Lecture

Quantum Systems for Information Technology (QSIT)

spring term (FS) 2015

Lectures & Exercises:

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What is this lecture about?

Quantum Physics and its Applications in Information Processing

Questions:

- How can one use quantum physics to process information and to communicate more efficiently than using classical physics only?
- How does one build physical systems for this purpose?

Is it really interesting?

Even fashion models talk about it!

You do not believe it?

Watch this!

Goals of the Lecture

- understand how quantum physics is used for
  - quantum information processing (QIP)
  - quantum communication (QC)

- know basic features of important quantum algorithms
  - prime number factorization (Shor algorithm)
  - searching in a database (Grover algorithm)
  - simulating quantum systems (Feynman)

- explain protocols for quantum communication
  - efficient information transfer (quantum dense coding)
  - transfer of unknown quantum information (teleportation)
  - secure communication (quantum cryptography)

Goals of the Lecture (continued)

- convey basic concepts of QIP
  - representation of information in qu(antum)bits
  - manipulation and read-out of information stored in qubits

- discuss physical systems used for QIP
  - including photons, atoms, spins, solid state quantum systems
  - know characteristic energy scales and operating conditions
  - know criteria to evaluate suitability of physical systems for QIP

- explore basic experimental techniques to realize and characterize quantum systems
  - realization of quantum devices/systems
  - experimental setups
  - general measurement and characterization techniques

Skills and Competencies to be Developed

- You
  - are able to apply quantum mechanics in different physical contexts relevant for QIP: atomic physics, solid state physics, optical physics, nuclear physics
  - know basic concepts for performing QIP experiments in different physical systems
  - can use your knowledge of QIP concepts to understand research in areas not discussed in the lecture
  - are able to judge the state of the art and relative progress in different technologies for QIP
  - are able to critically evaluate prospects of practical use of quantum mechanics for information processing and other quantum technologies
  - acquire a basis to decide if you want to work in this field of research
  - come up with your own idea of how to do an interesting QIP project

These skills seem to be quite relevant, even in talk shows.

Watch Conan O'Brien and Jim Carrey on the 'Late Night' show.

Tell us about yourself!

- Who are you?
  - (What is your name?)
  - Which degree program are you in?
  - Do you attend / have you attended Quantum Physics (Exp/Theo) or Quantum Information (Exp/Theo) classes?
  - Where are you from (prior university)?

Basic Structure of QSIT course

Part I: Introduction to Quantum Information Processing (QIP)

- basic concepts: qubits, gate operations, measurement
- circuit model of quantum computation
- examples of quantum algorithms

Part II: Superconducting Quantum Electronic Circuits for QIP

- qubit realizations, characterization, coherence
- physical realization of qubit control, qubit/qubit interactions and read-out
- interfacing qubits and photons: cavity quantum electrodynamics
- realizations of algorithms and protocols

Part III: Physical Implementations for QIP

- photons in linear optics
- ions and neutral cold atoms
- electrons and spins in semiconductor quantum dots
- spins in nuclear magnetic resonance

Guest Lectures

- Mesoscopic Physics for Quantum Information Processing (Sorin Paraoanu, Aalto University, Finland)

... potentially additional guest lectures on other topics

Student Presentations

- Topics: implementations of quantum information processing
- Goal: present key features of implementation and judge its prospects
- Material: research papers and review articles
- Preparation: teams of two students, ~ 10-20 slots for teams available, advice and support by TAs
- Duration: presentation + discussion (30+15 minutes)
- Presentation: blackboard, transparencies, PowerPoint …
- feedback on both content and presentation of your talk

Competencies to be Developed for Presentations

- You
  - can interpret current research results in quantum information science
  - know how to extract relevant information from scientific papers, possibly neglecting details
  - have the skill to document your understanding of a scientific topic in an aural presentation
  - are able to summarize the scientific content of a paper in short written form (abstract)
  - collaborate effectively with a fellow students (taking into account the different backgrounds) on joint projects

Exercise Classes

- part I & II (week 1 - 7)
  - discuss and practice topics of lecture

- part III (week 8 - 12)
  - student presentations

- teaching assistants:
  - Abdufarrukh Abdumalikov (abdumalikov@phys.ethz.ch)
  - Philipp Kurpiers (philipp.kurpiers@phys.ethz.ch)
  - Tobias Thiele (tobias.thiele@phys.ethz.ch)

Reading

- Quantum computation and quantum information
  Michael A. Nielsen & Isaac L. Chuang
  Cambridge : Cambridge University Press, 2000
  676 S.
  ISBN 0-521-63235-8

- additional reading material will be provided throughout the lecture and on the web page: www.qudev.ethz.ch

Credit Requirements

- active contribution to lectures and exercises
- prepare and present a high quality talk on one of the physical implementations of quantum information processing

Exam & Credits

- aural exam (20 mins) during summer or winter exam session
- exam dates as required by your program of study
- 8 credit points (KP) can be earned successfully completing this class
- content of exam:
  - see goals of lecture
  - good presentation and active contribution to lecture will be a bonus

Time and Place

- lecture: Friday (13-15), 12:45 – 14:30, HIT F 13
- exercises: Friday (15-17), 14:45 – 16:30, HIT F 13
- are there timing conflicts with other lectures?

Registration & Contact Information

your registration and contact information

- please register online for the class
- in this way we can contact you

contact information

- qsit-lecture@phys.etzh.ch
- www.qudev.ethz.ch (will be updated constantly)

Let's get started!