Competing structures in dipolar gases

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We study a system of dipolar molecules confined in a two-dimensional (pancake) trap and subject to an optical square lattice. The repulsive long-range dipolar interaction D/R^3 favors a hexagonal arrangement of the molecules (with lattice constant a), which competes against the square symmetry of the underlying optical lattice with strength V_0. We search for the minimal energy configurations at commensurate filling $n = 1/b^2$, where n denotes the density of molecules and $b = (4/3)^{1/4}\, a$ is the period of the optical lattice, in the absence of quantum ($\hbar = 0$) and thermal ($T = 0$) fluctuations. A perturbative study at weak substrate potential V_0 yields a locked, distorted particle lattice characterized by a non-trivial angle of orientation with respect to the substrate which depends on the lattice misfit $s = a/b-1$. In the opposite limit, the strong substrate potential V_0 locks the particles to a square-lattice configuration. As the substrate potential is reduced, an instability of the square lattice towards a shear mode at the Brillouin-zone edge manifests itself at a critical value $V_\Box \approx 0.20\, e_{\scriptscriptstyle D}$, with $e_{\scriptscriptstyle D} = D/b^3$ the characteristic energy in the problem. The resulting lattice undergoes a period-doubling along one direction (we choose the x-direction) and exhibits a zig-zag distortion (along y). The transition from the interaction-dominated to the substrate-dominated region occurs via a solitonic phase. Within a harmonic elastic description of lattice-distortions, we find two candidate soliton-arrays taking the period doubled phase to the distorted triangular phase within the V_0 interval $[0, (0.07 - 0.08)\, e_{\scriptscriptstyle D}]$. On the one hand, this is a shear-type 'diagonal' array of domain-walls (rather than solitons) separating regions of twin-type zig-zag phases, on the other hand, a compression-type horizontal array of domain-walls. Given the large anharmonicities in the elastic energy, a precise evaluation of the critical potentials V_c^d and V_c^h for the first diagonal and horizontal domain-wall entry is not possible within a harmonic theory and a numerical analysis is required.