

*Lecture*

# ***Quantum Systems for Information Technology (QSIT)***

*spring term (FS) 2014*

*Lectures & Exercises:*  
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# *What is this lecture about?*

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Quantum Mechanics 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?*

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Even fashion models talk about it!

You do not believe it?

Watch this!

# 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 protocols
  - 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 to 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

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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!***

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



# ***Basic Structure of course QSIT Experiment***

## **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

## **Part III: Physical Implementations for QIP**

- electrons and spins in semiconductor quantum dots
- ions and neutral cold atoms
- photons in 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, ~ 10-20 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

# *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 1 - 7)
  - discuss and practice topics of lecture
- part III (week 8 - 12)
  - student presentations
- teaching assistants:
  - Christopher Eichler ([christopher.eichler@phys.ethz.ch](mailto:christopher.eichler@phys.ethz.ch))
  - Tobias Thiele ([tobias.thiele@phys.ethz.ch](mailto: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](http://www.qudev.ethz.ch)

# ***Credit Requirements***

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- 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

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- 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***

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- lecture: Friday (13-15), 12:45 – 14:30, HIT F 13
- exercises: Friday (15-17), 14:45 – 16:30, HIT F 13
  
- alt. time: lecture: Friday (14-16), 13:45 – 15:30, HIT F 13  
exercises: Friday (11-13), 10:45 – 12:30, HIT J ??
- are there timing conflicts with other lectures?



# ***Registration & Contact Information***

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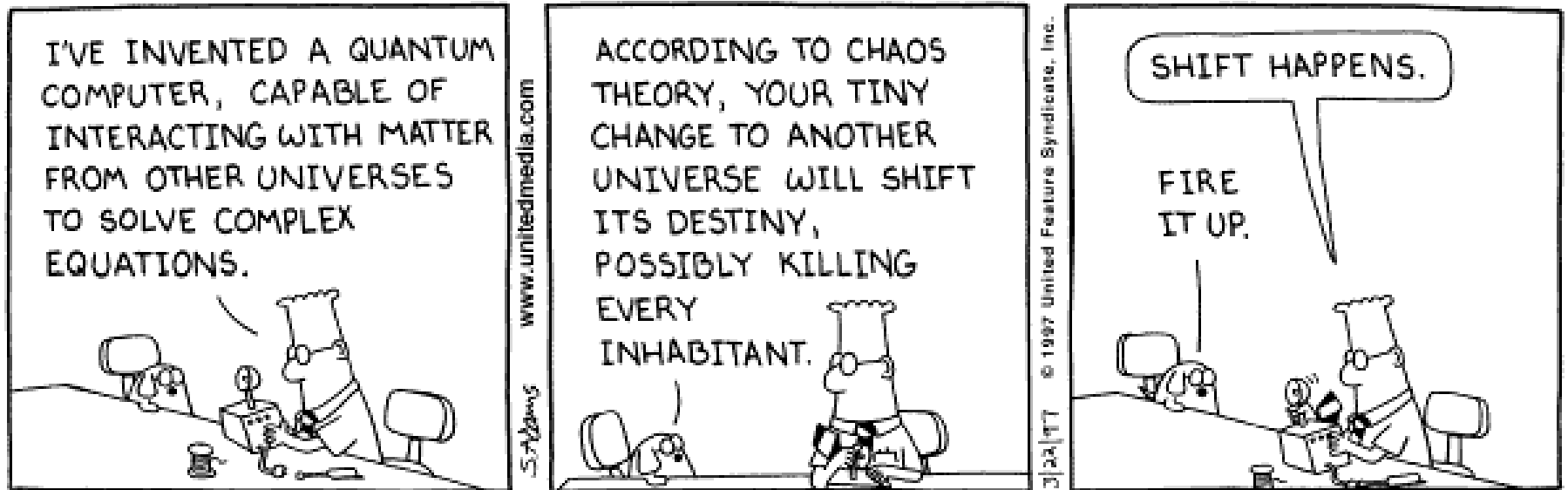
## **your registration and contact information**

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

## **contact information**

- [qsit-lecture@phys.ethz.ch](mailto:qsit-lecture@phys.ethz.ch)
- [www.qudev.ethz.ch](http://www.qudev.ethz.ch) (will be updated constantly)

# Let's get started!



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