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Equilibrium and nonequilibrium properties of Tonks-Girardeau gases confined on optical lattices[1]

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In this talk we discuss recent exact results for the in and out of equilibrium properties of Tonks-Girardeau (TG) bosons confined on one-dimensional lattices. The TG gas, introduced theoretically more than 40 years ago, has been recently realized in experiments with ultracold quantum gases loaded on optical lattices. We show that universal quasi-long range correlations are present in the ground state of trapped TG gases. These correlations account for the existence of quasi-condensates whose occupation scales proportionally to the square root of the number of particles in the trap. We find that when such systems are allowed to expand, by turning off the confining potential, their momentum distribution function rapidly approaches the one of noninteracting fermions. Remarkably, no loss in coherence is observed in the system as reflected by a large occupation of the quasi-condensates. We also study the expansion of TG gases starting their evolution from a pure Mott insulating state with one particle per lattice site. In this case quasi-long range correlations develop dynamically, and lead to the formation of traveling quasicondensates with a momentum determined by the underlying lattice. This effect could be used to create atom lasers with full control of the wavelength. Finally, we analyze the dipolar oscillations of TG gases in the combination harmonic trap - optical lattice. We show that damping is always present, and produces dramatic effects in the momentum distribution of the bosons. These effects are similar to the ones that would create a finite temperature in the system. In the presence of Mott insulating domains, the dipolar oscillations of the TG gas are overdamped and the center of mass barely moves from its initial displaced position.

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