One dimensional lattice quantum droplets

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Following the seminal work of Petrov [1] on ultradilute quantum droplets in binary mixtures of ultracold atoms, we extend the ideas to a 1D optical lattice. We demonstrate the existence of quantum droplets in two-component one-dimensional Bose-Hubbard chains [2]. The droplets exist for any strength of repulsive intraspecies interactions provided they are balanced by comparable attractive interspecies interactions. The ground-state phase diagram is presented and the different phases are characterized by examining the density profile and off-diagonal one- and two-body correlation functions. A rich variety of phases is found, including atomic superfluid gases, atomic superfluid droplets, pair superfluid droplets, pair superfluid gases, and a Mott-insulator phase. A parameter region prone to be experimentally explored is identified, where the average population per site is lower than three atoms, thus avoiding three-body losses.
We reveal that the formation and stability of liquid phases can be interpreted in terms of finite-range interactions between dimers (see figure). We derive an effective model of composite bosons (dimers) which correctly captures both the few- and many-body properties and validate it against exact results obtained by DMRG method for the full Hamiltonian [3]. The threshold for the formation of the liquid coincides with the appearance of a bound state in the dimer-dimer problem and possesses a universality in terms of the two-body parameters of the dimer-dimer interaction, namely scattering length and effective range. For sufficiently strong effective dimer-dimer repulsion we observe fermionization of the dimers which form an effective Tonks-Girardeau state. Finally, we identify conditions for the formation of a solitonic solution.

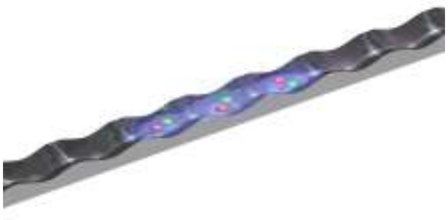

Figure 1: Artistic depiction of the dimer liquid described in the text.

REFERENCES

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