advantages face extensive scientific and engineering challenges. Investments by the Department of Energy (DOE) have driven progress toward addressing such challenges. Quantum algorithms have been recently developed, in some cases offering asymptotic exponential advantages in speed or accuracy, for fundamental scientific problems such as simulating physical systems, solving systems of linear equations, or solving differential equations. Empirical demonstrations on nascent quantum hardware suggest better performance than classical analogs on specialized computational tasks favorable to the quantum computing systems. However, demonstration of an end-to-end, substantial and rigorously quantifiable quantum performance advantage over classical analogs remains a grand challenge, especially for problems of practical value. The definition of requirements for quantum technologies to exhibit scalable, rigorous, and transformative performance advantages for practical applications also remains an outstanding open question, namely, what will be required to ultimately demonstrate practical quantum advantage?

- **Quantum error mitigation by layerwise Richardson extrapolation**, arXiv preprint (2024), A. Mari, V. Russo, [2402.04000]
  Abstract:
  A widely used method for mitigating errors in noisy quantum computers is Richardson extrapolation, a technique in which the overall effect of noise on the estimation of quantum expectation values is captured by a single parameter that, after being scaled to larger values, is eventually extrapolated to the zero-noise limit. We generalize this approach by introducing \emph{layerwise Richardson extrapolation (LRE)}, an error

Abstract:
We demonstrate that the problem of amplitude estimation, a core subroutine used in many quantum algorithms, can be mapped directly to a problem in signal processing called direction of arrival (DOA) estimation. The DOA task is to determine the direction of arrival of an incoming wave with the fewest possible measurements. The connection between amplitude estimation and DOA allows us to make use of the vast amount of signal processing algorithms to post-process the measurements of the Grover iterator at predefined depths. Using an off-the-shelf DOA algorithm called ESPRIT together with a compressed-sensing based sampling approach, we create a phase-estimation free, parallel quantum amplitude estimation (QAE) algorithm with a total query complexity of ~4.9/ε and a parallel query complexity of ~0.40/ε at 95% confidence. This performance is a factor of 1.1× and 14× improvement over Rall and Fuller [Quantum 7, 937 (2023)], for worst-case complexity, which to our knowledge is the best published result for amplitude estimation. The approach presented here provides a simple, robust, parallel method to performing QAE, with many possible avenues for improvement borrowing ideas from the wealth of literature in classical signal processing.

- **QuTiP 5: The Quantum Toolbox in Python**, arXiv, (2024), Neill Lambert, Eric Giguère, Paul Menczel, Boxi Li, Patrick Hopf, Gerardo Suárez, Marc Gali, Jake Lishman, Rushiraj Gadhvi, Rochisha Agarwal, Asier Galicia, Nathan Shammah, Paul Nation, J. R. Johansson, Shahnawaz Ahmed, Simon Cross, Alexander Pitchford, Franco Nori, [2412.04705]

Abstract:
QuTiP, the Quantum Toolbox in Python, has been at the forefront of open-source quantum software for the last ten years. It is used as a research, teaching, and industrial tool, and has been downloaded millions of times by users around the world. Here we introduce the latest developments in QuTiP v5, which are set to have a large impact on the future of QuTiP and enable it to be a modern, continuously developed and popular tool for another decade and more. We summarize the code design and fundamental data layer changes as well as efficiency improvements, new solvers, applications to quantum circuits with QuTiP-QIP, and new quantum control tools with QuTiP-QOC. Additional flexibility in the data layer underlying all "quantum objects" in QuTiP allows us to harness the power of state-of-the-art data formats and packages like JAX, CuPy, and more. We explain these new features with a series of both well-known and new examples. The code for these examples is available in a static form on GitHub and will be available also in a continuously updated and documented notebook form in the qutip-tutorials package.

Other Unitary Foundation staff research

- **Optimal discrimination of quantum sequences**, T. Gupta, S. Murshid, V. Russo, Somshubhro Bandyopadhyay [2409.08705]
  Abstract:
  A key concept of quantum information theory is that accessing information encoded in a quantum system requires us to discriminate between several possible states the system could be in. A natural generalization of this problem, namely, quantum sequence discrimination, appears in various quantum information processing tasks, the objective being to determine the state of a finite sequence of quantum states. Since such a sequence is a composite quantum system, the fundamental question is whether an optimal measurement is local, i.e., comprising measurements on the individual members, or collective, i.e. requiring joint measurement(s). In some known instances of this problem, the optimal measurement is local, whereas in others, it is collective. But, so far, a definite prescription based solely on the problem description has been lacking. In this paper, we prove that if the members of a given sequence are drawn secretly and independently from an ensemble or even from different ensembles, the optimum success probability is achievable by fixed local measurements on the individual members of the sequence, and no collective measurement is necessary. This holds for both minimum-error and unambiguous state discrimination paradigms.

- **"Schrödinger as a Quantum Programmer: Estimating Entanglement via Steering"**, Quantum 8, 1366, (2024), A. Philip, S. Rethinasamy, V. Russo, M. M. Wilde, [2303.07911]
  Abstract:
  Quantifying entanglement is an important task by which the resourcefulness of a quantum state can be measured. Here, we develop a quantum algorithm that tests for and quantifies the separability of a general bipartite state by using the quantum steering effect, the latter initially discovered by Schrödinger. Our separability test consists of a distributed quantum computation involving two parties: a computationally limited client, who prepares a purification of the state of interest, and a computationally unbounded server, who tries to steer the reduced systems to a probabilistic ensemble of pure product states. To design a practical algorithm, we replace the role of the server with a combination of parameterized unitary circuits and classical optimization techniques to perform the necessary computation. The result is a variational quantum steering algorithm (VQSA), a modified separability test that is implementable on quantum computers that are available today. We then simulate our VQSA on noisy quantum simulators and find favorable convergence properties on the examples tested. We also develop semidefinite programs, executable on classical computers, that benchmark the

results obtained from our VQSA. Thus, our findings provide a meaningful connection between steering, entanglement, quantum algorithms, and quantum computational complexity theory. They also demonstrate the value of a parameterized mid-circuit measurement in a VQSA.

- **“Locally distinguishing a maximally entangled basis using LOCC and shared entanglement”**, arXiv preprint (2024), V. Russo, S. Bandyopadhyay, [2406.13430]
  Abstract:
  We consider the problem of distinguishing between the elements of a bipartite maximally entangled orthonormal basis using local operations and classical communication (LOCC) and a partially entangled state acting as a resource. We derive an exact formula for the optimum success probability and find that it corresponds to the fully entangled fraction of the resource state. The derivation consists of two steps: First, we consider a relaxation of the problem by replacing LOCC with positive-partial-transpose (PPT) measurements and establish an upper bound on the success probability as the solution of a semidefinite program, and then show that this upper bound is achieved by a teleportation-based LOCC protocol. This further implies that separable and PPT measurements provide no advantage over LOCC for this task. We also present lower and upper bounds on the success probability for distinguishing the elements of an incomplete orthonormal maximally entangled basis in the same setup.

- **Assessing the Benefits and Risks of Quantum Computers**, arXiv (2024), Travis L. Scholten, Carl J. Williams, Dustin Moody, Michele Mosca, William Hurley (“whurley”), William J. Zeng, Matthias Troyer, Jay M. Gambetta, [2401.16317]
  Abstract:
  Quantum computing is an emerging technology with potentially far-reaching implications for national prosperity and security. Understanding the timeframes over which economic benefits and national security risks may manifest themselves is vital for ensuring the prudent development of this technology. To inform security experts and policy decision makers on this matter, we review what is currently known on the potential uses and risks of quantum computers, leveraging current research literature. The maturity of currently-available quantum computers is not yet at a level such that they can be used in production for large-scale, industrially-relevant problems, and they are not believed to currently pose security risks. We identify 2 large-scale trends -- new approximate methods (variational algorithms, error mitigation, and circuit knitting) and the commercial exploration of business-relevant quantum applications -- which, together, may enable useful and practical quantum computing in the near future. Crucially, these methods do not appear likely to change the required resources for

cryptanalysis on currently-used cryptosystems. From an analysis we perform of the current and known algorithms for cryptanalysis, we find they require circuits of a size exceeding those that can be run by current and near-future quantum computers (and which will require error correction), though we acknowledge improvements in quantum algorithms for these problems are taking place in the literature. In addition, the risk to cybersecurity can be well-managed by the migration to new, quantum-safe cryptographic protocols, which we survey and discuss.
Given the above, we conclude there is a credible expectation that quantum computers will be capable of performing computations which are economically-impactful before they will be capable of performing ones which are cryptographically-relevant.

- **Open Hardware Solutions in Quantum Technology,** N. Shammah, A. Saha Roy, C. G. Almudever, S. Bourdeauducq, A. Butko, G. Cancelo, S. M. Clark, J. Heinsoo, L. Henriet, G. Huang, C. Jurczak, J. Kotilahti, A. Landra, R. LaRose, A. Mari, K. Nowrouzi, C. Ockeloen-Korppi, G. Prawiroatmodjo, I. Siddiqi, W. J. Zeng, APL Quantum 1, 011501 (2024) doi:10.1063/5.0180987 [2309.17233]
  Abstract:
  Quantum technologies such as communications, computing, and sensing offer vast opportunities for advanced research and development. While an open-source ethos currently exists within some quantum technologies, especially in quantum computer programming, we argue that there are additional advantages in developing open quantum hardware (OQH). Open quantum hardware encompasses open-source software for the control of quantum devices in labs, blueprints and open-source toolkits for chip design and other hardware components, as well as openly-accessible testbeds and facilities that allow cloud-access to a wider scientific community. We provide an overview of current projects in the OQH ecosystem, identify gaps, and make recommendations on how to close them today. More open quantum hardware would accelerate technology transfer to and growth of the quantum industry and increase accessibility in science.

The Community

"You are **one of the best things** that happened to quantum software. Please continue the no nonsense approach."
- Fred Jendrzejewski

"During UnitaryHACK, we were **super impressed by both the high quality of the participant's contributions, and also their enthusiasm** — we've seen several become ongoing contributors long after the event! It's been a fantastic way to source applicants for our quantum software roles at Xanadu."
- Josh Izaac, Xanadu

"[unitaryCON] is **a great initiative** the people here are amazing. I really like the informal nature of the conference without compromising the quality of the content and presentations.."
- Harshit Gupta

"The visibility at unitaryHACK **prompted a discussion and then a collaboration with INRIA-Paris team and U of Edinburgh team** working on blind quantum computing."
- Shinichi Sunami

Digital community

31 Active project channels

26 QOSS channels

4 200 Discord members

Community calls

H-Hat, IONQ, metriq, mitiq, Piccolo.jl, Qiskit, QICK

Quantum Wednesday

26 Quantum Wednesday talks

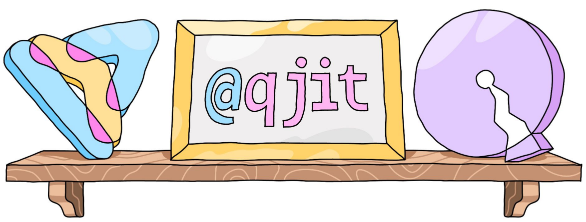
15 Guest talks

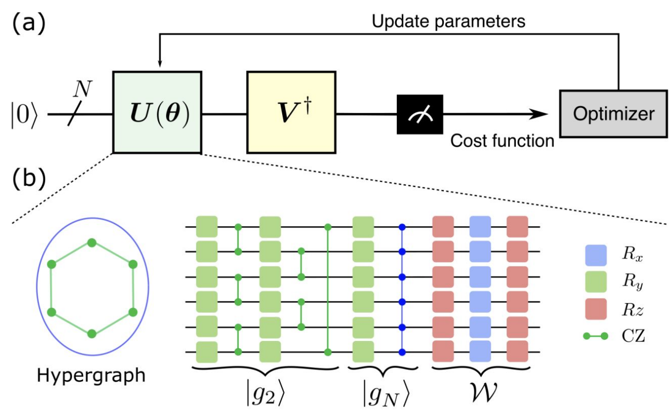
- **Qlasskit**, Davide Gessa
- **Quantum Optimal Control with Piccolo.jl**, Aaron Trowbridge *(Carnegie Mellon University)*
- **Quantum Advantage Seeker with Kernels**, Massimiliano Incudini *(U. of Verona)*, Francesco Di Marcantonio *(UPV)*, Michele Grossi *(CERN)*
- **Uniformly Decaying Subspaces for Error Mitigated Quantum Computation,** Nishchay Suri *(USRA/NASA)*
- **QRISE 2024 Unitary Fund Challenge Winner Talks**, Matthew Chang (*Case Western Reserve University)*, Eric Yarnot *(CWRU)*, Skylar Chan *(U. Maryland)*, Jeffrey Kwan *(UCLA)*, Wilson Smith *(U. Maryland)*, Marco Qin *(Carnegie Mellon University)*
- **Error Mitigation Benchmarking Pipeline**, Ella Carlander, Ruhee Nirodi, and Alexandros Peltekis *(University of Washington)*
- **Survey of Quantum Resource Estimation Tools**, Brian Goldsmith
- **mdopt - decoding quantum and classical error correcting codes in the MPS-MPO formalism**, Aleksandr (Alex) Berezutskii
- **Dynamically Generated Decoherence-Free Subspaces and Subsystems on Superconducting Qubits**, Gregory Quiroz *(Johns Hopkins U.)*
- **Error Mitigation with Quantum Subspace Expansion**, Joao Carlos de Andrade Getelina *(Iowa State University)*
- **Error mitigation and circuit division for early fault-tolerant quantum phase estimation**, Alicja Dutkiewicz & Stefano Polla *(Leiden University)*

Unitary Foundation Blogposts

Technical + Field Advancement

29 Feb | Adding Qibo as a new supported frontend for Mitiq*
06 Mar | HierarQcal - Quantum circuit generation and general compute graph design*
04 Apr | Qiskit-Qulacs - Execute Qiskit programs using Qulacs backend*
10 Jul | QJIT compilation with Qrack and (Xanadu PennyLane) Catalyst
11 Sep | An Introduction to Genetic Algorithms for Quantum Architecture Search*
08 Oct | toqito: Quantum Information Science Impact through Open Source
17 Oct | Aquapointer, a software package for quantum biology applications
21 Oct | QCoder - A platform for quantum competitive programming*
01 Nov | What algorithms exist to emulate quantum computers?





Community Engagement + Impact

02 Jan | Looking Back at Unitary Con
22 Jan | Unitary Fund Announces Brian Goldsmith as Newest Ambassador*
04 Mar | Expanding our board: Anastasia Gamick and Liz Durst
07 Mar | Open Hardware Solutions in Quantum Technology
28 May | Meet the UF interns - Srila Palanikumar*
14 Jun | Introducing the Open Quantum Benchmark Committee with Metriq
28 Aug | The first in-person Mitiq Workshop at the 2024 QNumerics Summer School
04 Oct | UnitaryCON 2024: Bringing together the open source quantum software community
24 Oct | Welcoming two new members to the Open Quantum Benchmark Committee with Metriq
18 Nov | Just in time for just-in-time error mitigation: Mitiq meets Catalyst
25 Nov | Teaching Learning, Teaching Science in High Schools*
25 Nov | Introducing the Unitary Fund's Advisory Board 2025
09 Dec | 2024 Quantum Open Source Software Survey Results
17 Dec | Unitary Fund awarded EU grant in the QLASS consortium
24 Dec | On the Impact of Mitiq and its Future

* Guest post

unitaryHACK

Our annual hackathon, unitaryHACK brought together nearly **900 participants from more than 70 countries** to move the open source ecosystem forward together. Over a two week period, these participants closed dozens of open issues on some of the largest and most important open source tools in the field.

unitary hack **Empower Quantum.** > > > > >

First-Time Contributors	Nearly **50%** of participants, highlighting the inclusive and welcoming nature of the open source quantum computing community
Bounties Closed	**139**
Total Earnings	**$13,142** distributed among participants
Hackers Awarded	**68** hackers won bounties
Participating Projects	**49** projects up from **33** in last year's event

A major thank you to the 100+ maintainers who helped to guide the participants, and to the University of Washington, Aalto University and UNAM for organizing in-person hack days for participating students.

- Aer
- AI-inspired Classification of Quantum Computers
- Amazon Braket Default Simulator
- Amazon Braket SDK
- AutoQASM
- Azure Quantum Development Kit
- bloqade-python
- BQSKit
- Braket.jl
- BraketAHS.jl
- BraketSimulator.jl
- Cirq
- Classiq Library
- CUDA-Q
- Fusion Blossom
- graphix
- HierarQcal
- Ion(Q) Thruster
- KQCircuits
- lambeq
- metriq
- mitiq
- OpenQAOA
- OpenQASM 3 Parser
- PennyLane
- PennyLane Plugin for Amazon Braket
- Perceval
- Piccolo.jl
- PyClifford
- Qadence
- qBraid-QIR
- qBraid-SDK
- Qiskit
- Qiskit Provider for Amazon Braket
- qlasskit
- Qrack
- Quantum Machines QUA-to-Qiskit compiler & simulator
- Quantum Open Source Foundation (QOSF)
- Quantum Universal Education
- QuantumToolbox.jl
- Qublitz
- QuTiP Tutorials
- rustworkx
- scqubits
- Tangelo
- TensorCircuit
- TorchQuantum
- toqito

Shoutout to sponsors

Huge thanks to the following sponsors!

NVIDIA qBraid QuEra CLASSIQ

Unitary Foundation and its members (Core Members: IBM Quantum, DoraHacks, OQD, and Scientifica; Supporting Members: AWS, Microsoft, Pasqal, QC Ware, SandboxAQ)

unitaryCON

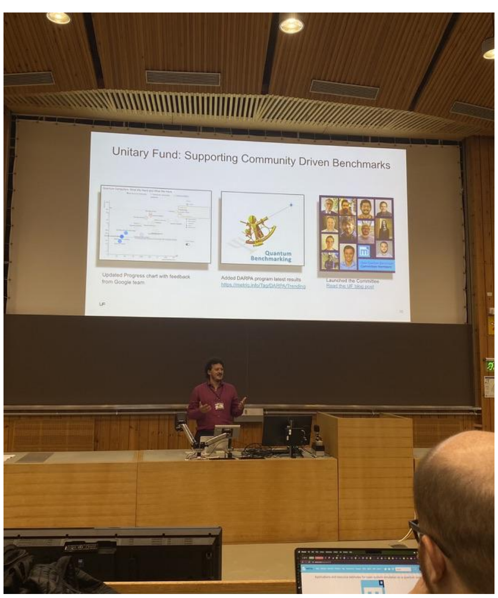
This year we gathered at Aalto University in Finland for our second annual unitaryCON. unitaryCON is an invite-only workshop for the Unitary Fund community and the leading open source maintainers across quantum technology. We want to thank Dr. Alexandru Paler for his help and leadership in graciously hosting our community this year!

Shoutout to sponsors

Huge thanks to the following sponsors!

Institute Q

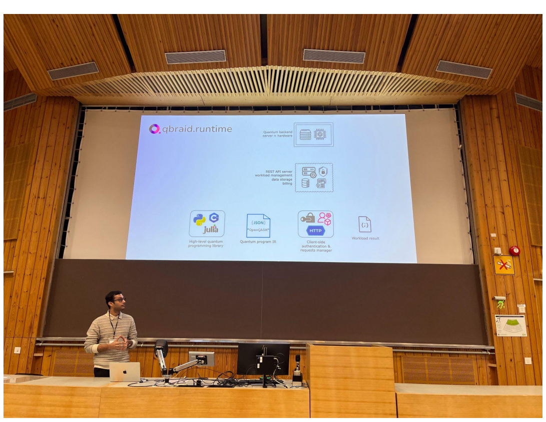
CLASSIQ

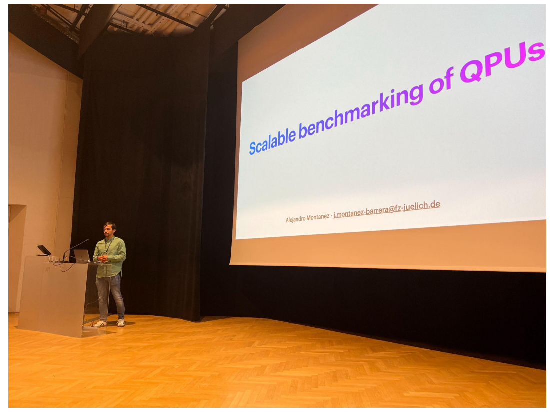


Talks @ unitaryCON

- **An overview of Unitary Foundation and recent focus areas**, Ben Castanon and Nathan Shammah, Unitary Foundation
- **Metriq: a web platform and community for quantum technology benchmarks**, Dan Strano, Unitary Foundation
- **Compiling Resource-Efficient Quantum Programs with BQSKit**, Mathias Weiden, BQSKit

- **OpenQuantum: open-source hardware for ultracold atoms**, Max Aalto, OpenQuantum
- **Qibo: an open-source hybrid quantum operating system**, Stefano Carrazza, Qibo
- **Open-Source Tools for Platform Agnostic Quantum Computing**, Harshit Gupta, QBraid
- **Qiskit 1.* and beyond**, Luciano Bello, IBM
- **Software-driven research with PennyLane**, Korbinian Kottmann, Xanadu
- **Lessons from building a cross-platform error mitigating toolkit**, Alessandro Cosentino, Unitary Foundation
- **Accelerating Quantum Simulations with QuTiP and QuTiP-JAX,** Rochisha Agarwal, QuTiP
- **Adversarial Circuit Benchmarking**, Spencer Churchill, IonQ





- **Method and results of GA-QAS for multi-target quantum compilation applications,** Viet Nguyen, GA-QASn
- **Combinatorial optimization problems in the OpenQAOA library**, Alejandro Montañez-Barrera, OpenQAOA
- **The QuEST to desperately maintain the relevance of statevector simulations**, Tyson Jones, EPFL
- **CUDA-Q for hybrid application development**, Bruno Schmitt, NVIDIA
- **Qadence IR: Compiling Digital-Analog QPUs**, Eduardo Maschio, Pasqal
- **Building a Full-Stack Open Quantum Computer with Trapped Ions**, Jake Malliaros, Open Quantum Design
- **Piccolo.jl: towards an open-source ecosystem for quantum optimal control**, Aaron Trowbridge, CMU
- **Preview of Unitary Compiler Collection (UCC)**, Jordan Sullivan, Unitary Foundation

Talks

In person

- **iQuHack**, Cambridge, MA | Jan 27-29
- **UW <> AWS Quantum Roundtable,** Seattle, WA | Jan 31
- **PyData Milano,** Milan, Italy | Feb 21
- **CSMT Innovative Contamination Hub,** Brescia, Italy | Feb 27
- **APS March Meeting** Minneapolis, MN | Mar 6
- **EPFL,** Lausanne, Switzerland | Mar 7
- **QuTiP Workshop,** Wako, Japan | Mar 26
- **RIKEN,** Wako, Japan | Apr 3
- **University of Milan Bicocca,** Milan, Italy | May 5
- **2nd TQCI Quantum Benchmarks Workshop,** Reims, France | Jun 4-5
- **Programming Language Design and Implementation (PLDI) Conference Workshop on Quantum Software,** Copenhagen, Denmark | Jun 24
- **Q4I,** Rome, NY | June 25-27

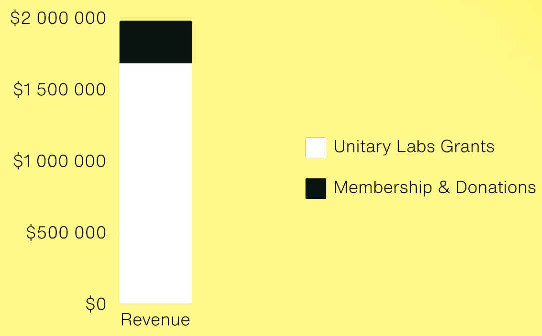
- **Numerical Methods in Quantum Information Science Summer School,** Boston, MA | Aug 17
- **Finnish Quantum Days,** Helsinki, Finland | Sept 10
- **unitaryCON,** Helsinki, Finland | Sept 12-14
- **Q4Bio Workshops,** Los Angeles, and London, UK | September 10 - 12
- **IEEE Quantum Week,** Montreal, Canada | Sept 20
- **OpenForum Academy Symposium,** Cambridge, MA | Nov 13-14

Digital (online)

- **QHACK 2024** | Feb 15
- **QRISE,** Seattle, WA | Mar 13
- **ARQC All Hands** | Mar 30-31
- **Beyond Research Quantum Computing: Introduction to Quantum Research for Girls** | June 13

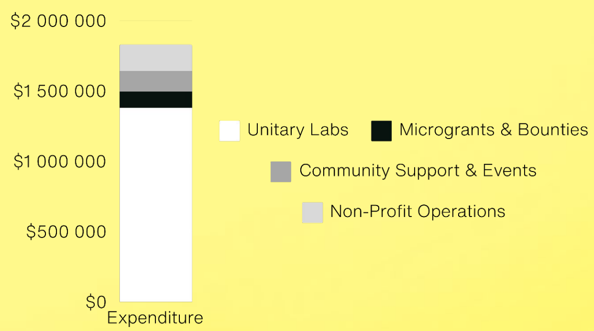
- **JuliaCon** | Jul 11
- **Qiskit Fall Fest, Mexico** | Oct 28
- **SMART Stack Kick-off Call** | Nov 1

Finances



Revenue

We forecast about **$ 1.98M** revenue in 2024
Unitary Labs Grants $ 1.68M
Membership & Donations $300K



Expenditure

We forecast about **$ 1.83M** expenditures in 2024.
Unitary Labs $ 1.38M
Microgrants & Bounties $ 115K
Community Support & Events $ 146K
Non-Profit Operations $189K

Unitary Foundation

www.unitary.foundation

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