Study materials for Quantum Hardware II – Spring 2023

Note: The exam will focus on the concepts and their experimental realization. The detailed history of who reported what and when is not part of the exam material. We also won't ask you to reproduce mathematical derivations.

DiVincenzo criteria

D.P. DiVincenzo, *The physical implementation of quantum computation,* Fortschritte der Physik, 48, 771 (2000). See also https://arxiv.org/pdf/quant-ph/0002077.pdf

Spin qubits in quantum dots

- Vandersypen and Eriksson, *Quantum computing with semiconductor spins,* Physics Today 2019

  Summarizes the main ideas, all part of the exam material.

- Hanson et al, *Spins in few-electron quantum dots,* Rev Mod Phys 2007

  Long review article. The important concepts are explained in more detail than in the Physics Today paper. Please refer to the following sections.

  IIA, IIB
  VI.A, VI.B
  VII.A.1, VII.A.3, VII.B.1, VII.B.2
  VIII.B, VIII.C
  IX.A, IX.B

Spin qubits in defect centers ("vacancy qubits")

Awschalom et al. *Quantum technologies with optically interfaced solid-state spins*, Nature Photonics 12, 516 (2018).

Overview of main control techniques for the most relevant optically-active spin qubit platforms. All part of exam material.

Quantum networks based on color centers in diamond
Maximilian Ruf, Noel H. Wan, Hyeongrak Choi, Dirk Englund, Ronald Hanson
Journal of Applied Physics **130,** 070901 (2021)

Forward-looking article on quantum network nodes and their spin-photon requirements, including scalability challenges. All part of exam material.

Superconducting qubits

- P. Krantz et al, *A quantum engineer's guide to superconducting qubits*, https://arxiv.org/abs/1904.06560 (TU Delft doesn't provide access to the journal publication in Applied Physics Reviews 6, 021318, 2019]

  Please refer to the main concepts explained in the following sections
  II.A
  II.B.1
  II.C.1
  III.C,E
  IV.D.1-2, IV.E, IV.F (but not IV.E.1-3), IV.G.1
  V.A

  Note that sections III.A,B,D give an excellent summary of noise and decoherence in general, and as such is useful reading for any type of qubit implementation.

Ion-based quantum computing

H. Häffner, C.F. Roos, R. Blatt, Quantum computing with trapped ions, Physics Reports 469 155–203 (2008).

Please refer to the main concepts explained in the following sections:
2.1, 2.3, 2.4, 2.5 (but not 2.5.1), 2.6.1, 2.6.2, 2.7 (but not 2.7.1-3), 3.1.1, 3.1.2, 3.2 (1st paragraph), 7, 8

QKD, quantum networks and repeaters

Quantum internet: A vision for the road ahead
S Wehner, D Elkouss, R Hanson
Science **362** (6412), eaam9288 (2018)

Introduces stages of development towards Quantum Internet, connecting experimental capabilities to network functionality and applications. General concepts are exam material, but it is not expected that you know the precise definition of each network stage and the respective applications.

Quantum repeaters: From quantum networks to the quantum internet
Koji Azuma, Sophia E. Economou, David Elkouss, Paul Hilaire, Liang Jiang, Hoi-Kwong Lo, Ilan Tzitrin
https://arxiv.org/abs/2212.10820

Comprehensive review that covers the basics of extending distance for QKD, repeaters and in the final part also has an up-to-date overview of experimental status. Exam material, but not all different versions of (MDI-)QKD and Twin-field need to be known; the main concepts and their experimental challenges are important.

Adiabatic quantum computing

Philipp Hauke et al, *Perspectives of quantum annealing: methods and implementations,* Rep. Prog. Phys. 83, 054401, 2020

Refer to pages 1-7 and section 4.1

T. Albash and D.A. Lidar, *Adiabatic quantum computation*, Rev. Mod. Phys. 90, 015002, 2018

Much too detailed for this course but you can read here about Grover's algorithm and adiabatic quantum computing.