Joseph Thywissen (University of Toronto, Canada): *Optical lattices*

Ultracold neutral atoms in optical lattices add a new chapter to a paradigmatic physics problem: the motion of massive particles in a periodic potential. The mathematics behind this problem have been studied for over a century, with foundational work by F. Bloch, G. Floquet, A. Lyapunov, and E. Mathieu, among others. Textbooks on solid state physics cover the eigenvalue problem in the context of naturally occurring crystal lattice geometries, occupied by electrons as ideal fermions. Similar band structure is also realized by atoms in optical lattices, but at the length scale set by the wavelength of light and at nanokelvin energy scales. The cold-atom scenario offers a choice of particle statistics (bosons as well as fermions), dynamically tunable lattice depth, tunability of atom-atom interaction strength, and both in-situ and time-of-flight probes.

These three lectures are intended as an introduction to this rich physical system. Time permitting, topics covered will include

-how to make an optical lattice
-symmetries of the system
-the formation of bands through Bragg scattering
-Bloch states and quasi-momentum
-the tight-binding limit
-band mapping through time-of-flight imaging
-the Hubbard Model
-response to external forces
-transport and currents

A full set of notes will be provided to students, with details of derivations. Although no systematic attempt is made to capture the state of the art, concepts will be illustrated with examples of experimental data. Several excellent reviews exist in the literature, including Jean Dalibard's 2013 lectures at the Collège de France and the references given below.

A. Eckardt, “Colloquium: Atomic quantum gases in periodically driven optical lattices,” *Rev. Mod. Phys*. **89**, 011004 (2017).

A. Georges and T. Giamarchi, "Strongly correlated bosons and fermions in optical lattices", in *Many-Body Physics with Ultracold Gases: Lecture Notes of the Les Houches Summer School*: **94** (Oxford University Press, 2012)

C. Gross & I. Bloch, “Quantum simulations with ultracold atoms in optical lattices,” *Science* **357**, 995 (2017).

Maciej Lewenstein, Anna Sanpera, and Veronica Ahufinger, *Ultracold Atoms in Optical Lattices: Simulating Quantum Many-body Systems* (Oxford University Press, 2006).