



Training session for Basic Quantum Knowledge

UAIC Quantum HUB

Session 1

07.12.2024, 9-14

L1 seminar Hall, Physics Faculty

1. States and Observables

1.1 Linear spaces. Vectors

1.2 Inner product. Hilbert spaces

1.3 Orthonormal bases. Computational basis

1.4 Outer product. Projectors

1.5 Operators in linear spaces

1.6 Matrices (normal, unitary). Examples (Pauli matrices)

1.7 Matrix diagonalization

1.8 Tensor product

Quantum mechanics postulates

2. The qubit. Single Qubit quantum gates

2.1 Qubit states. Superposition

2.2 Pure and mixed states. Qubit density matrix*

2.3 Bloch Sphere

2.4 Quantum circuit model

2.5 Single qubit quantum gates

2.5.1 NOT gate (X gate), Y, Z gates

2.5.2 Hadamard gate

2.5.3 Phase shift gate

2.5.4 Rotations

2.6 Measuring a qubit

* *advanced topic*

3. Multiple qubits. Multiple Qubit quantum gates

- 3.1 Tensor product revisited
- 3.2 Multiple qubit quantum gates
- 3.3 2-qubit quantum gates: CNOT gate
- 3.4 2-qubit quantum gates: SWAP gate
- 3.5 3-qubit quantum gates: CCNOT gate, CSWAP gate
- 3.6 Universal quantum gates
- 3.7 Measuring multiple qubits. Partial measurement
- 3.8 Distinguishing quantum states
- 3.9 The no-cloning theorem



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Session 2

14.12.2024, 9-14

L1 seminar Hall, Physics Faculty

4. Entanglement

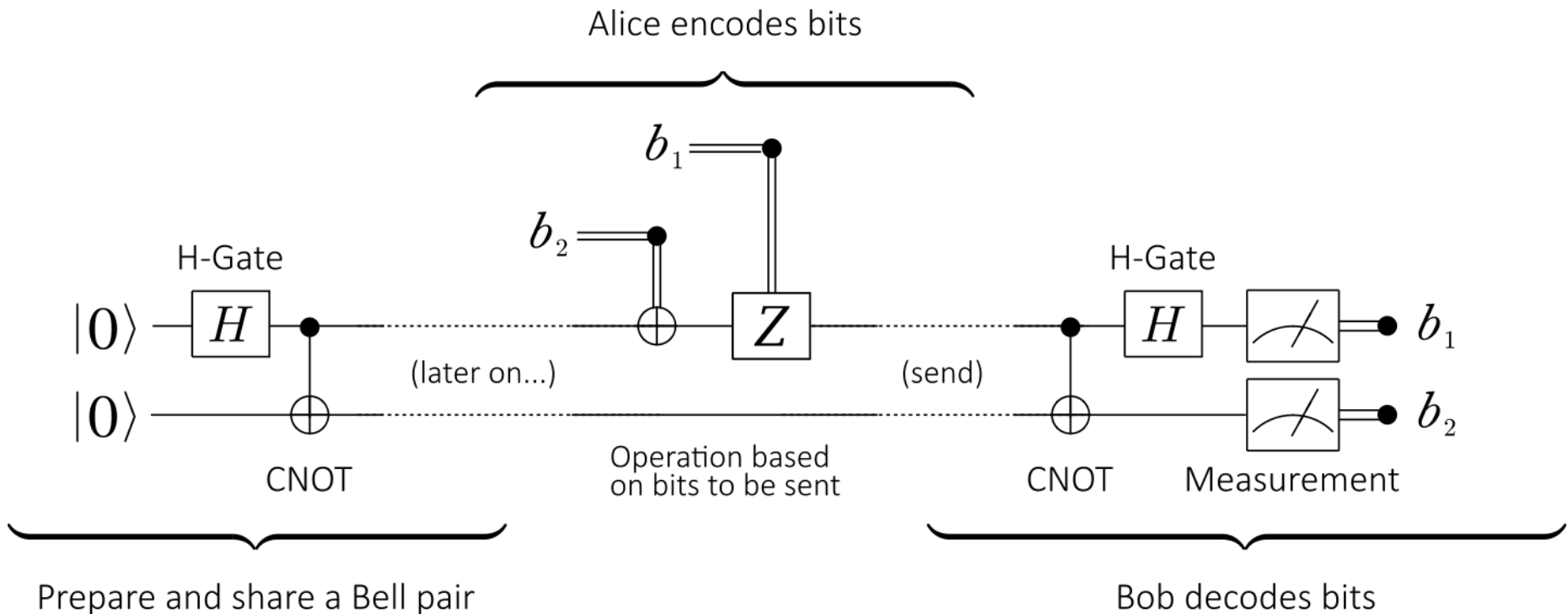
- 4.1 Introduction. Separable and non separable states
- 4.2 EPR paradox
- 4.3 Bell states
- 4.4 Bell states generation
- 4.5 Bell state analysis

5. Applications

- 5.1 Superdense coding
- 5.2 Entanglement swapping
- 5.3 Teleportation
- 5.4 QKD. BB84 protocol



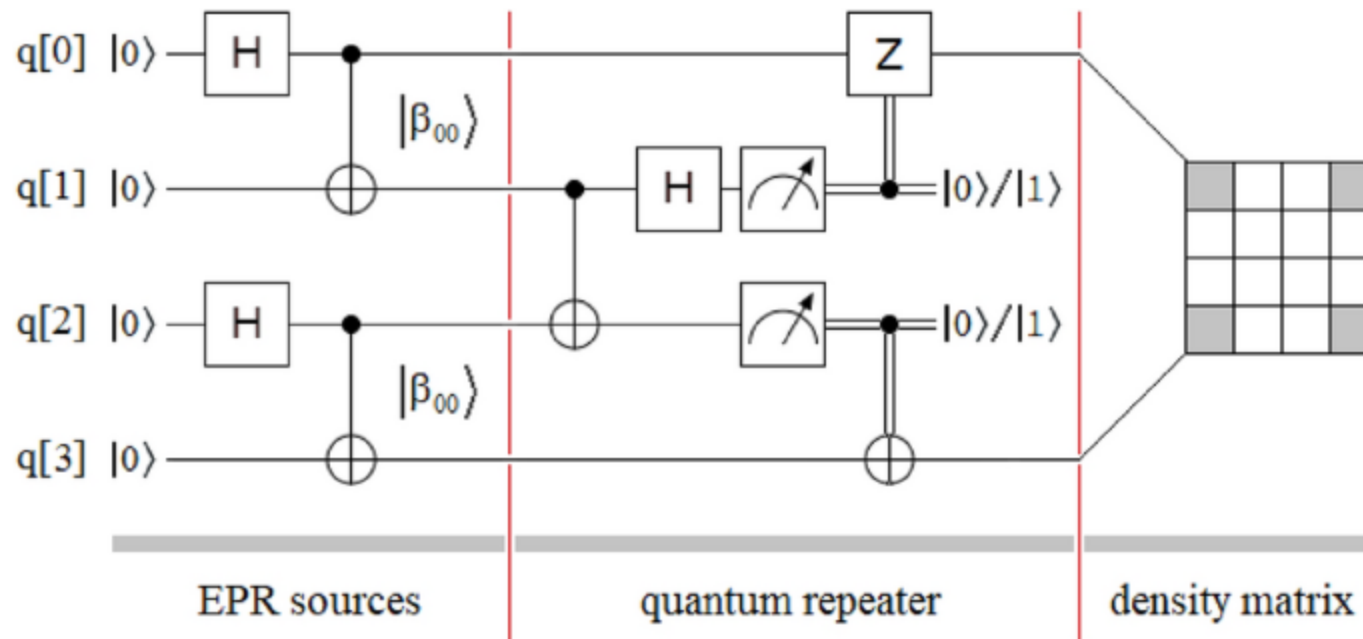
5.1 Superdense coding



<https://www.quantum-bits.org/?p=2694>



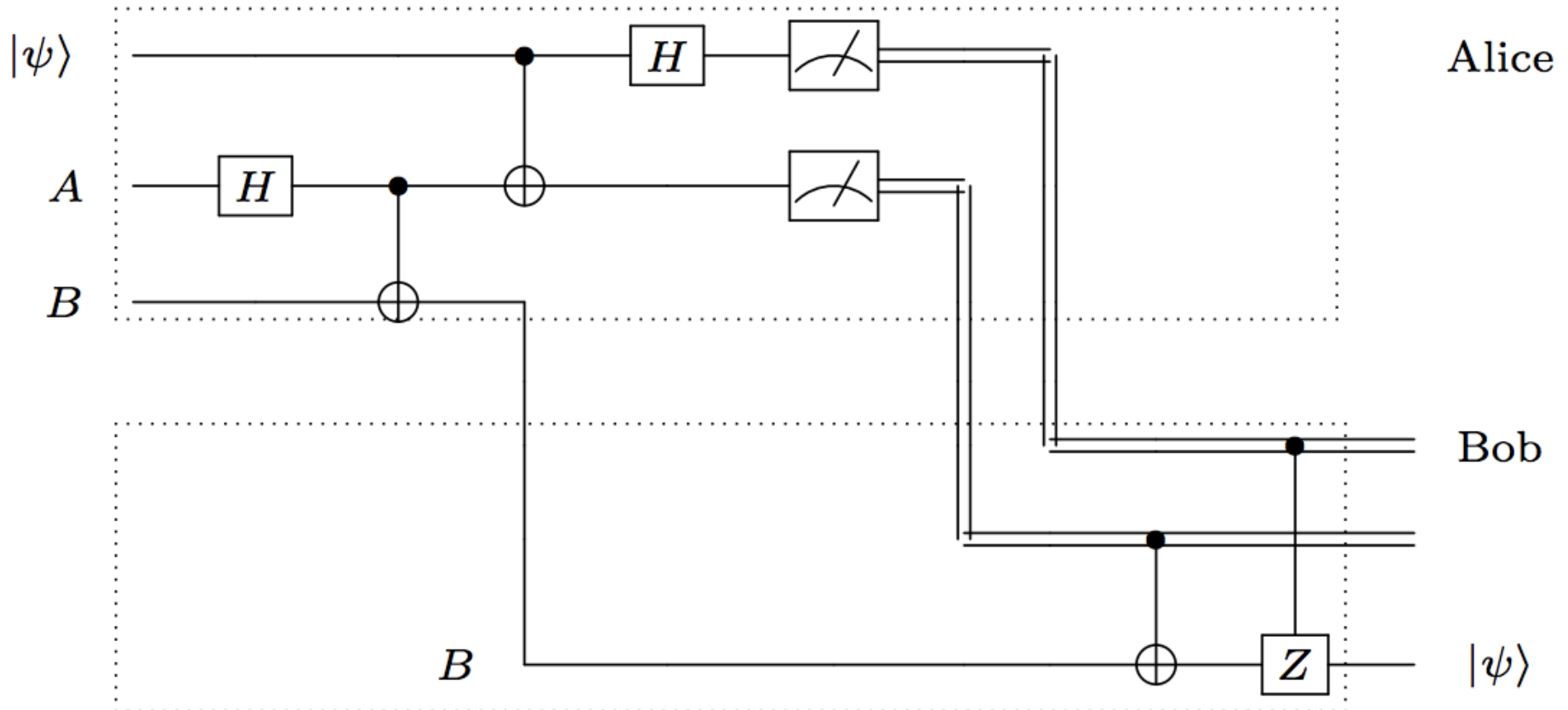
5.2 Entanglement swapping



Mastriani, M. Simplified entanglement swapping protocol for the quantum Internet. Sci Rep 13, 21998 (2023).
<https://doi.org/10.1038/s41598-023-49326-4>

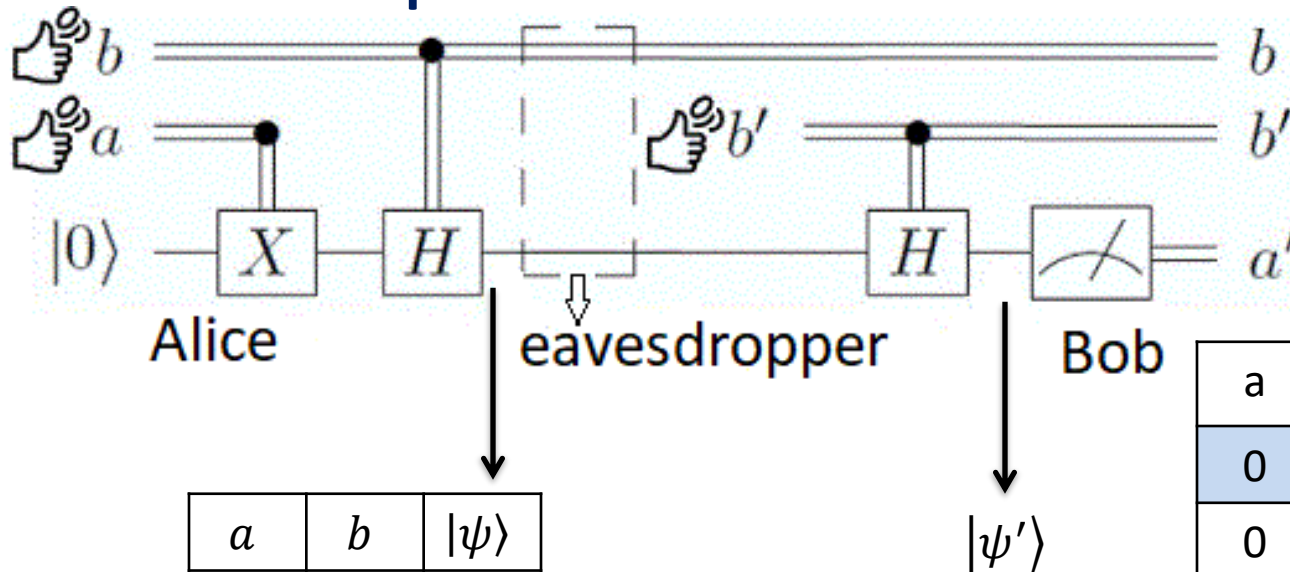


5.3 Teleportation protocol



<https://att-innovate.github.io/squanch/demos/quantum-teleportation.html>

5.4 BB84 protocol



a	b	$ \psi\rangle$
0	0	$ 0\rangle$
0	1	$ +\rangle$
1	0	$ 1\rangle$
1	1	$ -\rangle$

a	b	b'	$ \psi'\rangle$	a'
0	0	0	$ 0\rangle$	0
0	0	1	$ +\rangle$	0 sau 1
0	1	0	$ +\rangle$	0 sau 1
0	1	1	$ 0\rangle$	0
1	0	0	$ 1\rangle$	1
1	0	1	$ -\rangle$	0 sau 1
1	1	0	$ -\rangle$	0 sau 1
1	1	1	$ 1\rangle$	1

Quantum key distribution I: BB84 protocol
https://www.youtube.com/watch?v=u_K9jPBrOwA