DAMOP05-2005-000421
Abstract for an Invited Paper
for the DAMOP05 Meeting of
the American Physical Society

Observation of the Vacuum-Rabi Spectrum for One Trapped Atom

H. J. KIMBLE, California Institute of Technology

A cornerstone of optical physics is the interaction of a single atom with the electromagnetic field of a high quality resonator. Of particular importance is the regime of strong coupling, for which the frequency scale g associated with reversible evolution for the atom-cavity system exceeds the rates (γ, κ) for irreversible decay of atom and cavity field, respectively. In the domain of strong coupling, a photon emitted by the atom into the cavity mode is likely to be repeatedly absorbed and re-emitted at the single-quantum Rabi frequency $2g$ before being irreversibly lost into the environment. This oscillatory exchange of excitation between atom and cavity field results from a normal-mode splitting in the eigenvalue spectrum of the atom-cavity system, and has been dubbed the vacuum-Rabi splitting. Without exception experiments related to the vacuum-Rabi splitting in cavity QED with single atoms have required averaging over trials with many atoms (10^3) to obtain quantitative spectral information. By contrast, the implementation of complex algorithms in quantum information science requires the capability for repeated manipulation of an individual quantum system. With this goal in mind, we have succeeded in recording the entire vacuum-Rabi spectrum for one-and-the-same atom strongly coupled to the field of a high-finesse optical resonator [1]. These measurements are made possible by a new Raman scheme for cooling atomic motion along the cavity axis for single atoms trapped within a state-insensitive intracavity FORT [2], with inferred atomic localization $\Delta z_{axial} \simeq 33$ nm. Our measurements represent an important milestone towards the realization of more complex tasks in quantum computation and communication [3].

References

[1] A. Boca, R. Miller, K. M. Birnbaum, A. D. Boozer, J. McKeever, and H. J. Kimble, Phys. Rev. Lett. **93**, 233603 (2004).

[2] J. McKeever, J.R. Buck, A.D. Boozer, A. Kuzmich, H.-C.Nagerl, D.M. Stamper-Kurn, H.J. Kimble, Phys. Rev. Lett. **90**, 133602 (2003).

[3] This work was carried out in collaboration with A. Boca, R. Miller, K. M. Birnbaum, A. D. Boozer, and J. McKeever, and was supported by the Caltech MURI Center for Quantum Networks, by the National Science Foundation, and by the Advanced Research and Development Activity (ARDA).