Electric Dipole Forces on a Binary System of Atoms

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Dispersion forces between neutral atoms are the result of the coupling of the quantum fluctuations of the electromagnetic field in its vacuum state with the fluctuations of the atomic charges in (meta)stable states. In the electric dipole approximation, these forces are known as van der Waals (vdW) forces.

In recent decades renewed interest has been drawn to the interaction between excited atoms. From a practical perspective, this is the kind of interaction between Rydberg atoms which makes possible the coherent manipulation of their quantum states, facilitating the entanglement between separated quantum systems as well as the storage of quantum information [1]. On the other hand, from a fundamental perspective, the attention has focused on different aspects of the interaction, namely, its scaling behaviour with the distance, its inherent time dependence, and the net forces induced by parity and time-reversal violation on a binary system [2,3].

Here we address this problem on a system made of two two-level identical atoms. Following a fully Hamiltonian and time-dependent approach we show that, once the system is released with one of the atoms initially excited, two kinds of forces are involved in the interatomic interaction. On the one hand, conservative forces act along the interatomic axis. These forces are different on each atom, resulting in a net force upon the whole system. This apparent violation of the action-reaction principle is explained by the excess of linear momentum carried by the virtual photons which mediate the interaction. On the other hand, there exist nonconservative forces as a consequence of the time variation of the so-called Röntgen momentum which possess components orthogonal to the interatomic axis producing a net torque in the atomic system [4,5].

In the context of atomic arrays, both kinds of interactions might have implications on the improvement of coherence time and the directionality of the excitation transfer along the arrays, both determining the optimization of the scalability of multiple atom qubits [6,7].

References

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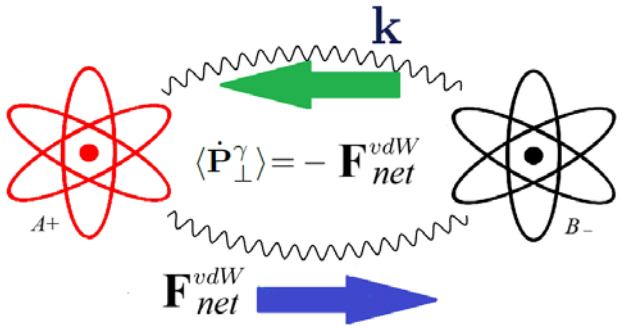

Figure 1: Conservative Net Force on the system

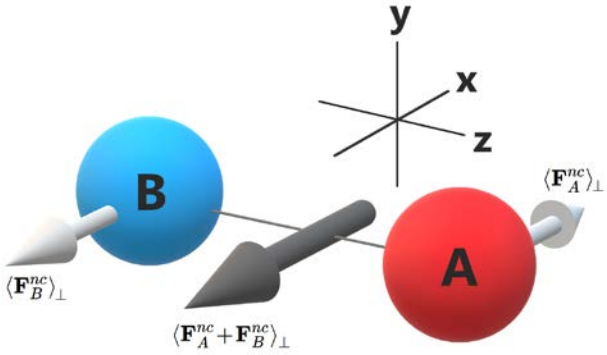

Figure 2: Non-Conservative Orthogonal Forces