Unconventional Bose-Einstein condensations and exotic orbital physics in high bands of optical lattices (LT26)

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Orbital is a degree of freedom independent of charge and spin, which plays an important role in transition metal oxides. Orbital physics is characterized by orbital degeneracy and spatial anisotropy. The recent progress of cold atom physics has provided another exciting opportunity to investigate orbital physics with both cold bosons and fermions in optical lattices. In this talk, we will present new features of orbital physics in the high orbital bands, which are not usually realized in solid state orbital systems. For bosons, the ferro-orbital interactions lead to a class of novel superfluid states with complex-valued wavefunctions breaking time reversal symmetry. These states are beyond Feynman's celebrated argument of the positive-definitiveness of many-body ground state wavefunctions for bosons. For fermions, the honeycomb lattice with the $p_{x,y}$-orbitals exhibits the flat band structure and the consequential non-perturbative strong correlation effects (e.g. Wigner crystallization) which is distinct from the graphene physics characterized by the p_z-orbital. The orbital exchange physics in the Mott-insulating states exhibits strong frustrations and provides a promising direction to realize the orbital liquid state. In the square and cubic lattice, the anisotropic band structure can stabilize the FFLO pairing phases in high dimensions. The current experimental efforts in realizing such novel states of matter will also been introduced.