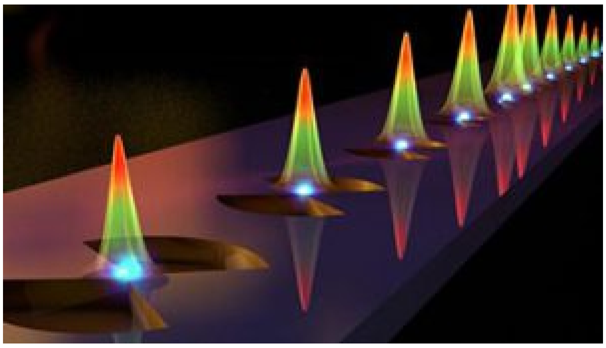
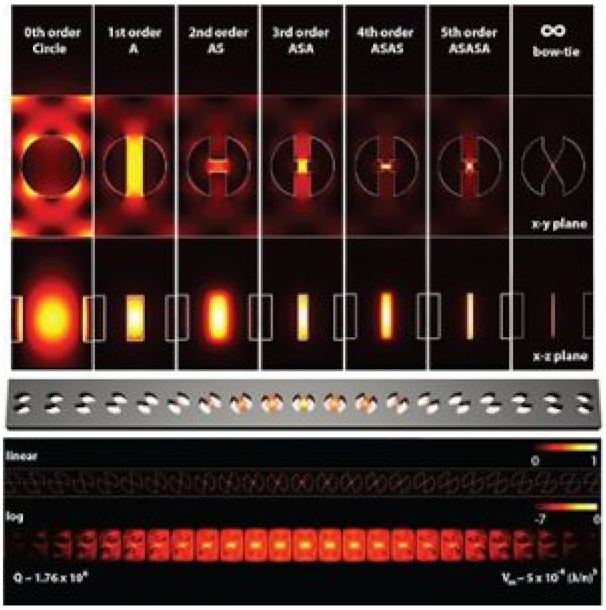
Extreme Light Confinement in Nano-Bowties

A team led by OSA Fellow Sharon Weiss of Vanderbilt University, USA, has demonstrated an all-dielectric "bowtie" structure that combines the tight spatial light confinement of plasmonic resonators with the ultralow losses and long cavity lifetimes of photonic crystals.

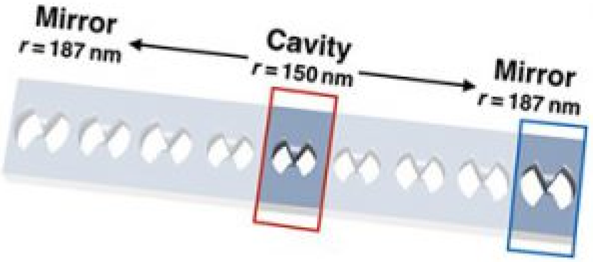


A long-standing conundrum of nanophotonics has been how to achieve deep-subwavelength light confinement (measured by a parameter called the mode volume, V_m) while holding the light in place in a cavity for long periods (an ability characterized by the cavity's quality factor, Q). Plasmonics—the enhancement of optical fields at metal-dielectric interfaces, using nanoscale metallic resonators or antennas—can give you very tight spatial confinement (low V_m). But plasmonic devices tend to be lossy, with anemic Q factors, and thus the spatially confined light energy quickly dissipates.

In a theoretical study in late 2016, Weiss, along with OSA member and then-grad-student Shuren Hu (now with the semiconductor fabrication firm GlobalFoundries), proposed an answer: combine the subwavelength-confinement properties of nanoscale dielectrics with the near-legendary Q values of photonic-crystal cavities. The process works in two steps. Incident light becomes localized in the photonic-crystal cavity air hole. Then, the cavity's bowtie geometry, and the energy concentration at the bowtie tips, funnels and squeezes the optical energy into the nanoscale dielectric bar. The result is deep subwavelength confinement of the light energy, combined with the photonic crystal's long cavity lifetime.



The result was a silicon photonic-crystal cavity consisting of unit-cell bowties with a radius of 150 nm, and with mirror unit cells of 187 nm radii on either end, arrayed in a 700-nm-wide waveguide. To put the structure through its paces, the team tied it, via lensed optical fiber, to a 1500-to-1630-nm tunable continuous-wave laser, and measured the field distribution using near-field scanning optical microscopy.The quality factor, on the order of $Q = 10^5$



Realizing those possibilities will take a significant amount of work to scale up from these initial experiments, and to reproducibly create the exquisitely precise photonic-crystal structures required. Hu, at GlobalFoundries, is now co-P.I. with Weiss on a new project, funded by a U.S. National Science Foundation GOALI (Grant Opportunities for Academic Liaison with Industry) award, to work toward scale-up and proof-of-concept applications. Weiss notes that Hu began the work as a grad student in her lab under another GOALI grant, with IBM.

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