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Phase Transitions of an Ultracold Gas in a Quasicrystalline Potential

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The recent experimental advancement to realise ultracold gases scattering off a quasicrystalline optical potential [Phys. Rev. Lett. 122, 110404 (2019)] heralds the beginning of a new technique to study the properties of quasicrystal structures. Quasicrystals possess long-range order but are not periodic, and are still little studied in comparison to their periodic counterparts. Ultracold
atoms are well described by Bose-Hubbard models when loaded into an optical lattice. Here, we consider an ultracold bosonic gas loaded into an eight-fold symmetric optical lattice. We study the ground state phases of the system, with particular interest in the local nature of the phases. We observe the usual Mott-insulator, superfluid, density wave, and supersolid phases of the standard
and extended Bose-Hubbard model. For non-zero long-range interactions we observe density waves that have spontaneously broken the quasicrystal symmetry, and can even possess no rotational symmetry. We find the local variation in the number of nearest neighbours to play a vital role in the phase transitions, local structure, and global symmetries of the ground states. This variation in the number of nearest neighbours is not a unique property of the considered eight-fold optical lattice, and we expect our results to be generalisable to any quasicrystalline potential where there are only small variations in on-site energy.

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