Quantum many-body effects in artificial atoms and electron-hole bilayers

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Charged particles in trapping potentials tend to from concentric rings (or shells in 3D) which resemble atoms. These "artificial atoms" have a number of interesting features missing in real atoms: by controlling the confinement strength they can be transformed from a weakly coupled state to a strongly coupled "phase" which resembles a Wigner crystal [1]. This is observed even for small particle numbers of the order of 20. There solid-like and liquid-like behavior can be detected by a modified version of the Lindemann parameter for the pair distance fluctuations [2]. After reviewing these results, I will discuss "artificial atoms" formed of Bose particles. Here, also crystallization is observed but, in addition, the system exhibits superfluidity. It is demonstrated that, depending on the particle number, the superfluid component is concentrated in the cluster core or at the edge [3].

In the second part of the talk, I present results for quantum bilayers of electrons and holes. This systems has a rich variety of phases. Particularly interesting is the possibility to control the pair interaction and the effective spin statistics: while at large layer separation the system consists of Coulomb interacting fermions, at smaller distances a transition to composite bosons with nearly dipole interaction is observed. The results are based on first principle path integral Monte Carlo simulations.

In the last part I present first time-dependent results for artificial atoms and e-h bilayers which have recently become possible by extending Nonequilibrium Greens functions methods to spatially localized systems [4].

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