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Mesoscopic cavity quantum electrodynamics with atomic systems and quantum dots

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We discuss electrodynamic techniques for strong, coherent coupling between spatially separated atoms or quantum dots on a microchip. These techniques are based on capacitive interactions between the electron charge and a superconducting transmission line resonator operating in microwave domain, and are analogous to cavity quantum electrodynamics. In the case of isolated neutral atoms, the coupling is achieved by exciting atoms trapped above the surface of a superconducting transmission line into Rydberg states with large electric dipole moments that induce voltage fluctuations in the resonator. In the case of quantum dots, interactions between the resonator and the electron charge may be exploited to couple spatially separated electron-spin states while only virtually populating fast-decaying superpositions of charge states. We discuss potential applications of such electrodynamic coupling for a long-range interaction between a variety of spatially separated quantum systems, for entangling isolated neutral atoms separated by millimeters, or for mapping the quantum states of a solid-state device onto atomic or photonic states. Finally, we discuss prospects for extending these on-chip cavity QED techniques into the optical domain.