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Designing the Environmental Structure for a Giant Artificial Atom ANTON FRISK KOCKUM, MARTIN GUSTAFSSON, THOMAS AREF, PER DELSING, GORAN JOHANSSON, Department of Microtechnology and Nanoscience, MC2, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden — In traditional quantum optics, where the interaction between atoms and light at optical frequencies is studied, the atoms can be approximated as point-like compared to the wavelength of the light. So far, this relation has also been true for artificial atoms made out of superconducting circuits or quantum dots, interacting with microwave radiation. However, recent and ongoing experiments using surface acoustic waves show that one can couple a single artificial atom to a bosonic field at several points wavelengths apart. In this work, we theoretically study this type of system. We find that the multiple coupling points give rise to a frequency dependence for the coupling strength between the atom and its environment, and also for the Lamb shift of the atom. The frequency dependence can be designed, since it is given by the discrete Fourier transform of the coupling point coordinates. We discuss a number of possible applications for this phenomenon, including tunable coupling, single-atom lasing, and other effects that can be achieved by designing the relative coupling strengths of different transitions in a multi-level atom.

Anton Frisk Kockum
Department of Microtechnology and Nanoscience, MC2,
Chalmers University of Technology,
SE-412 96 Gothenburg, Sweden

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