Lecture

Quantum Systems for Information Technology

fall term (HS) 2011

Lecturers:

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What is this lecture about?

Quantum Mechanics and its Applications in Information Processing

Questions:

- How can one use quantum physics to process information or to communicate?
- What kind of problems can be solved more efficiently using the ideas of quantum information processing?
- How does one build systems to process information quantum mechanically?

Is it really interesting?

Even fashion models talk about it!

You do not believe it?

Watch this!

Tell us about yourself!

- Who are you?
  - What is your name? Where are you from?
  - Which degree program are you in?
  - Have you attended Quantum Physics (Exp/Theo) or Quantum Information (Exp/Theo) classes before?

- Present your thoughts on the question:

  How could quantum physics potentially be useful in information technology?

- What are your expectations about the lecture?
  - What would you like to learn in the lecture?

Goals of the Lecture

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

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

- know basic examples of quantum communication
  - efficient information transfer (quantum dense coding)
  - transfer of unknown quantum information (teleportation)
  - secure communication (quantum cryptography)

Goals of the Lecture (continued)

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

- be knowledgeable about physical systems used for QIP
  - e.g. spins, atoms, solid state quantum systems
  - know characteristic energy scales and operating conditions
  - know criteria to evaluate suitability of physical systems for QIP

- know basic experimental techniques used to realize and characterize quantum systems
  - fabrication of quantum devices
  - experimental setups
  - general measurement and characterization techniques

Skills and Competencies to be Developed

- You
  - are able explore the use of quantum mechanics in different physical contexts: atomic physics, solid state physics, optical physics, nuclear physics
  - know basics concepts of how quantum information experiments are performed 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 quantum information processing
  - 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.

Basic Structure of Course

- Part I: Introduction to Quantum Information Processing (QIP)
  - basic concepts
  - qubits, qubit control, measurement, gate operations
  - 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
- Part III: QIP Implementations (Lectures and Student Presentations)
  - electrons and spins in semiconductor quantum dots
  - ions and neutral cold atoms
  - photons and linear optics
  - spins in nuclear magnetic resonance

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 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

Skills and Competencies to be Developed

- 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
  - collaborate effectively with a fellow students (taking into account the different backgrounds) on joint projects

Exercise Classes

- part I & II (week 2 - 8)
  - discuss and practice topics of lecture
- part III (week 9 - 13)
  - student presentations
- teaching assistant:
  - Arkady Fedorov (fedoroar@phys.ethz.ch)

Guest Lecture

topic:

- Ion Trap Quantum Computing (Jonathan Home, ETHZ)

... potentially additional guest lectures on one or two additional topics

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:
  qudev.ethz.ch/content/courses/coursesmain.html

Credit (Testat) Requirements

- active contribution to lectures and exercises
- successfully prepare and present a 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: Monday (15-17), 14:45 – 16:30, HCI H 2.1
- exercises: Monday (11-13), 10:45 – 12:30, HCI H 8.1

- are there timing conflicts with other lectures?
  - Quantum Field Theory (ends 15:45), Irchel [Sidler]

- potential alternative time slots:
  - TBD

Registration & Contact Information

your registration and contact information

- please register online for the class

- in this way we can contact you

our contact information

- qsit-lecture@phys.etzh.ch
- www.qudev.ethz.ch/content/courses/coursesmain.html
  (will be updated constantly)

Let’s get started!