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Interaction of free electrons and photons in photonic integrated circuits

Abstract

Integrated photonics facilitates extensive control over fundamental light–matter interactions in manifold quantum systems including atoms, trapped ions, quantum dots, and defect centers. Ultrafast electron microscopy has recently made free-electron beams the subject of laser-based quantum manipulation and characterization, enabling the observation of free-electron quantum walks, attosecond electron pulses, and holographic electromagnetic imaging. Chip-based photonics promises unique applications in nanoscale quantum control and sensing but remains to be realized in electron microscopy. Here we merge integrated photonics with electron microscopy, demonstrating continuous-beam electron phase modulation [1], cavity-mediated electron-photon pair generation [2], and free-electron interaction with nonlinear optical states [3].

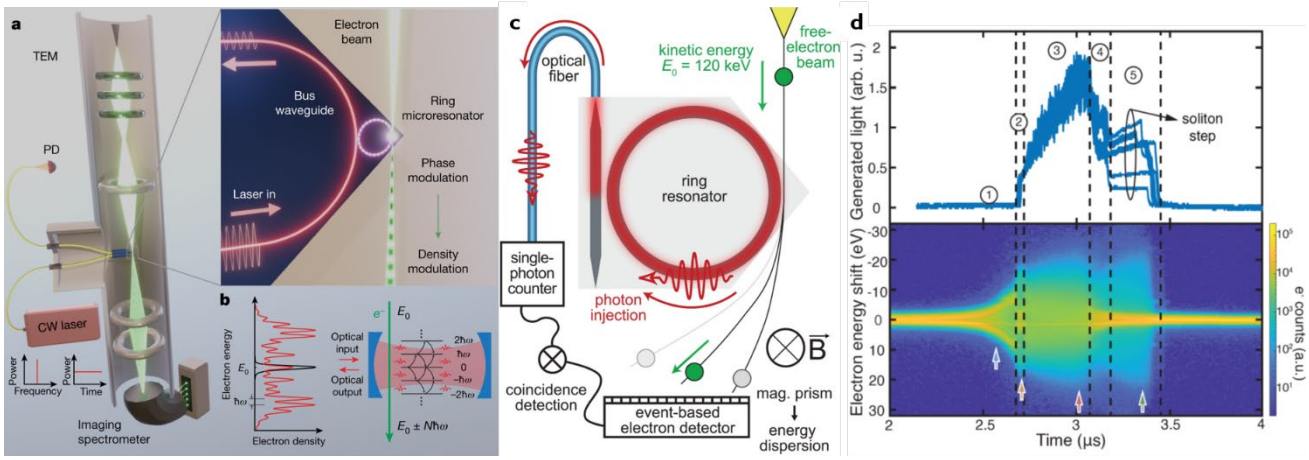

Figure 1. Interaction of free electrons and photons in photonic integrated circuits. (a) Experimental setup including a transmission electron microscope and a fiber-coupled Si_3N_4 photonic chip. (b) Depiction of electron spectral broadening and cQED-type electron-photon interaction. (c) Schematic for cavity-mediated electron-photon pair generation. (d) Optical and electron measurement for free-electron interaction with nonlinear optical states in microresonators.

References

[1] J.-W. Henke et al., Nature, 600(7890) (2021) 653-658.

[2] A. Feist et al., Science, 377(6607) (2022) 777-780.

[3] Y. Yang et al., arXiv:2307.12142 (2023).