

Surface Code Quantum Computation (WS 18/19)

Start:

Tuesday, **09.10.2017 at 12.30 in room 25.32.03.51**

(Lecture time and day can be discussed/shifted if necessary)

Summary:

This lecture covers advanced concepts in Quantum Information Theory. Previous attendance of the lecture “Theoretical Quantum Optics and Quantum Information” is helpful but not mandatory. The lecture starts with general concepts of quantum computation and continues with basic concepts of (quantum) error correction. We will introduce the stabilizer formalism and discuss the toric code as well as more general surface codes. In the last part, we describe universal quantum computation with the surface code. We will explain how to implement a universal set of quantum gates, as well as how to initialize and how to measure in a surface code computation. Finally, we introduce the concept fault tolerance and how this could be achieved in a surface code computation.

Lectures: Tuesdays
12.30-14.30, room: 25.32.03.51
and (sometimes) Thursdays,
12:30-14:30, room: 25.32.02.51

Exercises: Thursdays (after announcement),
12.30-14.30, room: 25.32.02.51

Further information: www.tp3.hhu.de/lehre.html

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Content:

1. Concepts of Quantum Computation
2. Quantum Error Correction
 - a. Basic concepts:
 - i. Encoding/decoding
 - ii. Logical qubits and logical operations
 - b. The repetition code, Shor code
 - c. Stabilizer codes
 - d. Topological codes:
 - i. Toric code
 - ii. General surface codes
3. Surface code quantum computation
 - a. Logical qubits in the surface code array
 - i. Initialization
 - ii. Measurement
 - b. Universal set quantum gates
 - i. Pauli gates
 - ii. CNOT gate
 - iii. Hadamard gate
 - iv. T gate
 - c. Fault tolerant quantum computation

Literature:

- M.A. Nielsen, I.L. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press (2000).
- D. Bruß and G. Leuchs, *Lectures on Quantum Information*, Wiley-VCH (2007).
- J.K. Pachos, *Introduction to Topological Quantum Computation*, Cambridge University Press (2012).
- D.A. Lidar, T.A. Brun (Editors), *Quantum Error Correction*, Cambridge University Press (2013).
- A.G. Fowler, M. Mariantoni, J.M. Martinis, A.N. Cleland, "Surface codes: Towards practical large-scale quantum computation", *Phys. Rev. A* 86, 032324 (2012).
- S. Vijay, T.H. Hsieh, L. Fu, "Majorana Fermion Surface Code for Universal Quantum Computation", *arXiv:1504.01724*.
- C. Nayak, S.H. Simon, M. Freedman, S.D. Sarna, "Non-Abelian anyons and topological quantum computation", *Rev. Mod. Phys.* 80, 1083 (2008).