Tunable Collective Quantum States in Bragg and Anti-Bragg Superatoms in Waveguide QED

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Abstract

Many-body quantum systems hosting collective states, such as superradiant and subradiant states, can behave as multi-level "superatoms" in light-matter interactions, unveiling novel physical phenomena inaccessible in individual atoms. In this work, we experimentally investigate the spectral and dynamical properties of one-dimensional (1D) superatoms within a waveguide quantum electrodynamics (QED) architecture, utilizing a periodic array of superconducting artificial atoms [1-3]. By engineering the array with two distinct nearest-neighbor spacings ($d=\lambda_0/2$ and $d=\lambda_0/4$), we achieve modification of Bragg and anti-Bragg superatoms. Our platform demonstrates a diverse range of quantum optical phenomena, including collectively induced transparency (CIT), enhanced/suppressed spontaneous decay rates, and the formation of a broad photonic bandgap. These results highlight the versatility of waveguide-coupled atomic arrays for efficient light manipulation and the development of scalable quantum photonic devices.

References

[1] Zhengqi Niu et al.,arXiv:2507.00935
[2] Daqiang Bao, Zhirong Lin, Opt. Express 32 (2024), 26470-26477
[3] Daqiang Bao, Zhirong Lin, Phys. Rev. Research 6 (2024), 043121

Figures

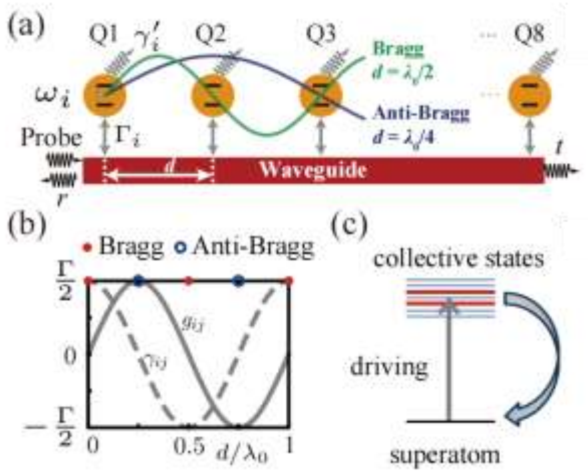

Figure 1: The schematics of a waveguide QED system with N = 8 superconducting qubits.

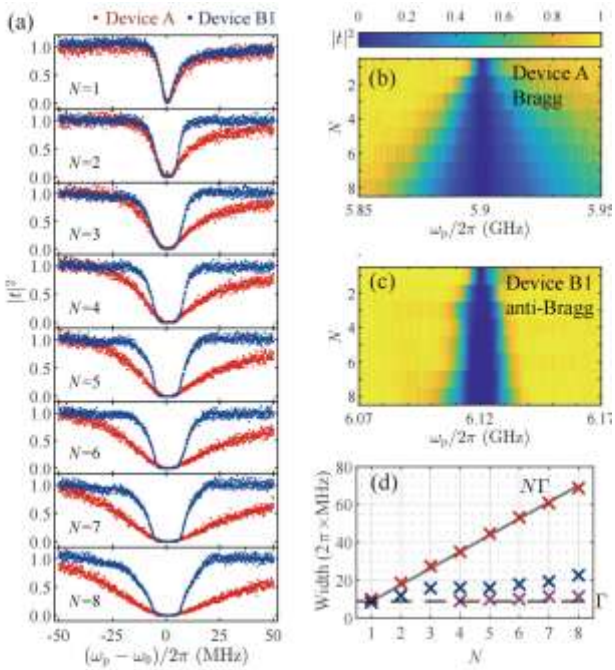

Figure 2: Transmission spectra of Bragg and anti-Bragg superatoms in Devices A and B1.