Effect of an optical dipole trap on resonant atom-light interactions

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The optical properties of a fixed atom are exquisitely well-known and investigated. For example, one important phenomenon is that the atom can have an extraordinarily strong response to a resonant photon, as characterized by a resonant elastic scattering cross section given by the wavelength of the transition itself, $\sigma_{sc} \sim \lambda^2$. The case of a tightly trapped ion, where the ground and excited states are equally trapped, is also well-known [1]. Then, the elastic cross section is reduced by a fraction corresponding to the square of the "Lamb-Dicke parameter", while this same parameter also dictates the probability of inelastic scattering that gives rise to motional heating.

In contrast, there are many emerging quantum optics setups involving neutral atoms in tight optical dipole traps, such as coupled to nanophotonic waveguides and cavities [2] or in atomic arrays [3], where the goal is to utilize efficient atom-light interactions on resonance. Often, while the ground state is trapped, the excited state may in fact be untrapped or even anti-trapped. Here, we systematically analyze the consequences that this unequal trapping has on reducing the elastic scattering cross section, and increasing the motional heating rate. This analysis may be useful to optimize the performance of quantum optics platforms where equal trapping cannot be readily realized.

References

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