Phases of an Ultracold Gas in a Quasicrystalline Potential

Authors: *Dean Johnstone, Patrik Öhberg & Callum W. Duncan*
Institution: *Heriot-Watt University*
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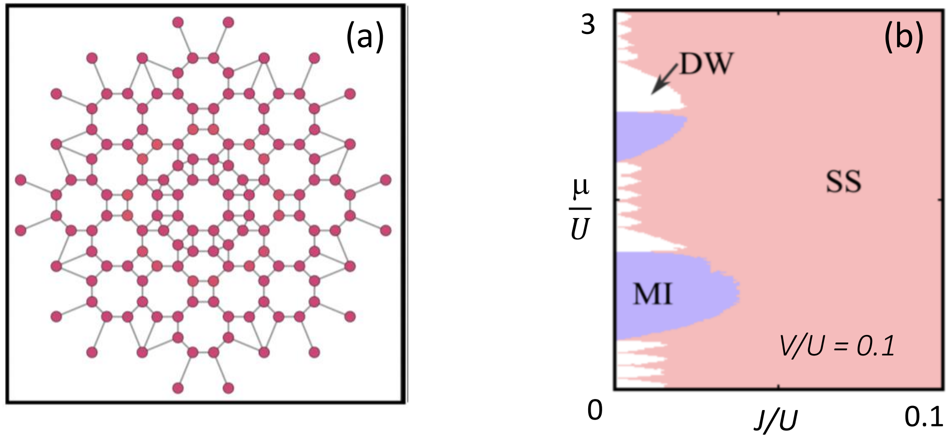
Abstract

Quasicrystals possess long-range order but are not periodic, and are still little studied in comparison to their periodic counterparts. Here, we consider the ground state properties of a bosonic gas in an eight-fold symmetric lattice. We find that the fluctuating coordination number from site-to-site plays an important role in the formation and structure of the quantum phases.



Main results showing the (a) 8-fold lattice and (b) phase diagram of the extended quasicrystalline Bose-Hubbard model. Here, μ is the chemical potential, U is the onsite interaction strength, V is the offsite interaction strength and J is the offsite tunnelling rate.

Project Description

We study the ground state properties of an ultracold gas trapped in a quasicrystalline optical lattice. Such a system can be modelled by a Bose-Hubbard Hamiltonian, which describes a collection of atoms interacting and traversing on a lattice.

To this end, we employ a mean-field ansatz to the wavefunction and work within the grand canonical ensemble. From the ground state, we can then define order parameters to identify different quantum phases. The expected Mott-Insulating (MI) and Supersolid (SS) phases appear as for finite, periodic systems. However, we also find new, exotic Density Wave (DW) states that can spontaneously break the rotational symmetry of the lattice.

Conclusions

- The usual Mott-Insulating, Density Wave and Supersolid phases can be observed in quasicrystalline systems.
- Rotational symmetry of ground states can be broken with extended range interactions.
- Incommensurate nature of lattice gives rise to intermediate Density Wave fillings, unlike that to what is observed in period systems.
- Structurally exotic phases can be found without invoking disorder.

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