PHOTONIC-CRYSTAL WAVEGUIDES

Trapping single atoms

A highly desirable goal in photonics is the integration of nanophotonics with atomic systems. Although much progress has been made in this area using cavity quantum electrodynamics and nanoscale dielectric waveguides, researchers at California Institute of Technology in the USA have now presented another exciting possibility — the combination of atomic physics with photonic-crystal waveguides (*Appl. Phys. Lett.* **104**, 111103; 2014). Su-Peng Yu and Jonathan D. Hood together with co-workers used silicon nitride (Si_3N_4) nanowires to fabricate dispersion-engineered photonic-crystal waveguides that are capable of trapping single atoms and generating strong light-matter interactions.

The key component of their waveguide is an 'alligator' photonic-crystal waveguide region consisting of two parallel Si_3N_4 waveguides whose outer edges are sinusoidally modulated and whose straight inner edges are separated by a constant-width gap (see image). These waveguides are designed such that the lower (dielectric) and upper

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(air) band edges lie close to the D1 and D2 transitions of caesium atoms, respectively. This configuration allows caesium atoms to be trapped in the waveguide gap by using a dielectric-band blue-detuned from the D1 line as a trapping beam and the air-band mode as a probe on the D2 line of the trapped atoms. When this is done, caesium atoms become trapped in areas of the x-y plane where the intensity of the dielectric-band mode is zero.

The researchers report that these waveguides satisfy five criteria for hybrid atom-photon systems suitable for use in experiments in quantum optics and atomic physics involving optically trapped

ultracold atoms. Specifically, they can be fabricated with a high enough precision to permit photonic bandedges to be reliably produced near electronic transitions of atoms, can stably trap atoms while simultaneously realizing a strong atom-field interaction, enable efficient coupling to and from guided modes of nanophotonic elements, provide sufficient optical access for laser cooling and trapping, and have a low optical absorption and a high thermal conductivity thereby enabling 1 mK trap depths.

The team considers that this waveguide technology represents a significant advance towards performing experiments using ultracold atoms and nanophotonic chip-based optical circuits. They anticipate that further enhancement of the waveguide performance through reducing the optical absorption and scattering loss in the nanowire waveguides should permit atoms to be trapped using the fields of far-off-resonance guided modes.

SIMON PLEASANTS

QUANTUM EMITTERS

Route to indistinguishable photons

The dot-to-dot variation of the optical transition frequency makes it impractical to use single-photon sources based on semiconducting quantum dots in quantum computing, which requires indistinguishable photons. This can now be overcome by using coherently scattered single photons from a dot and tuning them using a microcavity.

Alexander Tartakovskii

Single-photon pulses and interference of indistinguishable photons lie at the heart of optics protocols for quantum computing. Semiconducting nanostructures known as quantum dots have proved to be among the most versatile and efficient single-photon sources. However, despite the considerable effort that has gone into researching crystal growth, no technology exists that can produce identical quantum dots for generating indistinguishable photons, which are required for quantum optics networks and distributed quantum computing. This significantly hampers the scalability necessary for quantum computers

and networks in this otherwise attractive solid-state implementation.

Reporting in *Nature Photonics*, Timothy Sweeney and co-workers demonstrate new optical techniques designed to overcome the natural scatter in the photon frequencies of quantum dots¹. They use a process called spin-flip Raman scattering to show that it is possible to generate single photons by coupling a laser to the long-lived electron spin in a quantum dot placed in an optical cavity. The spectrally broad (~100 GHz) cavity mode enables efficient Raman scattering with the laser detuned far off resonance from

the optical transition of the quantum dot. A frequency range of 125 GHz (0.5 meV), which exceeds the natural quantum-dot linewidth by two orders of magnitude, is now accessible for generating coherent single photons. This demonstration opens a new way to realize quantum networks, as generation of indistinguishable photons from dissimilar single-photon sources is now within the reach of researchers. This can be achieved by frequency matching the cavity-stimulated Raman-scattered photons from different dots. Further functionality is also envisaged, as the scattered photons can also be spin tagged and carry information