Anisotropic optical trapping of ultracold erbium atoms

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In the field of ultracold matter, dipolar quantum gases, which are composed of atoms or molecules with an intrinsic permanent electric or magnetic dipole moment, have drawn growing attention in the last few years. When they interact with each other or with an external electromagnetic field, such dipoles show an anisotropic behaviour, which means that the energy of interaction significantly depends on the relative orientation of the dipoles and the field polarization. In this respect, lanthanide atoms are of particular interest, since they possess a strong permanent magnetic dipole moment (up to 10 Bohr magnetons for dysprosium), which is due to their rich energy-level structure. The recent Bose-Einstein condensations of dysprosium [1] and erbium [2] testify to this increasing interest in lanthanides.

When confined in a dipole trap, ultracold atoms are submitted to a potential whose depth is proportional to the real part of their dynamic dipole polarizability. The atoms also experience photon scattering whose rate is proportional to the imaginary part of their dynamic dipole polarizability [3]. In this work we calculated the complex dynamic dipole polarizability of ground-state erbium, using the sum-over-state formula inherent to second-order perturbation theory. The summation is performed on transition energies and transition dipole moments from ground-state erbium, which are computed using the Racah-Slater least-square fitting procedure provided by the Cowan codes [4]. This allows us to predict 9 unobserved odd-parity energy levels of total angular momentum $J = 5$, 6 and 7, in the range 25000-31000 cm^{-1} above the ground state.

Regarding the trapping potential, we find that ground-state erbium essentially behaves like a spherically-symmetric atom, in spite of its large electronic angular momentum. We also find a mostly isotropic van der Waals interaction between two ground-state erbium atoms, characterized by a coefficient $C_6^{\text{iso}} = 1760$ a.u.. On the contrary, the photon-scattering rate shows a pronounced anisotropy, since it strongly depends on the polarization of the trapping light [5].

References

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