Introduction to Reversible and Quantum Computing (03-IMAT-IRQ)

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WINTER SEMESTER 2024-2025

Contact Persons

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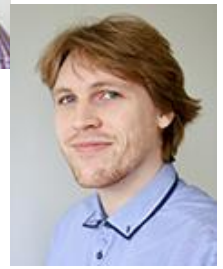
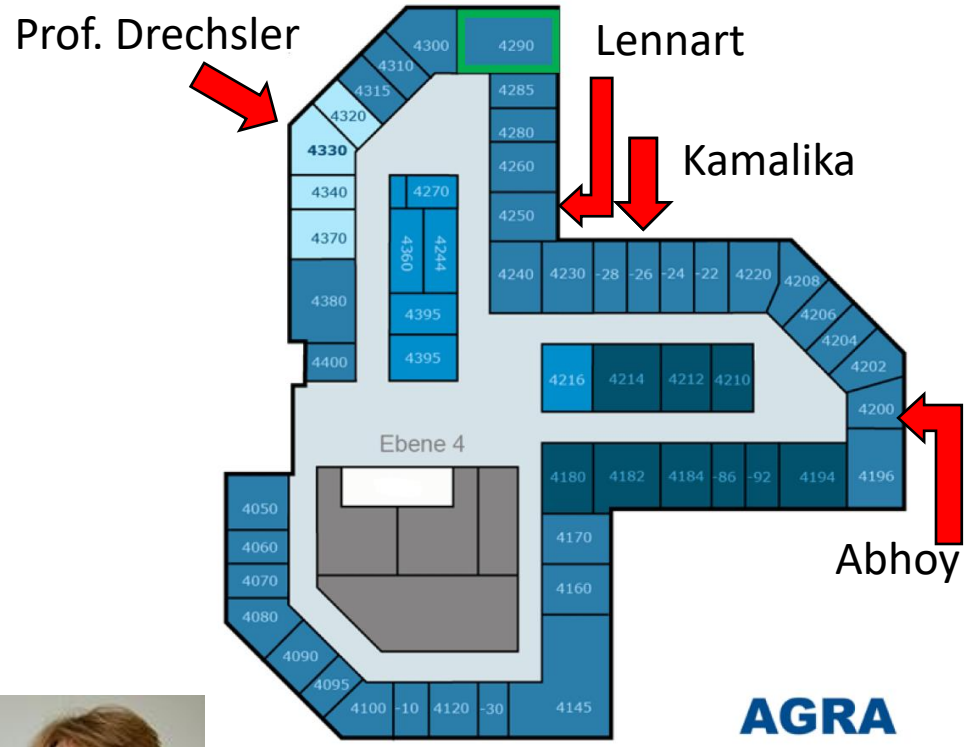




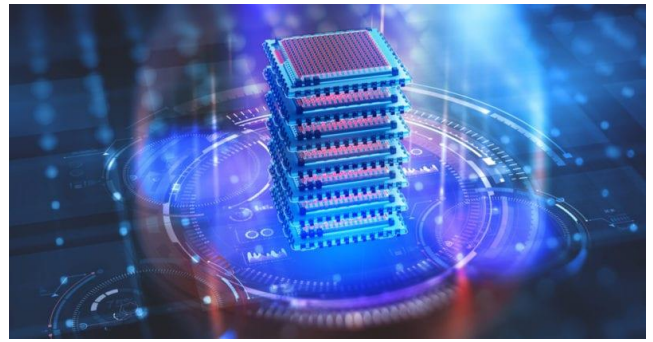
Organisation

- **Lectures**
  - Monday: 10:00 – 12:00, weekly (from 14.10.24)
  - Location: MZH 5500
  - Language: English

- **Tutorials**
  - Tuesday: 08:00 - 10:00,
  - Location: MZH 5500
  - Language: English

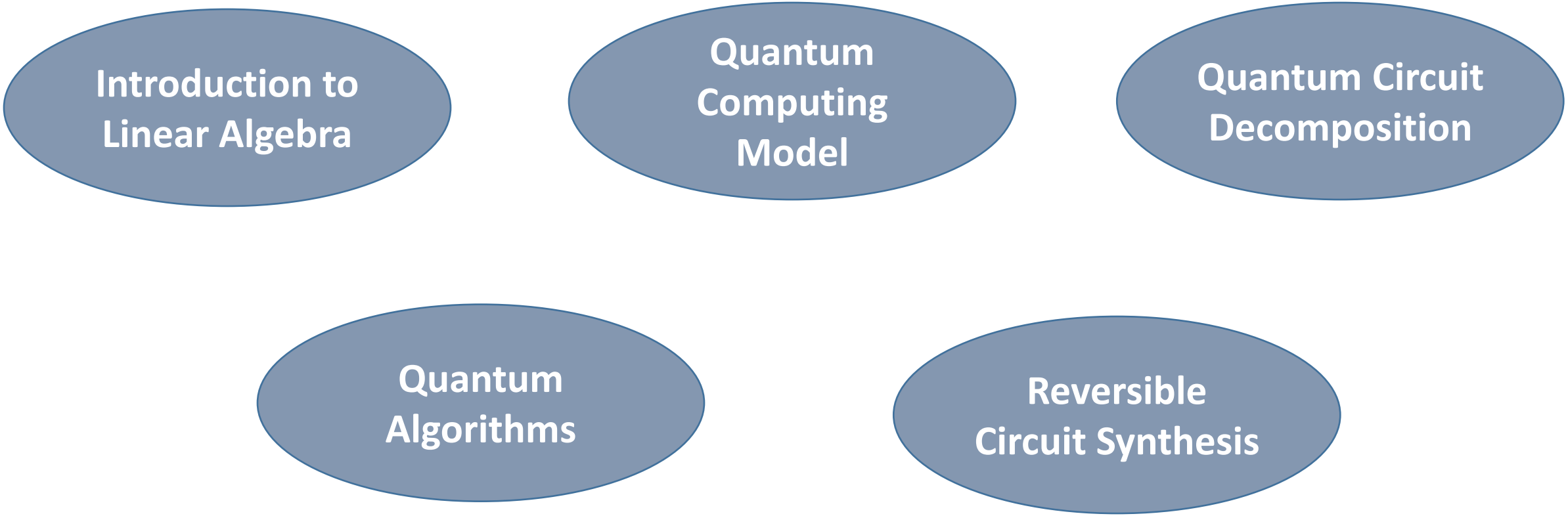
- **Website**
  - http://www.informatik.uni-bremen.de/agra
    - Lehre -> Lehrmaterial ->
  - Slides and exercises in Stud.IP (https://elearning.uni-bremen.de/)

Course Objective



- Fundamentals of quantum computing
- To analyze quantum gates and quantum Circuits
- Synthesis and optimization of reversible circuits
- Design and analysis of the quantum algorithms

Introduction to the course



Schedule

Sr.	Lecture	Topics	Tutorials
0	Course organisation	General info	-
1	Preliminaries of Quantum Computing	• Introduction to the course • Complex numbers • Complex Vector Space • Transpose, Complex Conjugate, Adjoint	
2	Preliminaries of Quantum Computing	• Basis and dimension • Bra-ket formalism • Inner product, Outer product, • Hilbert space, Eigen Value and Eigen Vector • Hermitian, Unitary and normal matrices • Tensor product	
3	Quantum Computing Basics	• Quantum Circuit Model • Bit, Qubit, Quantum Gates • Pauli gate, Hadamard gate, two-qubit controlled gate	
4	Quantum Computing Basics	• Quantum state transformation • Quantum gate evaluation • Entanglement	

Merge the topics to fit in 14 lectures

Schedule

Sr.	Lecture	Topics	Tutorials
5	Quantum Computing Basics	• Quantum Entanglement • No-Cloning Theorem • Quantum Teleportation	
6	Reversible Circuit : Introduction	• Introduction to Reversible Computing • Reversible function representation • Non-reversible to reversible function transformation • Reversible Circuit design	
7	Reversible Circuit : Synthesis and Optimization	• Transformation based synthesis method • Exclusive-Or-Sum-of-the-Product (ESOP) based • synthesis • Various optimization method	
8	Quantum Computing Advance	• Quantum circuit compilation • General and Special Unitary operation • Construction of Unitary operations	

Merge the topics to fit in 14 lectures

Schedule

Sr.	Lecture	Topics	Tutorials
9	Quantum Computing Advance	• Construction of Unitary operations • Pseudo Boolean expression • Clean and dirty ancilla based decomposition	
10	Quantum System Evolution	• Evolution of Quantum System • Measurement Postulates: Projective measurement and POVM • Expectation value	
11	Quantum System Evolution	• Unitary evolution of closed systems • Density operator of pure mix state • Density matrix representation	
12	Quantum Algorithm	• Superdense coding, quantum parallelism • Introduction to Quantum algorithm, Deutsch-Jozsa • algorithm, Bernstein Vazirani algorithm	

Merge the topics to fit in 14 lectures

Schedule

Sr.	Lecture	Topics	Tutorials
13	Quantum Algorithm	• Grover's search algorithm • Amplitude amplification • Oracle for searching	

14	Quantum Computing Application	• Design of Quantum SAT solver
		  • Circuit synthesis
		  • Oracle
		  • Applying Grover's search	

15	Quantum Computing Application	• Exploring Optimization Problem	

Merge the topics to fit in 14 lectures

Assignment Dates

Sl. No	Assignment Date	Submission Date
1	22nd October 2024	6th November 2024
2	5th November 2024	20th November 2024
3	19th November 2024	4th December 2024
4	3rd December 2024	22nd December 2024
Mini-Project	13th November 2024	
Mid. Evaluation	Implementation Discussion	7th January 2025
Final Evaluation	Report & Presentation	28th January 2025

All Assignments and Mini-project are mandatory

Examination Rules

- Technical discussion
  - Successful completion of the assignments required (All assignments including Mini-project is mandatory)
    - Min. 50% is considered successful per exercise sheet
  - Oral examination, in group/individual, 20-30 min
  - Includes lecture, assignment and project
- Module examination
  - Oral exam, individually, 30-40 min
  - Includes lecture, assignment and project
- Language
  - English

Examination Dates

- **February 4, 2025: 11:00 to 14:00**
- **February 5, 2025: 11:00 to 14:00**

Literature / Reference Books

- Towards a Design Flow for Reversible Logic, Robert Wille, Rolf Drechsler, Springer Publishing, 2010
- Quantum computing for computer scientists, Mirco A. Mannucci and Noson S. Yanofsky, Cambridge University Press, 2008.
- Quantum computing explained, David McMahon, Wiley-interscience, John Wiley Sons, Inc. Publication 2008.
- Quantum computation and quantum information, Michael A. Nielsen and Isaac L. Chuang, Cambridge University Press 2010.
- Introduction to Quantum Mechanics, 2nd Edition, David J. Griffiths, Prentice Hall New Jersey 1995.
- Quantum Computer Science, Marco Lanzagorta, Jeffrey Uhlmann, Springer Publishing, 2008
- An Introduction to Quantum Computing Phillip Kaye, Raymond Laflamme, Michele Mosca.