

12WQC: two-way quantum computers

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~postselection of higher success rate evolving backward in time (CPT), conditions as for state preparation e.g. $V(t) \xleftrightarrow{CPT} -V(-t)$

adding postparation as state preparation in CPT perspective

1) Standard 1WQC assumes state preparation $|0\rangle$, then unitary evolution U , then measurements. However, physics is believed to be CPT symmetric - governed by nearly the same equations when evolving backward in time. Therefore, applying conditions which for backward evolution are original state preparation conditions, e.g. $V(t) \leftrightarrow -V(-t)$ reversed shape of prepare impulse, we should get postparation $\langle 0|$ - analogously enforcing the final state, mathematically acting as postselection $\langle 0|$, but with higher success rates.

Let's speedup quantum supremacy! (e.g. solve NP, better error correction)

CPT symmetry: having $|0\rangle$, there is also $\langle 0|$ [Jarek Duda, www.qaif.org/2wqc](http://www.qaif.org/2wqc)

2WQC: two-way quantum computers adding $\langle 0|$ postparation: CPT (state preparation) Acts as postselection, but with higher success rate

In CPT symmetry perspective use state preparation process e.g. low temperature: $|0\rangle \leftrightarrow \langle 0|$

$\langle \psi_f | U | \psi_i \rangle \xleftrightarrow{CPT} \langle \psi_i | U^\dagger | \psi_f \rangle$

Evolve forward \leftrightarrow backward

12WQC

QuantumCircuitOperator [["00", "H" \rightarrow 1, "CNOT", (1, 2)]]

Wolfram Quantum Framework

CPT ($|0\rangle$)

QC [["ProbabilityPlot"]]

1WQC $|0\rangle$ only

2WQC two-way $|0\rangle, \langle 0|$

QuantumCircuitOperator [["00", "H" \rightarrow 1, "CNOT", SuperDagger ["0"], (2)]]

e.g. silicon quantum dots (Intel)

Apply Magnetic Field strong B just before: preparation $|\uparrow\rangle$ strong B just after: postparation $\langle\uparrow|$ switched in CPT perspective

2) CPT symmetry is crucial for modern physics, experimentally widely tested, however, seems only in microscale. Macroscopic applications are proposed here, which if unsuccessful would present experimental macroscopic CPT violation, requiring to modify modern physics. For CPT symmetric: general relativity and quantum field theories, it is crucial to use eternalism/block universe philosophy of time: traveling through already found 4D solution, working on 4D scenarios like spacetime shape or Feynman paths/diagrams.

Physics should be governed by the same equations in CPT symmetry perspective

CPT for Electron

C - charge conjugation, P - parity, T - time

"The CPT theorem says that CPT symmetry holds for all physical phenomena (...)" (link)

any Lorentz invariant local quantum field theory with a Hermitian Hamiltonian must have CPT symmetry

"CPT Violation Implies Violation of Lorentz Invariance"

Feynman-Stueckelberg: "antiparticles travel backward in time"

Many microscopic confirmations: "Data Tables for Lorentz and CPT Violation"

Macroscopic tests? ... applications like 2WQC?

CPT symmetry in equations governing physics

Can be violated in solutions e.g. 2nd law of thermodynamics

Big Bang as 'the rock'? Everything localized: low entropy

presentism

directional evolution like wave propagation

3D local: past \rightarrow future evolution

particle: moving point

"hidden" evolving state

Kolmogorov 3rd axiom \rightarrow Bell inequalities

CPT eternalism, block universe GR, QFT

symmetric boundary conditions static e.g. Ising model, 4D spacetime

4D local: past \leftrightarrow future equilibrium

"4D jello" minimizing tension particle: its trajectory

Born rule \rightarrow Bell violation

$\Phi \rightarrow$ S-matrix = $\langle \phi | U(t_f, t_i) | \psi \rangle$

$T_{SVE} \propto G_{\mu\nu} \propto T_{\mu\nu}$

3) Evolving in low temperature reservoir, like in superconducting quantum computers, eventual energy is dissipating to reservoir, allowing to prepare nearly certain (Boltzmann) ground state 0 by just waiting: thermalization. Evolving backward in time (e.g. Lindblad from $+\infty \rightarrow 0$ instead of $-\infty \rightarrow 0$): temperature is the same, CPT says equations should be practically the same, so shouldn't energy also dissipate to 0? It suggests to just wait thermalization time ($\sim 1s$) after unitary evolution to enforce given qubit to 0 (postparation).

Superconducting QC e.g. IQM

Measurement/readout by coupling with resonator (invasive, reverse?)

$V(t) \rightarrow V(-t)?$

superconducting QC ~ 20 mK, CPT: same state preparation by reset (fast), or thermalization: just wait (long: ms, s)

unitary (CPT) perspective unitary

thermalization: dissipate energy to reservoir evolving backward?

wait (CPT) wait

perspective same equations evolve backward

1 qubit test: Hadamard for 0/1, mid-measure before thermalization (wait)

wait (CPT) wait

perspective same equations evolve backward

4) Standard electronics has two-way control: we both push and pull electrons by electric potential. Also for hydrodynamics we have two-way control using pump, for superfluid QC getting 2WQC. EM and (superfluid) hydrodynamics are governed by nearly the same equations, suggesting to take two-way control to microwaves and photons. For "pump for photons" we need e.g. ring laser or synchrotron source, in CPT perspective emitting photon in reversed direction - injecting them to the back of photonic chip, analogously as in hydrodynamics.

EM & hydrodynamics governed by nearly the same equations

optical heating-cooling, pushing-pulling, also tweezers

Radiation pressure is a vector: $\vec{p} = (\vec{E} \times \vec{H})/c$ (source)

Positive: toward surface, negative radiation pressure: outward

"two-way" symmetric computing, 2WQC: $\langle \psi_f | U | \psi_i \rangle \leftrightarrow \langle \psi_i | U^\dagger | \psi_f \rangle$

Push&pull for better flow control electrons battery as "pump"

hydrodynamics fluid pump positive pressure negative pressure

microfluidic superfluid QC? chip

microwave waveguide quant. chip?

ring laser positive pressure negative pressure

photonics chip? chip?

EM field (photons?) nearly the same equations as superfluid (mechanical vibrational qubits?)

CPT (process used for state preparation) to influence the final state

setting	Gauge fields	Circulation	Gauge condition	Matter field
Electro-dynamics	φ, \vec{A} four-potential	$\vec{B} = \nabla \times \vec{A}$ magnetic f.	$\vec{\nabla} \cdot \vec{A} + \frac{1}{c^2} \frac{\partial \varphi}{\partial t} = 0$	$\vec{E}_e = -\frac{\partial \varphi}{\partial t} - \nabla \varphi$
Hydro-dynamics	$\chi = v^2/2, \vec{v}$ flow velocity	$\vec{\omega} = \nabla \times \vec{v}$ vorticity	$\vec{\nabla} \cdot \vec{v} + \frac{1}{c_s^2} \frac{\partial \chi}{\partial t} = 0$	$\vec{E}_h = -\frac{\partial \chi}{\partial t} - \nabla \chi$

5) For example in silicon quantum dots, all operations have to be realized with electromagnetic impulses, for which e.g. $V(t) \leftrightarrow -V(-t)$ impulses of reversed shape would become the original one in perspective of CPT symmetry. For example impulse of electric field can be used to tunnel electrons to dots for state preparation, reversed impulse would do it in CPT perspective. Or strong magnetic field can enforce spin direction: applied before unitary evolution for preparation of initial state, after for postparation of final state.

Silicon quantum dots e.g. Intel 12 qubit

All operations with EM fields - easy to reverse spin or position qubits

state preparation E impulse to tunnel

unitary evolution U

T (state preparation) E impulse to tunnel

reverse applied impulse: $V(t) \leftrightarrow V(-t)$

Elzerman readout: only \downarrow spin can tunnel in Intel 2024 article for state preparation

Or use magnetic field to enforce spin direction before for $|0\rangle$, opposite after for $\langle 0|$

From Quantum Dots to Qubits

Single/Few Electrons

Apply Magnetic Field

6) Mathematically, we can treat the final density matrix (including noise) in various ways: in 1WQC we just measure n qubits. We can use additional m qubits and postselect them (p1WQC): measure and discard if getting unwanted values, however, its success probability usually drops exponentially with m . In 2WQC we would like to go through unitary evolution in reversed direction, or equivalently apply projection to this final density matrix - getting the same probability distribution as with postselection, but without exponential drop of success probability - allowing to attack postBQP containing NP problems.

2WQC - "higher success rate postselected 1WQC"

Quantum computing \rightarrow ρ density matrix (including noise), then:

1WQC: measurement (e.g. n qubits): $P(s) = \text{Tr}(\Pi_s \rho)$

p1WQC: earlier postselect to condition c (m qubits)

Measure $n + m$ qubits discarding all but c : $P(s) = \frac{\text{Tr}(\Pi_s \otimes \Pi_c \rho)}{P(c)}$

$P(c) = \sum_s \text{Tr}(\Pi_s \otimes \Pi_c \rho) = \text{Tr}(\Pi_c \rho) \sim 2^{-m}$ success rate

2WQC: $\rho \rightarrow (I_s \otimes \Pi_c) \rho (I_s \otimes \Pi_c)$ postpare/project to c , then measure n qubits: $P(s) = \frac{\text{Tr}(\Pi_s \otimes \Pi_c \rho)}{P(c)}$ as in p1WQC but with ≈ 1 success rate (instead of $\sim 2^{-m}$ for p1WQC)

Potentially exponential speedup, e.g. to solve NP problems

Aaronson's postBQP adding postselection: containing NP conflicts need imperfections e.g. $\langle 0|1\rangle$ ferromagnet: $\uparrow\uparrow\uparrow\uparrow\uparrow\uparrow\uparrow\uparrow\downarrow$

7) One of potential approaches to quantum NP solvers is based on Shor algorithm: start with state preparation, then Hadamard gates to get ensemble of exponential number of inputs, then some classical function, and finally its measurements restricting ensemble to fixed output of this function, which is periodic - by Fourier transform getting hint for factorization. For quantum NP solver we could use verifier as classical function, and replace measurement with postparation to restrict ensemble to only satisfying our instance of NP.

NP problem: find input satisfying polynomial time verifier

+ $\langle 0|$ postparation

2WQC in theory allows NP solvers, e.g. cipher breaking (resistant PQC???) global optimizers like drug design ... Also 2WQC allows better stability, error correction

for example 3-SAT problems, like:

$\exists x_1, x_2, \dots, (x_1 \vee \neg x_2 \vee x_3) \wedge (\neg x_1 \vee x_2 \vee \neg x_3) \wedge (x_5 \vee \neg x_4 \vee x_2) \dots ?$

basic 3-SAT setting:

n variables used up to 4 times, m clauses using 3 variables

- prepare ensemble of 2^n inputs

- calculate C-ORs with NOTs

- enforce all C-ORs to 1 with $|1\rangle$

- measure input qubits

Shor quantum routine, measurement restricts to $\{b: y^b \text{ mod } N = m\}$:

$|00\rangle \xrightarrow{H_1^{\otimes n}} \sum_{a=0}^{2^n-1} |a\rangle |0\rangle \xrightarrow{\text{classic}} \sum_a |a\rangle |y^a \text{ mod } N\rangle \xrightarrow{\text{meas}} \sum_b |b\rangle |m\rangle \xrightarrow{QFT, \text{meas}} |c\rangle |m\rangle$

3-SAT attack (NP), $\langle 1|_{II}$ restricts ensemble to $\{b: \text{SAT}(b) = \text{true}\}$

$|00\rangle \xrightarrow{H_1^{\otimes n}} \sum_{a=0}^{2^n-1} |a\rangle |0\rangle \xrightarrow{\text{SAT?}} \sum_a |a\rangle |\text{SAT}(a)\rangle \xrightarrow{\langle 1|_{II}} \sum_b |b\rangle |1\rangle \xrightarrow{\text{meas}} b$

for imperfect $\langle 1|$ would leave exponential number of false solutions

8) To overcome imperfections, such potential quantum NP solver would rather require exponential reduction of error rate. Fortunately, postparation also provides new error correction ways, like equalizer below allowing to work on multiple identical copies, hopefully to arbitrarily reduce error rate, or generally on superpositions of codewords of some error correction codes, having large Hamming distance. Working on copies is different than cloning, which is still forbidden for postselection and postparation (arXiv:2407.15623).

arXiv:2408.05812: 3-SAT solver for 2QWC, C_1, \dots, C_m clauses ... satisfied?

imperfection model for ϵ C-OR(1) error: $\rho = \sum_k \epsilon^k \sum_{x: |i-C_i(x)|=k} |x\rangle\langle x|$

for C-OR(1)

j copies: $\epsilon \rightarrow \epsilon^j$, needed $\epsilon \sim 2^{-n}$ - should be realizable with $O(n)$ copies

adding error correction 2WQC allows equalizer: enforcing qubit equality

robust 3-SAT solver: multiple copies of C-ORs (all $|1\rangle$) and variables (all measured) with mesh of equalizers

serial/parallel? equalizer mesh?

syndrome to zero for $\{00,11\}$ code book

serial: equalizers

parallel: equalizers

9) Grover's algorithm offers alternative approach for NP solvers, and with postparations seems to allow for exponential speedup. For below simple setting it allowed to reduce time to constant $O(1)$, and its two-way control of information flow also allowed to improve stability: resistance to various types of noise, like bit flip, phase flip, phase damping, depolarization channel.

better stability thanks to 2WQC two-way flow control

arXiv:2406.09450 Grover's algorithm on two-way quantum computer (G. Zelusta) in $O(1)$ time instead of $O(\sqrt{n})$, more error resistant

Quantum circuit for 2WQC Grover solving Sudoku

Phase flip

Phase damping

Depolarizing channel

FIG. 6: Quantum circuit for 2WQC Grover solving Sudoku

10) Current post-quantum cryptography is focused on Shor and Grover. Possibility of e.g. quantum NP solver seems completely neglected(?) - what seems highly irresponsible. For resistance in some nextgen PQC, we could increase required resources by orders of magnitudes above reachable in near future, e.g. requiring costly initialization to build large decoding tables based on the key. Another way is going to higher complexity classes, like still practical PSPACE, e.g. requiring multiple interaction game to establish connection.

Post-quantum cryptography (PQC): now focused on Shor, Grover

What if better algorithms, upgrades like 2WQC are there/coming?

NP solver verifier: does decryption with given key lower entropy? Are some of current PQC already resistant? (NP-hard is not enough)

Building nextgen PQC: immune/resistant to quantum NP solver? E.g. require initialization: large calculations based on cryptographic key before proper decoding (tough for key superposition)

Maybe based on higher class like PSPACE (private/public key?) <https://en.wikipedia.org/wiki/PSPACE-complete>

e.g. formal languages, 3-SAT \vee quantifier ($\forall x, \dots, \exists y, \dots (\forall \vee) \wedge \dots$), reconfiguration: find path satisfying constraints (\sim arXiv:1204.5317), puzzles/games: multiple-interaction cryptography (before low entropy)

11) This research has also lead to proposed further potential applications of CPT symmetry, or, if unsuccessful, tests to show CPT violation. For scenarios emitting photons in CPT perspective, like synchrotron with charge travelling on circle in both perspectives, for us should cause deexcitation with stimulated emission e.g. for novel radiotherapy to starve cancer tissue. Or CPT analog of CT scanner below, mapping emission coefficient instead of absorption, what should have much better transparency as blocked by excited atoms N.

Other applications?

arXiv:2409.15399

e.g. mapping emission coefficient? e.g. in human body time, space resolution

absorption

betatron, synchrotron, FEL

CT scan of emission coefficient for 3D map of e.g. tryptophan $\sim 340\text{nm}$, NADH $\sim 460\text{nm}$, flavins $\sim 525\text{nm}$ emission should have much better transparency as usually $N_2 \ll N_1$

emits photons

target for measurement of absorption coefficient

push: positive radiation pressure

pull: negative radiation pressure

stimulated emission

laser

powered by cell biochemistry

12) The general relativity in theory allows for additional realizations, rather impractical but valuable as stimulating thought experiment. While below black hole horizon it rotates time into space light cones, e.g. non-orientable wormhole could allow to rotate twice further - e.g. reversing time direction inside a rocket travelling through it. For external observer, entropy would decrease there, 1WQC would use pre-measurement and postparation, its laser would cause stimulated emission, CT scanner would map emission coefficients.

https://en.wikipedia.org/wiki/Non-orientable_wormhole

General relativity in theory allows black hole horizon $t \leftrightarrow x$

Klein-bottle-like wormhole apply T symmetry to rocket

For external observer:

entropy decreases, e.g. egg unscrambles, Reversed 1WQC, state preparation $|0\rangle \leftrightarrow$ postparation $\langle 0|$, pre-measurement, CT emission scan, laser causes deexcitation/negative radiation pressure,

thought experiment

non-orientable wormhole applying T (or P) transform

light cones

1WQC

past future

Klein bottle

laser causes excitation of target

T (laser) causes deexcitation

time, photons