Happy 10th Birthday, QuTiP!

QuTiP

Open source software for simulating open quantum systems.

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What is QuTiP?

- **Python library**
- **Extensive documentation** (link)
- **Extensive tutorials & lectures** (from beginner to cutting edge research; link)
- Built using Cython, numpy and SciPy
- **Truly open source** (active development community; open governance)

Who is QuTiP for?

- **Researchers** (e.g. physicists, chemists) in academia and industry.
- **Postdocs** doing cutting edge research.
- **Graduate students** exploring quantum mechanics.
- **Undergraduate students** learning quantum mechanics.
- **Educators** teaching quantum mechanics.
- **You!**

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What can QuTiP do?

Represent quantum objects:

- States & density matrices
- Operators & superoperators
- Hamiltonians & Liouvillians

Quantum information processing:

- Quantum gates and circuits
- Simulation of noisy decohering gates and circuits on models of underlying physical systems.

Provide many helpful utilities, for example:

- Simultaneous diagonalization
- Random states, density matrices, operators
- Bloch sphere visualisation
- Hinton plots
- Wigner functions

Determine evolution and steady states using:

- Schrödinger equation
- Master equation
- Montecarlo methods
- Bloch-Redfield
- Stochastic equations
- Floquet formalism
- Permutation Invariant Quantum Solver (PIQS)
- Hierarchical Equations of Motion (HEOM)
- Transfer tensor method (TTM)
- GRAPE (quantum control)

Efficiently represent quantum states and operators using:

- Sparse matrices; dense matrices; tensor networks; make-your-own if you like.

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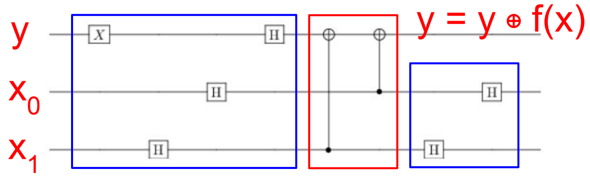
Use case 1: Simulating the Deutsch–Jozsa algorithm at the pulse level

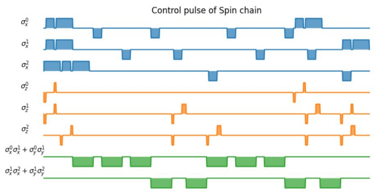
1. Define your circuit (*9 lines of code*)
2. Compile it to control pulses for a simulated 3-qubit spin chain (*2 lines of code*)
3. Optimise the control pulses (*8 lines of code*)

The plots on the right each require a single line of code.

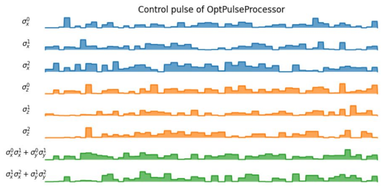
1.



2.



3.



Link: https://github.com/qutip/qutip-notebooks/blob/master/examples/qip-processor-DJ-algorithm.ipynb

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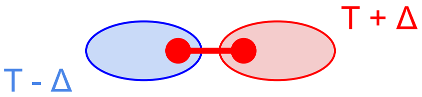
Use case 2: Simulating quantum heat transport using hierarchical equations of motion (HEOM)

1. Define the system: two qubits each connected to their own Drude-Lorentz bosonic bath, one hot, one cold (*1 line of code to define each bath; 1 line to add a HEOM terminator for each bath*)
2. Evolve the system (*2 lines of code*)
3. Calculate the heat currents between the system and the bath from the auxiliary density operators (*~10 lines of code*)

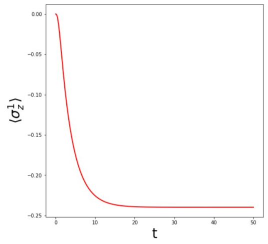
The two plots on the right require a line of code per series.

1.



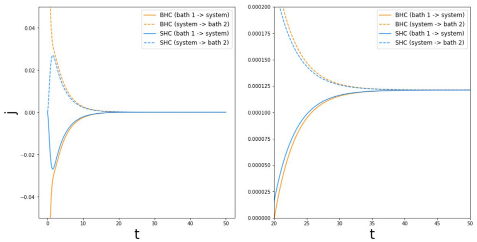
Two qubits connecting hot and cold baths

2.



System state thermalises quickly (t ~ 20)

3.



System-bath currents reach steady state later (t ~ 40)

Link: https://github.com/qutip/qutip-notebooks/blob/master/examples/heom/heom-3-quantum-heat-transport.ipynb

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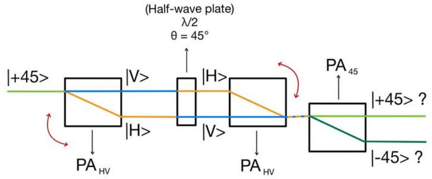
Use case 3: Student project on single photon interference

- Students drew the apparatus (*figure a*) and translated each optical element into a QuTiP operation (*1 line of code per element*)
- Students could examine the quantum state at any point in the apparatus (compliments lack of information available in real experiments)
- Students could simulate measurement for comparison with experimental results (*figures b and c*).

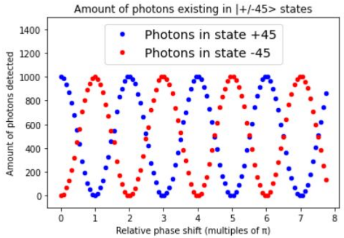
Everything can be run in Google Colab if needed.
No need to install Python locally.

a.



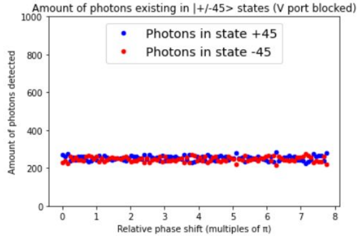
Single photon follows two paths.

b.



Measurement outcomes as a function of phase shift

c.



Measurement outcomes with one path blocked

Link: https://github.com/qutip/qutip-notebooks/blob/master/examples/single-photon-interference-example.ipynb

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QuTiP

GitHub:
https://github.com/qutip/qutip

RIKEN:
https://dml.riken.jp/

Theoretical Quantum Physics Laboratory

Chief Scientist: Franco Nori

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Outline

8 slides total

Slide 1: Title slide
Slide 2: What is QuTiP & Who is QuTiP for?
Slide 3: What can QuTiP do?
Slide 4: Use Case 1: Simulating the Deutsch-Jozsa algorithm at the pulse level
Slide 5: Use Case 2: Simulating quantum heat transport using hierarchical equations of motion (HEOM)
Slide 6: Use Case 3: Student project on single photon inteference
Slide 7: Links
Slide 8: Outline

Questions to answer:

- What is QuTiP? What is in QuTiP? What can I do with QuTiP?
- Why should people care about QuTiP? Who is using QuTiP? What work is being done with it?
- What has been added to QuTiP in the last couple of years?
- What is planned for the near future?
- What progress has been made on the moonshot goals?

5 minute video presentation on one of the HEOM notebooks