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Cooperative spontaneous emissions from resonant long-range dipole-dipole interactions: Super- and subradiance, and superradiant laser[1] HSIANG-HUA JEN, Institute of Physics, Academia Sinica, Taipei 11529, Taiwan, MING-SHIEN CHANG, YING-CHENG CHEN, Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei 10617, Taiwan, IOP QUANTUM LIQUID TEAM, IOP AND IAMS COLLABORATION — Resonant long-range dipole-dipole interaction (LRDDI) has played an important role in initiating super- and subradiance in a cold atomic ensemble. This universal effect is induced from the atom-photon interaction in the dissipation process. Here we propose a complete space of singly-excited states which can be the candidates for superradiance and subradiance. Cooperative single- and multi-photon subradiant states can also be prepared in our proposed scheme by imprinting the required phases via pulsed gradient magnetic or electric fields. This effect of LRDDI is also present in a steady-state superradiant laser (SL) in the bad-cavity limit. We demonstrate that cavity photon number oscillates as an inter-particle distance of the atoms varies. Similarly the atom-atom coherence alternates with signs, showing critical transitions alternatively in SL operations. This suggests a complexity of the collective effect emerging in a large ensemble of atoms. The scaling of a finite number of atoms shows that a steady-state SL outperforms the one without LRDDI, which allows for probing narrow atomic transitions and is potentially useful for precision measurements and next-generation optical clocks.

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