Ultra-cold polar molecules in one-dimensional optical lattices

Ultra-cold polar molecules in optical lattices open fascinating novel possibilities for many-body physics, due to the crucial role played by the dipole-dipole interactions. I will briefly review some aspects of the physics of dipolar gases, with a particular emphasis on the new physics introduced by the dipole-induced inter-site interactions in lattice gases. I will then focus the rest of the talk to the physics of polar gases in one-dimensional optical lattices. I will first comment on polar bosons in disordered and quasi-disordered optical lattices, showing that the interplay between disorder and inter-site interactions leads to a rich ground-state phase diagram.

I will then discuss the case of bosons in zig-zag lattices which may be connected to a frustrated j1-j2 spin-1 chain. In this case the interplay between geometrical frustration and interactions leads again to a rich phase diagram (even for non-dipolar gases), including chiral superfluidity and double-Haldane phases. Interestingly, the peculiar dispersion at the so-called Lifshits point may allow for a Mott-insulator regime for very weak interactions. Moreover at that point, a non-dipolar gas with large three-body losses may allow for the observation of a Haldane-insulator phase, which up to now has been only proposed for a polar 1D gas. Finally, I will comment on the possibility of simulating spin-orbital Hamiltonians characteristic of transition-metal Mott-insulator compounds using polar molecules in properly tailored zig-zag lattices