Loading and cooling in an optical trap via dark states

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Recently self-emergence phenomena, like glassiness and crystallization, have been extensively studied using pumped condensed atomic samples, coupled to a high finesse optical resonator. So far most of these experiments have been realized in standing wave cavities, which impose the resonator geometry to the lattice being formed by the atoms and the light scattered into the cavity modes. Adopting degenerate multimode cavities opens new horizons to study order emergence effects, where compliant lattices between atoms and light can show a dynamical evolution [1].

The optical cavity we use to study self-ordering has a bow-tie geometry [2] and the intra-cavity field is in a traveling wave configuration. Therefore, there are no constraints at the cavity mirrors on the intra-cavity light, and the phase of the expected light-atom crystals results in a free parameter. As a first step, we developed a novel protocol to load cold rubidium atoms in the telecom dipole trap enhanced by the cavity: we substituted the conventional red molasses phase with a gray molasses technique utilizing hyperfine dark and bright states arising through two-photon Raman transitions [3]. In this way we obtained a seven-fold increase in the atomic loading, and the technique was crucial to obtain an all-optical BEC in microgravity [4]. Furthermore, with the same technique we could cool the atoms directly in the dipole trap, exploiting the position dependence introduced by the differential light shift caused by the light at 1560 nm. Atoms at deeper potentials need to be addressed by a further, red-detuned cooler on the D2 line, since the dipole trap creates a large differential Stark shift between ground and exited states. We could thus cool the trapped atoms by a factor of 4 in few ms, limited by the gray molasse scheme being applied on the D2 line, and notably by the presence of the F'=3 upper level. The cooling scheme could be improved by using cooling light on the D1. In general, the cooling protocol is fast, lossless, and could be applied to other atomic species.

References

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