Tutorial to teach quantum circuits using the ZX-calculus

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IBM **Quantum**

UNIVERSITY OF OXFORD

The idea: Teach quantum computing with diagrams.
- Learn what they mean mathematically
- Write quantum circuits in ZX-calculus

Forms: matrices, braket, unit circle, Bloch sphere, ZX

Recommended: a high school degree; knowing matrix multiplication, complex numbers, & basic probability

Goal: Go from what is a qubit to quantum teleportation

Outside this tutorial, **where can one learn ZX-calculus...**

Outside Oxford

For high school students:
- Coming soon: Quantum Theory in Pictures book by Coecke and Gogioso, along with its lectures

Graduate level and up:
- Picturing Quantum Processes textbook by Coecke and Kissinger, and its upcoming sequel by Kissinger and van de Wetering

For quantum computing researchers:
- ZX-calculus for the working quantum computer scientist review by van de Wetering

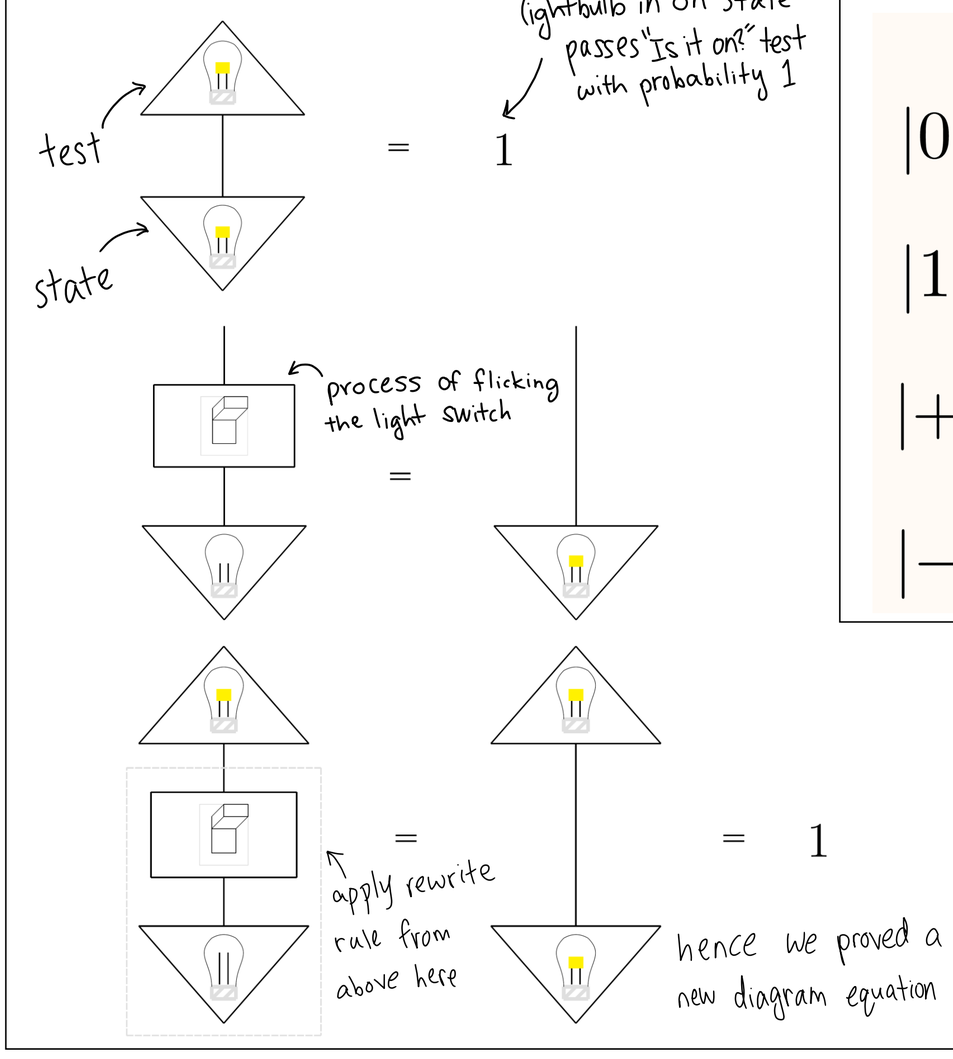
Courses at U of Oxford

For Oxford graduate students:
- Quantum Natural Language Processing
- Quantum Processes and Computation
- Quantum Software

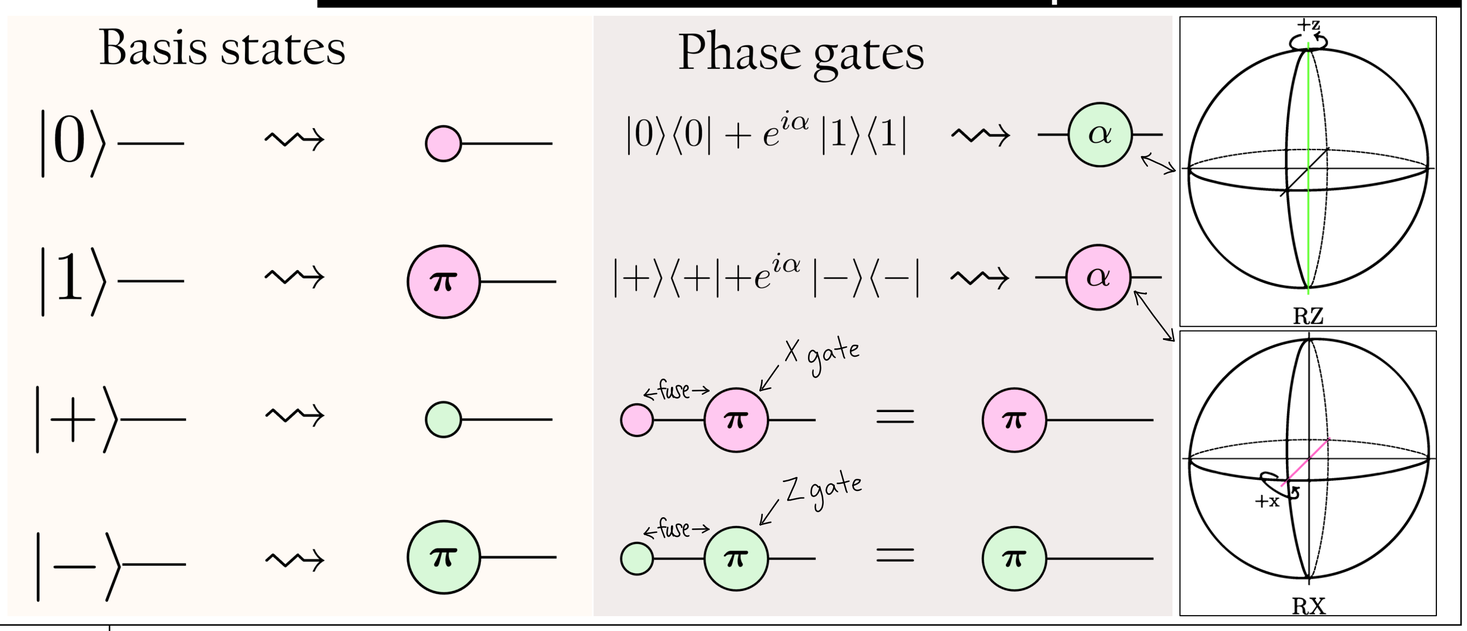
For software developers:
- Quantum computing bootcamp

- PyZX
- zxcalculus.com
- About 200 research papers so far

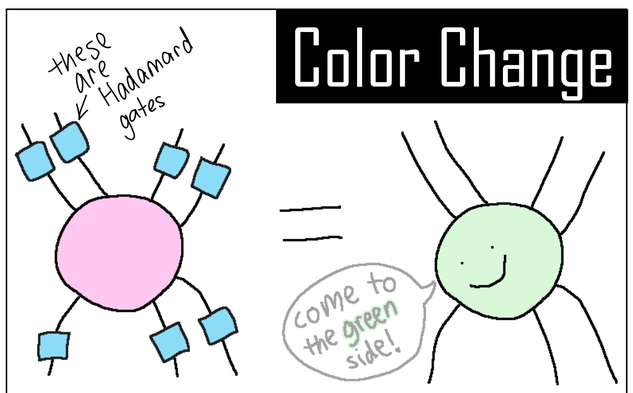
The 1st diagram rewrite



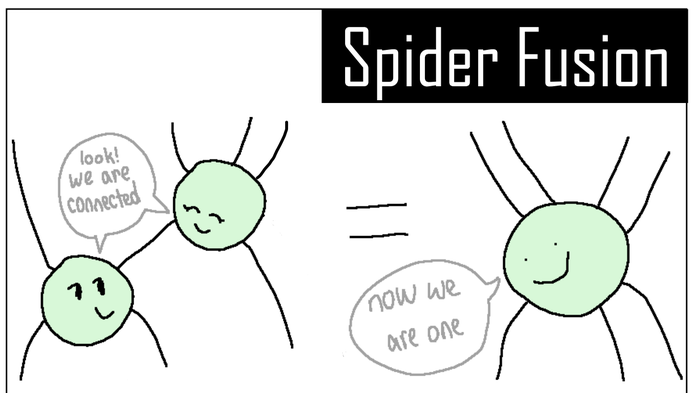
Let's use the ZX-calculus to teach quantum circuits

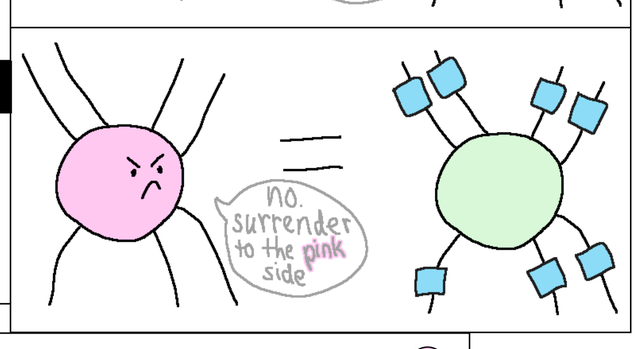


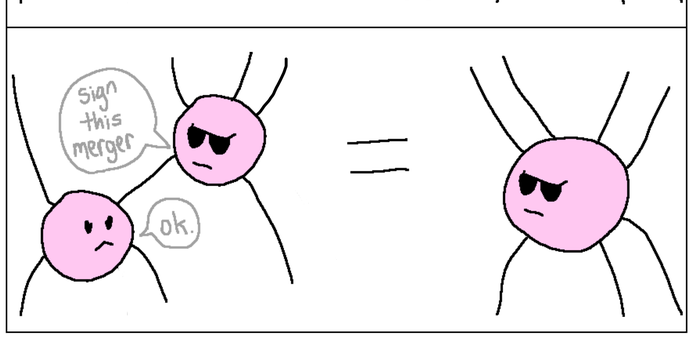
Color Change



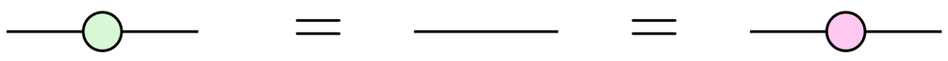
Spider Fusion







When you do a phase gate but the phase is zero,

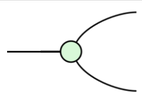


the spider dies.

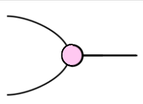
When Alice did a Bell measurement, two bits, a and b, were born.

After meeting 3-legged green and pink spiders,

$|00\rangle\langle 0| + |11\rangle\langle 1| \rightsquigarrow$

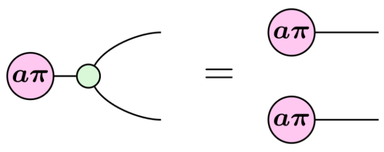


$|-\rangle\langle --| + |+\rangle\langle ++| \rightsquigarrow$

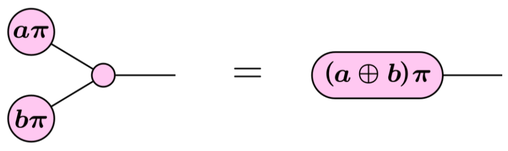


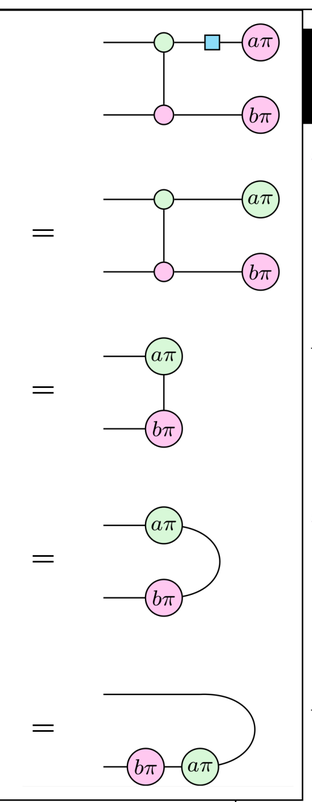
our two bits, a and b, learned...

... how to be copied...

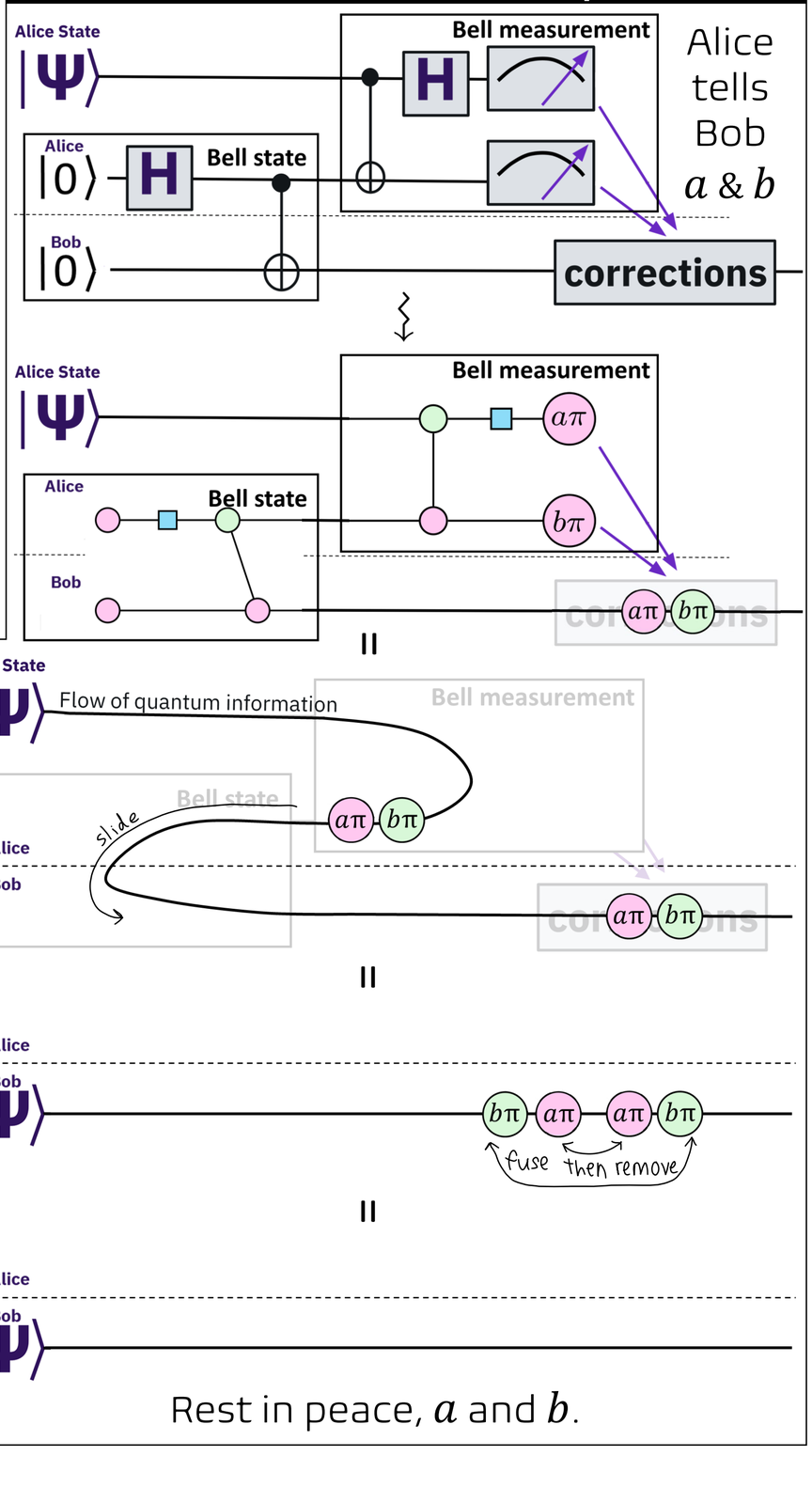


... and how to be XOR'd.

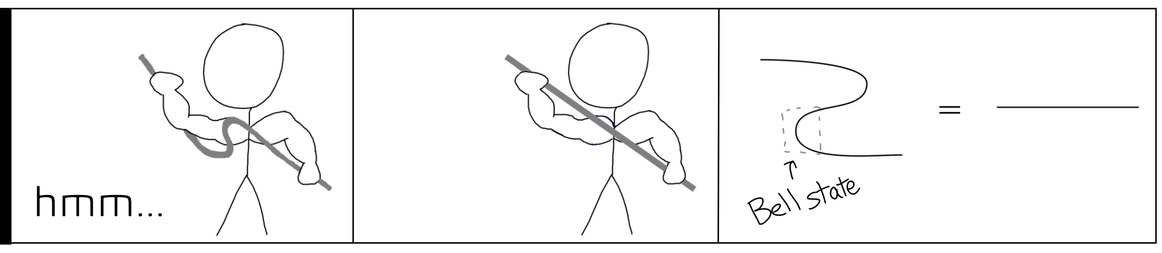


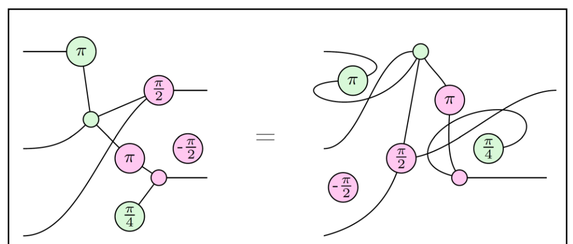


Quantum teleportation

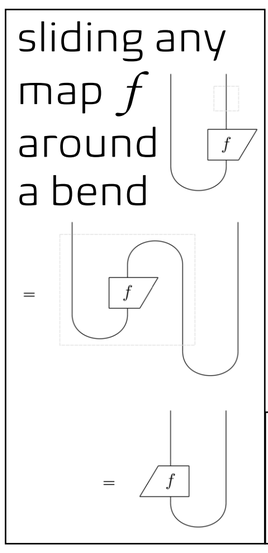


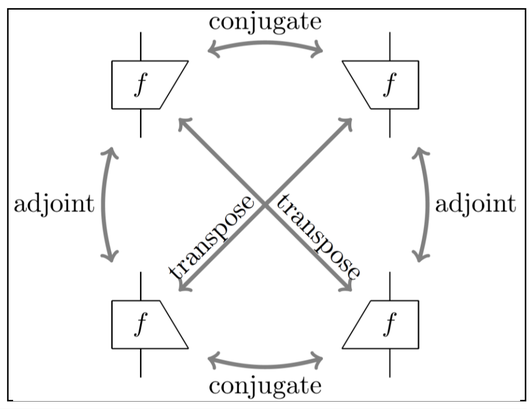
Wire bending



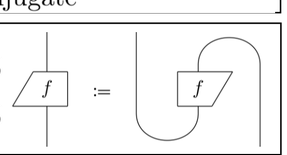


With these diagrams, we have the power to bend the wires however we want.





swap inputs and outputs



Rest in peace, a and b.