EIT and EIT-Like Resonances in Inhomogeneously Broadened Ensemble of Quantum Emitters in Solids

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Quantum emitters in solids, such as rare-earth ions in dielectric crystals or color centers in diamond with narrow atomic-like quantum transitions in the IR/optical ranges present a promising platform for the realization of the quantum networks due to scalability and an absence of a motional dephasing without the requirement for sub-μK cooling. Using the high-density ensembles of such emitters would allow to achieve an efficient light-matter coupling in the absence of the cavities and to realize very compact and efficient quantum memory. At the same time, the inhomogeneous broadening inherent to both optical and spin transitions in solids may severely limit the potential benefits of such ensembles. So far, two specific cases of the inhomogeneously broadened ensembles of the lambda type quantum emitters were considered: i) negligible population relaxation rate from the ground to the first excited state [1], and ii) equal population relaxation rates between those states [2]. Besides, a population decay rate at the optical transitions was assumed to be much faster as compared to the low-frequency transition. In this work, we consider the general case of an arbitrary relation between the relaxation rates both at the low-frequency and optical transitions. We show that depending on the relation between the relaxation constants; the narrow transparency resonances may be observed in two different regimes, namely, with the linewidth proportional either to the amplitude of the control field or to its intensity. Both the threshold intensity and the width of the resonance in the first regime can be significantly lower than in the second regime. We show that only the second regime has been realized experimentally so far. Moreover, the physical origin of the observed transparency resonances was an Autler-Townes splitting in each homogenously broadened sub-ensemble, while summation of those resonances perfectly mimicked an EIT resonance in the whole inhomogeneously broadened ensemble. We also discuss the possibility of an experimental observation of the first regime, corresponding to EIT, *i.e.* based on the formation of the dark state in each homogenously broadened sub-ensemble.

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References

[1] H Q Fan, K H Kagalwala, S V Polyakov, A L Migdall and E A Goldschmidt, Phys. Rev. A **99**, 053821 (2019)

[2] E Kuznetsova, O Kocharovskaya, P Hemmer and M O Scully, Phys. Rev. A **66**, 063802 (2002)