Quantum Information Science Comprehensive Lecture Note

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From Classical to Quantum Information

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- 2.2 Quantum State Representation
- 2.2.1 State Vectors and Ket Notation
- 2.2.2 Density Matrices
- 2.2.3 Pure vs Mixed States
- 2.2.4 Bloch Sphere Representation
- 2.3 Quantum Operations
- 2.3.1 Unitary Operators
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10.2.1	Mach-Zehnder Interferometer
10.2.2	SU(1,1) Interferometer
10.2.3	NOON States
10.2.4	Phase Estimation Protocols
10.3	Squeezed State Sensing
10.3.1	Quadrature Squeezing
10.3.2	Spin Squeezing
10.3.3	Two-Mode Squeezing
10.3.4	Applications in Interferometry
10.4	Quantum Imaging
10.4.1	Ghost Imaging
10.4.2	Quantum Illumination
10.4.3	Sub-Wavelength Imaging

10.4.4 Quantum Microscopy

10.5

Specific Sensing Applications

Quantum Error Correction

- 11.1.1 Pauli Error Models
- 11.1.2 Syndrome Measurements
- 11.1.3 Error Detection vs Correction
- 11.1.4 Fault-Tolerant Syndrome Extraction
- 11.2 Stabilizer Codes
- 11.2.1 Stabilizer Formalism
- 11.2.2 Encoding and Decoding
- 11.2.3 Logical Operations
- 11.2.4 Code Distance and Rate
- 11.3 Specific Code Families
- 11.3.1 CSS Codes
- 11.3.2 Surface Codes
- 11.3.3 Color Codes
- 11.3.4 Quantum LDPC Codes
- 11.4 Topological Codes
- 11.4.1 Toric Code
- 11.4.2 Planar Codes
- 11.4.3 Anyonic Excitations
- 11.4.4 Topological Protection
- 11.5 Fault-Tolerant Computing

Quantum Hardware Platforms

12.1	Superconducting Qubits
12.1.1	Josephson Junctions
12.1.2	Transmon Qubits
12.1.3	Flux Qubits
12.1.4	Control and Readout
12.2	Trapped Ion Systems
12.2.1	Ion Trapping Techniques
12.2.2	Laser Cooling
12.2.3	Gate Implementation
12.2.4	Ion Shuttling
12.3	Photonic Quantum Computing
12.3.1	Linear Optical Quantum Computing
12.3.2	Measurement-Based Computing
12.3.3	Integrated Photonics
12.3.4	Photonic Interconnects
12.4	Neutral Atom Platforms
12.4.1	Optical Lattices
12.4.2	Rydberg Atoms

Optical Tweezers

Many-Body Physics

Solid-State Platforms

12.4.3

12.4.4

12.5

13.4.3 Path Selection

13.5

13.4.4 Network Coding

Quantum Networks and Internet

13.1	Quantum Network Architecture
13.1.1	Network Topologies
13.1.2	Quantum Repeaters
13.1.3	Quantum Routers
13.1.4	End-to-End Connectivity
13.2	Physical Layer
13.2.1	Quantum Channels (Fiber, Free-Space)
13.2.2	Wavelength Division Multiplexing
13.2.3	Mode Conversion
13.2.4	Quantum Transduction
13.3	Link Layer Protocols
13.3.1	Entanglement Generation
13.3.2	Link-Level Error Correction
13.3.3	Entanglement Purification
13.3.4	Multiplexing Strategies
13.4	Network Layer Functions
13.4.1	Routing Protocols
13.4.2	Entanglement Swapping

Application Layer Services