Unitary Fund 2020 Annual Report

CREATING A QUANTUM TECHNOLOGY ECOSYSTEM FASTER, BETTER, AND TO BENEFIT EVERYONE.

GROWING OUR ACTIVITIES IN A CHALLENGING YEAR

It's been a disruptive year and we've been amazed by the resilience of the quantum open-source community and the efficiency of Unitary Fund's operations model. Here are some highlights from these 12 months (more in the next slides):

We've further grown the **microgrants program**, adding 20 more projects, spanning from software to education and new community development.

We set up an **advisory board** of 15 amazing volunteers that reviewed over 60 microgrant applications.

We created Unitary Fund's **research arm, Unitary Labs**, hiring six top experts in open-source quantum software.

Mitiq, the quantum software package developed at Unitary Labs, is the world's **first quantum error mitigation toolkit**, compatible with most existing frameworks and already used for two published research papers.

We've further grown our **social media presence** with Twitter, Discord, Twitch and YouTube accounts.

We connect, **nurture** and help acknowledge talent in the **open-source quantum community**. With the QOSF, we've inaugurated the **Wittek Prize**. We develop Mitiq with weekly community calls on Discord and streamed the first two episodes of our **Quantum Software Talks** series.

We're committed to supporting established open-source projects. **QuTiP has become Unitary Fund's first affiliated project** and we helped set up its official governance, as well as further fostering its adoption in the quantum industry (Pasqal) and in strategic research collaborations by the U.S. Department of Energy.

We've designed a **corporate sponsorship program**, adding new backers to secure the growth of the microgrant program into 2021.

MICROGRANTS FACTS AT A GLANCE (2019–2020)

35 funded projects (20 in 2020)

Awardees from 14 countries, 4 continents

5-minute application at https://unitary.fund/grants

$100K granted to date

*"The Unitary Fund supported zxQentiana **more than financially**: it enabled lively discussion with researchers from other sponsored projects, it was a quality guarantee seal, and it helped transform a small project into a promising research direction"*
– Alexandru Paler,

8 new folks working full-time in quantum technologies, whose first project in the field was a Unitary Fund grant

1 project stemmed into a venture-funded startup (Quantastica).
1 project is now a non-profit org. (QWorld)

Open source **metrics**:
> 20 open source libraries
> 950 stars
> 150 forks

WE GREW THE MICROGRANT PROGRAM X2.5 FROM LAST YEAR

In 2020 we've given 20 microgrants to 35 explorers in the field, up from 8 in 2019 and 7 in 2018. We were able to review over 60 grant applications thanks to a newly established, fantastic Advisory Board. The 25 microgrants include **13 open-source libraries**, support or creation of over **7 communities**, and among them, 5 focus on **education** while 10 lean more toward **research**.

SUPPORTED BY UNITARY FUND

FS QC **Full-Stack Quantum Computation**
Community-driven, open-source education resources

Worldwide community developing educational content that reaches into new channels, i.e. Discord.

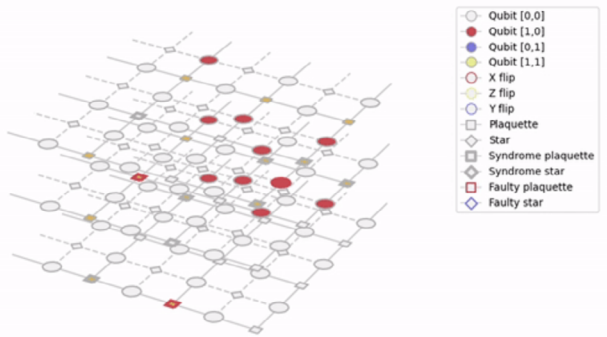
SUPPORTED BY UNITARY FUND

Extensible, Efficient Quantum Algorithm Design For Humans

Star Us 441

Yao's domain specific language, YaoLang, released support for its first circuit optimization pass based on ZX calculus (inspired by pyZX, a 2019 grant).

SUPPORTED BY UNITARY FUND



Qsurface, a simulator for surface codes with visualization of the decoders.

FROM OUR AWARDEES

"We need more open source supporters like the Unitary Fund"
- Ryan Sweke

"The Unitary Fund is an **outstanding program**! It offered me the opportunity to do funded research in a speciality topic that likely wouldn't have been funded otherwise, and to attend FOSDEM in Brussels, which was a **life changing experience**, and an excellent introduction to presenting and participating in sharing open source technologies!"
- Lucas Saldyt

"Every step of the way the people at the Unitary Fund have been **incredibly helpful, generous, and just amazing to work with.**"
- Ethan Hansen

"The Unitary Fund helped take my project to the next level and incentivized me to continue working on it long term. **It allowed me to bring in students to contribute to the project** furthering the goal of building a community around open source quantum network simulators."
- Stephen DiAdamo

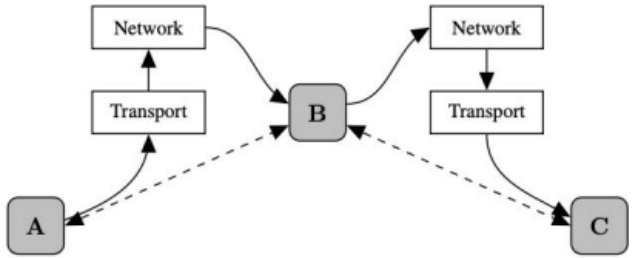
"Participation in **Unitary Fund gave me the conviction that the projects I want to do are really valuable for the community** and also the motivation to actually make them a reality"
- Michał Stęchły

"What I like about the **Unitary Fund is a straightforward formula: explain plainly what you want to create (as if it were an email), attach a video, send it. No bureaucracy. No BS questions.** For small open-source projects in quantum, it should be a no-brainer to apply."
- Piotr Migdal

"The Unitary Fund is a **fantastic opportunity** for researchers wanting to get started on their very own open source project in quantum computation."
- Hendrik Poulsen Nautrup

2020 MICROGRANTS: OPEN-SOURCE LIBRARIES

Open-source libraries (selection):

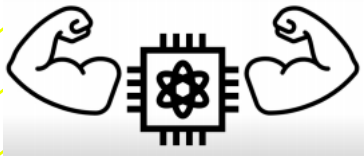


QuNetSim, a quantum network Python simulation framework for investigating quantum network protocols.

toqito, an open source Python toolkit for quantum information theory with extra functionality to study non-local games.

|toqito⟩

QRand, a multi-platform quantum random number generator library integrated with numpy.



OLSQ, Optimal Layout Synthesizer for Quantum Computing. This compiler beats other benchmarks on optimal layout of computational qubits onto physical qubits.

Table 4. Evaluation of QAOA-OLSQ

	t|ket⟩		TB-OLSQ		Depth	SWAP	QAOA-OLSQ		Depth	SWAP
M	Depth	SWAP	Depth	SWAP	Reduction	Reduction	Depth	SWAP	Reduction	Reduction
10	16	7.3	6.9	7.3	56.7%	0	6.5	5.5	59.3%	23.6%
12	17.8	11.7	8.5	9.3	52.3%	20.4%	5.6	5.8	67.3%	46.2%
14	19.0	13.2	9.0	12.3	52.6%	6.8%	6.0	6.6	68.3%	48.0%
16	21.7	20.2	9.1	13.6	58.2%	32.7%	6.4	6.9	70.2%	62.6%
18	25.5	26.7	8.9	14.5	64.9%	45.7%	6.0	8.3	75.5%	65.7%
20	30.6	37.5	9.3	16.3	68.9%	57.7%	7.2	10.8	75.7%	68.8%
22	29.8	38.4	10.3	17.8	65.4%	53.6%	7.8	14.2	73.7%	61.8%
Geometric Mean					59.5%	29.4%			70.2%	53.8%

MICROGRANTS: COMMUNITY, EDUCATION AND SEEDING PROJECTS

Education and Communities (selection):

QWorld Association, to sustain the incorporation costs and become a non-profit organization.

Qubit By Qubit, to develop courses and materials to educate a diverse ecosystem of open source quantum contributors.

Seed grants at inception/early development stage (selection):

TorchMPS A PyTorch toolbox for matrix product state models

A Quantum Machine Learning Textbook with integrated code and visualization

Quantum Tales, short stories with code where quantum algorithms are applied to solve tasks

EIGHT RESEARCH PAPERS IN 2020 FROM MICROGRANTS

[OLSQ] "Optimal Layout Synthesis for Quantum Computing", Arxiv:2007.15671; "Optimality Study of Existing Quantum Computing Layout Synthesis Tools", IEEE Trans. Comp. Arxiv:2002.09783.

[NISQAI] "Robust data encodings for quantum classifiers" Phys. Rev. A 102, 032420 (2020).

[QHyp] "Evaluating probabilistic programming languages for simulating quantum correlations", PLOS One 14,208555 (2019).

[QuNetSim] "QuNetSim: A Software Framework for Quantum Networks", Arxiv:2003.06397.

[AAVQE-Tutorial] "Scaling of variational quantum circuit depth for condensed matter systems', Quantum 4, 272 (2020).

[pyZX] "Reducing T-count with the ZX-calculus", Phys. Rev. A 102, 022406 (2020); "PyZX: Large Scale Automated Diagrammatic Reasoning", EPTCS 318, 229 (2020).

WE CREATED AN ADVISORY BOARD WITH WORLD EXPERTS

Advisory Board:

15 experts in quantum systems and software volunteered time to review microgrant applications and award the Wittek Prize over 15 meetings in 2020. Thanks to their commitment Unitary Fund has grown its scope and impact, reaching new folks.

Amy Brown	UCSC	amybrown
Alex McCaskey	Oak Ridge Nat. Lab	Amccaskey
Chris Granade	Microsoft	cgranade
Christa Zoufal	IBM	Zoufalc
Hannah Sim	Harvard/Zapata	hsim13372
Josh Izaac	Xanadu	josh146
Mark Fingerhuth	QOSF/ProteinQure	markf94
Michal Stechly	Zapata	mstechly
Nathan Killoran	Xanadu	co9olguy
Ntwali Bashige	Zapata	ntwalibas
Peter Karalekas	AWS CQC	karalekas
Roger Luo	U. of Waterloo	Roger-luo
Shahnawaz Ahmed	Chalmers Tech. U.	quantshah
Tomas Babej	QOSF/ProteinQure	tbabej
Travis Scholten	IBM	Travis-S

UNITARY LABS: LEADERS IN QUANTUM OPEN SOURCE

Unitary Labs is the research arm of Unitary Fund, which develops open-source software for quantum computing.

Team:

WILL ZENG, PhD

President. Head of Quantum Research at Goldman Sachs. Fmr. product/sw lead at Rigetti. Oxford quantum algorithms PhD.

SARAH KAISER, PhD

Co-founder of Q# community and founder of Women in QC and Applications Group. U. Waterloo, PhD in quantum computing.

PETER KARALEKAS

Research Scientist at AWS Center for Quantum Computing. Fmr. lead of quantum cloud software at Rigetti Computing.

NATHAN SHAMMAH, PhD

CTO. Lead developer at QuTiP. Visiting scientist at RIKEN & U. of Milan. PhD in quantum physics from Univ. of Southampton.

ANDREA MARI, PhD

> 40 peer-reviewed scientific publications. Contributor to Pennylane. Fmr. researcher at Xanadu & fmr postdoc at Scuola Normale di Pisa. PhD in quantum information at U. Potsdam

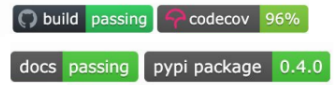
RYAN LAROSE

NASA Fellowship PhD student at University of Michigan. Fmr at Alphabet X. Wrote first paper benchmarking quantum software packages.

We went from no team to releasing v0.4 of Mitiq, the world's first open-source quantum error mitigation toolkit, in 8 months.

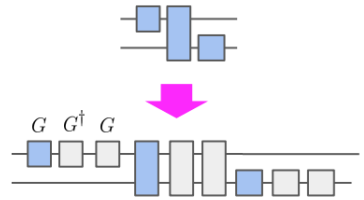
MITIQ: ERROR-MITIGATION COMPILER BUILT AT UNITARY LABS

Mitiq is a multiplatform, open-source, easy-to-use toolkit to perform error mitigation on noisy quantum computers and simulators. Mitiq is supported on: cirq, qiskit, pyquil, XaCC, Strangeworks, Tensorflow Quantum, with more to come.



With Mitiq, we performed **original research** implementing a set of **digital zero-noise extrapolation** techniques and tested them on real hardware, on IBM Q and Rigetti:

Digital Zero Noise Extrapolation for Quantum Error Mitigation https://arxiv.org/abs/2005.10921 (IEEE Quantum Week Proc.)



Mitiq: A software package for error mitigation on noisy quantum computers https://arxiv.org/abs/2009.04417

Collaborators

Stanford University · Lawrence Livermore National Laboratory · University of Maryland · APL · Dartmouth · The University of Chicago

Our research is supported by the **Department of Energy** (through an ARQC grant) and by IBM. You can find out more about Mitiq at: https://github.com/unitaryfund/mitiq

WE ARE NURTURING A LIVELY QUANTUM SOFTWARE COMMUNITY

Community: We started our **Quantum Software Talks** series, summarized at unitary.fund/talks and streamed online on **Twitch** (52 followers), available also on our new **YouTube** channel (69 subscribers).

Quantum Software Talks

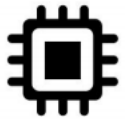
We hold a **weekly community call** on Friday at 2pm ET on our **Discord** channel (joined by over 200 folks) in which the Unitary Labs team reviews Mitiq's development.

Together with the Quantum Open Source Foundation, we inaugurated the **Wittek Quantum Prize** for Open Source Software. The prize received more than 50 nominations from the community, reviewed by our advisory board and tech team.

Unitary Fund

qosf

We signed a partnership with IBM to provide **access to dedicated quantum hardware** from the cloud to microgrant awardees (current & alumni), a feature already used by three projects.



We created a Twitter account to reach out to the community (668 followers) and wrote blog posts and guest articles as with educational resources for high schoolers.

twitter

blog

2021 SNEAK PEAK: INDUSTRY, ACADEMIA AND COMMUNITY

Industry: We have provided technical advisory to Pasqal, a Rydberg-atom-based quantum computing startup, on how to develop and integrate their software stack with QuTiP, the quantum toolbox in Python. QuTiP is going to be Unitary Fund's first "affiliated project", which we helped set up an official governance model. Stay tuned for updates.

Community: In 2021, we will organize hackathons to support established projects in the quantum software ecosystem. Also, we will further develop Mitiq, our in-house but fully open-source error mitigation toolkit with novel techniques.

Academia: We're advising the SQMS project, led by Fermi National Lab, on how to maximize its impact on the eco-system. Within SQMS, Unitary Fund is involved in workforce development to enable researchers to fully leverage cutting-edge tools in the quantum software ecosystem.

2021 MICROGRANTS: ENABLED BY OUR SUPPORTERS

Supporters:

In 2021, we are **starting our corporate sponsorship program**, adding Boston Consulting Group to previous sponsors that donated in 2019 and 2020. We are further growing the support for microgrants.

GIVINGTUESDAY

We received **individual donations**, triggered by our involvement in the Giving Tuesday initiative that aims at spotlighting support for non-profits on the first Tuesday after Thanksgiving.

We are grateful to all our supporters!

unitary.fund

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