Spontaneous emission of dipolar adatoms near SSH chains

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The light-matter interaction in one-dimensional structures offers promising avenues for nanoscale photonics and quantum technologies. This study focuses on a two-level atom in the vicinity of Su-Schrieffer-Heeger (SSH) chains, modeling them in a tight-binding framework [1]. The adatom, modeled as a dipole source, is optically coupled to the chain. The primary quantity investigated is the imaginary part of the Green's function at the dipole's position, which characterizes the spontaneous emission rate of the dipolar emitter as modified by its proximity to the SSH chain [2].

In the first phase of the study, we analyze a one-dimensional metallic chain, exploring the impact of the local environment and symmetry-breaking effects by identifying two distinct interaction regimes based on the adatom-chain distance. As the adatom-chain distance varies, the adatom can enter a curved nodal plane near the chain's edge, resulting in a significant suppression of the spontaneous decay rate. The position and curvature of these nodal planes are examined for various resonant modes and chain lengths.

Subsequently, we parametrically introduce dimerization into the metallic chain, transforming it into a semiconducting chain by opening a bandgap. As the chain transitions from metallic to semiconducting, the impact of electron interactions is suppressed. The states in close vicinity of either side of the bandgap exhibit heightened sensitivity to the dimerization process, showing significant changes in the local density of states and charge redistribution across the two sublattices. This redistribution significantly alters the transition dipole moments involving these states causing modification of absorption spectra of the chain and the spontaneous decay rate of the adatom. Furthermore, we identify the distinct mechanisms governing spontaneous emission enhancement in metallic and semiconducting chains, demonstrating the impact of electron interactions in shaping these processes.

References

[1] Müller, M. M., et al. Phys. Rev. B, 104, 235414 (2021)
[2] M. Kosik, M. M. Müller, K. Słowik et al., Nanophotonics 11, 3281 (2022)