Engineering quantum matter in AMO systems

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Office Hours	KH: Wed 12-2p or by appointment. Can change to fit student schedules	**Classroom & time**	TBA & TBA

Learning outcomes:

Students will be able to

1. Explain the characteristic energy, length, and timescales in ultracold experiments.
2. Describe goals of the field, especially quantum simulation, quantum sensing, and quantum technology.
3. Define and mathematically model major tools for engineering and probing modern many-body cold atoms systems, and describe many of the field's major accomplishments.
4. Create effective oral and written presentations explaining these results at a level appropriate to other graduate students.

Topics covered will be chosen by the class. A (non-exhaustive) list of potential topics:

- Techniques for cooling atoms. Laser cooling and evaporative cooling.
- Bose-Einstein condensation. Thermodynamics, superfluidity, and vortices.
- Degenerate and superfluid Fermi gases. Feshbach resonance, BEC-BCS crossover.
- Optical lattices. Bose-Hubbard: Mott insulator/superfluid transition for bosons. Fermi-Hubbard: Mott insulator, antiferromagnetism, and superconductivity.
- Experimental methods to probe many-body ultracold systems: time-of-flight measurements, collective modes, RF spectroscopy, momentum-resolved RF spectroscopy, Bragg spectroscopy, lattice modulation spectroscopy
- Artificial gauge fields and spin-orbit coupling. Topological insulators. Fractional Quantum Hall.
- Low-dimensional (1D, 2D) systems
- Nonequilibrium dynamics, thermalization, and many-body localization.
- Ultracold molecules: creating, describing, and applications
- Rydberg atoms: creating, describing, and applications
- Trapped ions (not ultracold, but similar enough in spirit that it's a possible topic)
- Quantum metrology: squeezing, GHZ, Fisher information, …
- Quantum computation implementations.
- Other topics available, and students may choose their own projects

Course credit: 3 credits

Text:

There is no required text. References will be provided for specific topics we decide to cover. A good general book for background is *Pethick and Smith, Bose-Einstein Condensation in Dilute Gases.*

Coursework and evaluation:

The course assignments are two-fold: students taking the lead on 1-2 topics and (1) prepare and deliver 2-3 lectures to explain them and (2) provide a short (2-4 page) written summary of the topic, together with exemplary "homework questions" on the topic that would guide a beginner to understanding it. The exact number of topics and lectures will depend on the breadth of the topics chosen.

Students will meet multiple times with KH 1-on-1 with draft materials and receive feedback prior to giving their lecture to ensure that the material is covered appropriately.

Grades are determined on the speaking and writing assignment with equal weight. Completing these assignments at a level that explain the material at the level outlined in the "learning outcomes" section will result in an A. Students will have multiple rounds of feedback from 1-on-1 meetings to discuss draft versions of the material and ensure that detailed standards are clear.

The Rice Honor Code applies to all of these assignments. Students may work together on the assignments, as long as all discussions and contributions are explicitly acknowledged.

Disability and accommodations:

Any student with a disability requiring accommodations in this class is encouraged to contact the instructor after class. Additionally, students should contact the Disabled Student Services office in the Ley Student Center.