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Publication date:
2024

Document Version
Peer reviewed version

Self-aligned integration of self-assembled silicon photonic cavities with atomic-scale confinement in photonic circuits

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The need for enhancing the strength of the interaction between light and matter is at the heart of nanophotonics research because it is necessary for building new generations of nanolasers, optical interconnects, and quantum light sources [1]. Some of the latest developments in the field involve the experimental realization [2] of subdiffraction dielectric cavities [3]. Further miniaturization of the mode volume and thus enhancement of the light-matter interaction requires parting with conventional fabrication concepts, and we report on a new method that combines the atomic-scale resolution of self-assembly with the scalability and circuitry of planar photonic circuits [4]. The method bypasses the resolution limit of lithography and results in dielectric cavities with unprecedented dimensions, confining light in air gaps with widths of about a few silicon atoms as shown in Fig. 1. The new cavities feature mode volumes 100x below the diffraction limit while at the same time exhibiting quality factors 100x above the theoretical limit of plasmonics, while also being self-aligned to and efficiently coupled to a waveguide. The smallest dimension of devices obtainable with the new method is only limited by structural disorder [5].

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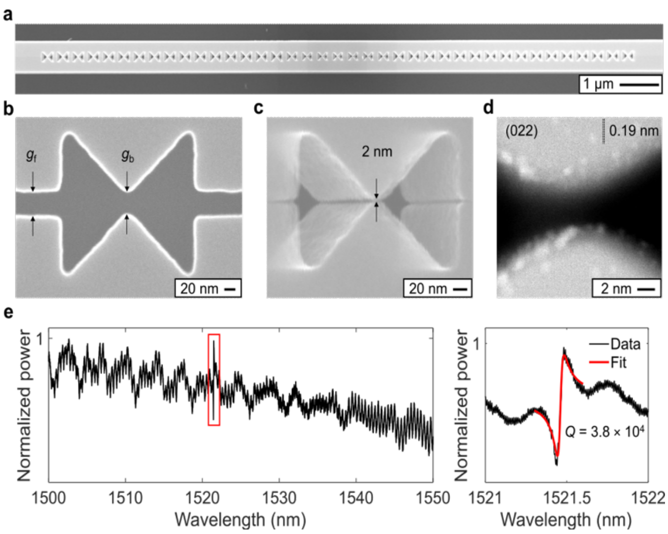

Figure 1. Fabrication and optical characterization of self-assembled atomic-scale photonic cavities. (a) Scanning electron microscope (SEM) image of a self-assembled nanobeam cavity. (b) Top-view SEM image of a single bowtie unit cell before self-assembly, with a fabricated gap, g_f, and a bowtie gap, g_b. (c) A bowtie unit cell after self-assembly with an approximate bowtie width of 2 nm. (d) Top-view high-resolution transmission electron microscope image of the central region of the bowtie with an approximate 2 nm gap. The interplanar distance between the (022) silicon crystal planes is 0.19 nm. (e) Scattered far-field spectrum of a self-assembled nanobeam cavity measured using cross-polarized optical microscopy. The inset shows the resonance of the fundamental mode at the wavelength of 1521.5 nm, and a quality factor of 3.8×10^4, extracted by fitting a Fano lineshape to the resonance.

Subdiffraction confinement of light in dielectric cavities

Session:
High-Q photonic resonances in all-dielectric nanostructures and their applications

Preferred format:
Extended invited (30 min)

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