PHY 631 Quantum Information Physical Systems and Materials
Spring 2024 (1-3 credits)

Instructor: Prof. Qiang Li
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Meeting Time and Place:	**Thursday 2:30 – 5:20 pm, Physics B131**
Office Hour:	**Wednesday 5:20 - 6:20pm, Physics B143**
Grades:	**Homework 50%, Participation 20%, Final presentation 30%**
Required Textbooks:	**None. The instructor's lecture notes provided when available**
Recommended:	**Quantum Computation and Quantum Information, M. Nielsen and I. Chuang (Cambridge University Press) and Review articles**

Course Description:

This course will cover various physical systems and materials currently used for quantum information processing. It is divided into a few modules, including quantum computers based on superconducting qubits, solid-state spins, photons, trapped ions, and topologically protected states, and also including quantum communications and networks. The course aims to bridge the gap between the physical principles and the state-of-the-art and future quantum information technologies.

This course has an emphasis on how to build and perform various quantum information experiments, as well as how to characterize materials used in quantum information systems. Experts in the field of quantum information science and technology may be invited for guest lectures on some topics. Programming on publicly available quantum computers is demonstrated in real time and visits to quantum information laboratories are planned. Lab skills (at undergraduate senior lab level) and general knowledge of quantum information science can be helpful, but not required.

Topics/Syllabus:

1) Introduction to quantum information science and technology (QIST), current status and challenges for quantum computing and communication hardware
2) Quantum computing basics: qubits, quantum process tomography, quantum memory, quantum gates, error-corrections
3) Superconducting materials and properties relevant to QIST, Josephson junction, microwave cavities, measurements of coherence time and loss tangents

4) Superconducting circuits and qubit processor, Rabi oscillations, low temperature experimental methods, dilution refrigerators

5) Programing on quantum computer

6) Semiconductor quantum dot qubits and characterizations

7) Tools and experiments to characterize noise and defects in quantum materials

8) Photoluminescence and color centers in diamond

9) Cooling and trapping of atoms, trapped ion processors

10) Topologically protected systems and qubit, Majorana fermions, integer and fractional quantum Hall effect, chiral qubits and transductions

11) Topological superconductivity, semiconductor/semimetal-superconductor hybrid systems, experimental probes to topological states

12) Spins in quantum materials and characterizations, spin-orbit coupling, spin chain, quantum spin liquid, quantum magnets

13) Light matter interaction, nonlinear electro-optic effect, second harmonic and sum frequency generation

14) Single-photon source and photonic qubit experiments

15) Cavity quantum electrodynamics experiments

16) Quantum network and distributed quantum computing, quantum transduction, acoustic-optical modulators

17) Quantum communications, cryptography, teleportation, repeaters

18) Quantum applications in sensing, imaging, metrology, and simulations

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