Photon-mediated interactions between spin 1 atoms

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Quantum simulators are highly controllable devices that exploit quantum effects to answer questions about another system. They can be built using different platforms, such as ultracold atoms in optical lattices, superconducting circuits or atoms interacting with nanophotonic structures [1]. This last system is particularly interesting because the nanophotonic environment can be tailored to generate exotic photon-mediated interactions between atoms [2], with both dissipative and coherent evolutions, opening the door for the exploration of a wide range of physical models. However, these atoms have been typically considered as two-level systems, which limits the type of models that can be explored [3,4]. Our work considers the full hyperfine structure of the atoms to go beyond this and study effective spin-1 interactions between the quantum emitters, where Raman-assisted transitions allow a mapping to well known models such as the Ising or the XX spin-1 interactions. These results could be interesting both in quantum simulation (where they could be applied to study spin chains or even simulating some lattice gauge theories [5,6]) and quantum computation (as a way to obtain quantum gates between qutrits [7]).

References

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[4] J. S. Douglas et al., Nature Photonics 9 (2015) 326-331.
[5] E. Zohar et al., Phys. Rev. A 95, 023604 (2017).
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[7] Y. Wang et al., Front. Phys., 10 (2020).

Figures

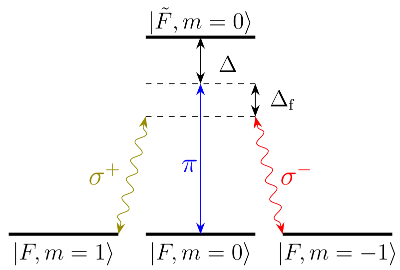

Figure 1: Different types of transitions between the ground hyperfine levels and an hyperfine excited state of a driven real atom.

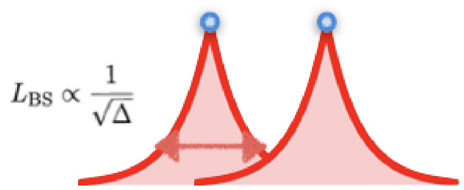

Figure 2: Atom-photon bound states for atoms coupled close to a waveguide. The range of the effective interaction between them can be tuned modifying the system's parameters and it can go beyond nearest neighbours.