

Course Syllabus: Building Quantum Computers

Master in Quantum Computing

Semester 2

University of Setif 1

1. Overview of Current Technologies

- Two-level systems.
- Bloch Sphere from an Experimental Point of View.
- DiVincenzo's Criteria.

2. Superconducting Qubits

- **Introduction to Superconductivity:** Cooper Pairs.
- **Josephson Junctions:** Introduction; Quantum tunneling and Josephson Tunneling; Josephson Energy and Washboard Potential; SQUID.
- **Superconducting Qubits:**
 - LC Oscillator, Anharmonic Oscillators and The Josephson Junction.
 - Cooper Pair Box – Artificial Atom: Josephson junction as a two-level system.
 - Transmon qubit: fundamentals (e.g., resonant frequency, anharmonicity).
 - Circuit QED, Jaynes-Cummings model, Vacuum-Field Rabi Oscillations, Dispersive Model, Qubit Readout.
- **Sources of Decoherence**
- **Other Qubits:** Charge, Phase, and Flux Qubits.
- **Quantum Gates:** Circuit Quantum Electrodynamics (QED), CNOT Gate Using Charge Qubits.

3. Atomic Qubits

- Relevant Structure of Atoms.
- Trapping and Cooling Atoms and Ions.
- Ion trap Quantum Gates.
- Sources of Decoherence.

4. Spin Qubits

- Spin in an External Magnetic Field.
- Spin Qubits in Silicon.
- Spin Qubits in Diamond NV Centers.
- Sources of Decoherence.

5. Photonic Qubits

- Basic Optical Components and Single Photon Sources.
- Polarization, Optical Angular Mode Encoded Qubits.
- Entangled Photons and Manipulations and Cluster States.
- Sources of Decoherence.

Evaluation

- Final exam: 60%
- Personal work: 40%