Renormalization group analysis of near-field induced dephasing of optical spin waves in an atomic medium

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Abstract

While typical theories of atom–light interactions treat the atomic medium as being smooth, it is well-known that microscopic optical effects driven by atomic granularity, dipole–dipole interactions, and multiple scattering can lead to important effects. Recently, for example, it was experimentally observed that these ingredients can lead to a fundamental, density-dependent dephasing of optical spin waves in a disordered atomic medium [1]. Here, we go beyond the short-time and dilute limits considered previously, to develop a comprehensive theory of dephasing dynamics for arbitrary times and atomic densities [2]. In particular, we make use of a novel, non-perturbative theory based on strong disorder renormalization group (RG) [3], in order to quantitatively predict the dominant role that near-field optical interactions between nearby neighbours has in driving the dephasing process. This theory also enables one to capture the key features of the many-atom dephasing dynamics in terms of an effective single-atom model. These results should shed light on the limits imposed by near-field interactions on quantum optical phenomena in dense atomic media as well as on quantum technological applications, and illustrate the promise of strong disorder RG as a method of dealing with complex microscopic optical phenomena in such systems.

References

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