Lecture outlines

Andrew Daley - theory

2 lectures on basic Bose-Hubbard physics. 1 lecture on scattering, pseudopotentials and the microscopic model. 1 research talk.

1) Derivation of the Bose-Hubbard model
- Single particle in a periodic potential, Bloch functions.
- Wannier functions
- Statement and explanation of the second-quantised field operator Hamiltonian
- Simple derivation of the Bose-Hubbard model, with quantitative justification for the various approximations (single-band, nearest neighbour tunnelling, etc.)

2) Introduction to the Basic Physics of the Bose-Hubbard model
- Hopping term in momentum space, relation to tight-binding model, -2J cos(ka) band shape
- Overview of the Phase diagram
- States in limit of large and small U/J
- Introduction of the Single-particle density matrix, long range order, condensate mode
- relationship to momentum distributions.
- Examples of the Superfluid and MI states in 1D, with Single-particle density matrices and off-diagonal behaviour
- Local density approximation and emergence of the layer structure in a Harmonic trap (This should connect to what Simon will present later)

3) Scattering and Pseudopotentials
- Two-Body scattering processes
- Use of the delta-function pseudopotential
- justification of the microscopic second-quantised Hamiltonian (the starting point for the Bose-Hubbard model).

4) Research seminar (topic t.b.d.) e.g. Adiabatic potentials for creating addressible, sub-wavelength lattices. Transport, especially Andreev reflections, but also potentially new ideas to measure currents in lattice systems. Atomic lattice excitons, and the study of excited many-body states on lattices more generally.

Dieter Jaksch - theory

2 lectures on Bose-Hubbard physics (more advanced topics) including time-dependent dynamics, numerical methods, and dissipative processes. 1 lecture on current research.

Simon Fölling

Experiments on atoms in optical lattices at Mainz.

- Illustrate application of BH model with two sites, illustrate SF/MI-transition with two atoms, show effective spin interactions with two atoms. Show the experimental way of doing this.
- look at "real" SF/MI transition, mean field approach, Shell structure, correlation measurements (interactions, molecule formation on one site).

Michael Köhl

1 lecture on fermions in lattices. 1 lecture on one-dimensional gases.

1. Fermi surfaces, Fermi Hubbard model, interacting systems in lattices, idea of quantum simulation, how to measure temperature in a lattice.
2. Bose-Fermi mapping in 1D, Luttinger liquids, Tonks gas, confinement induced molecules in 1D

Christopher Foot

Atoms in a rotating optical lattice. Artificial magnetic fields.