results because of *s*-wave scattering could then become visible, and details about the atomic scattering processes might become observable.

Selective addressing of single optical lattice sites allows the system to be disturbed locally in a controlled way. Gericke *et al.* allude to the likelihood that their technique will enable the coherent microscopic tunnelling dynamics between two sites of an optical lattice to be studied — a demonstration of which would probably become the textbook example of quantum tunnelling. And the ability to probe a degenerate quantum gas atom-by-atom could prove useful for quantum information processing applications. For instance, measurement-based quantum computing schemes[6] realized in optical lattices require the selective readout of atomic qubits from single lattice sites. By spatially splitting the atomic qubit wavefunction according to its logical state in an optical lattice[7], such a readout could be achieved by means of ionizing electron beams.

So does electron microscopy spell the end for the use of light to study ultracold atoms? Probably not. Part of the promise of using light is the potential to realize an intimate quantum coupling between it and a degenerate gas, producing entanglement and the transfer of quantum information between flying and stationary particles[8]. Such interactions are efficient only for optically dense samples. However, as Gericke *et al.* point out, the scattering cross-section for electrons is about eight orders of magnitude smaller than that of photons. And an electron beam acts as an inherently classical probe. These facts severely limit the prospects for using a beam itself for quantum information transfer. But as light is already a part of the present demonstration, there is no reason that light and electrons should not become complementary tools in future studies of BECs and other quantum degenerate atomic gases.

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LIGHT–MATTER INTERACTION

Perfect reflections

Mirror, mirror on the wall, can a single photon excite (an atom) at all? The question of how to couple light efficiently to single molecules and atoms is relevant for many experiments in fundamental quantum optics, as well as for the implementation of protocols for quantum information processing. In *Physical Review Letters*, Gert Zumofen and colleagues suggest that strong coupling between a single propagating photon and a single quantum emitter may be achievable — with efficiency as high as 100% — without the need for a cavity (*Phys. Rev. Lett.* **101,** 180404; 2008).

A 'traditional' way of creating efficient light–matter interaction is to use optical cavities — arrangements of mirrors that act as cavity resonators for light waves. The strongly localized optical modes in such systems provide an increased coupling efficiency to quantum emitters such as single atoms, molecules and quantum dots. However, ideally the cavity would not be needed, and experimental and theoretical efforts are currently underway to investigate strong-coupling schemes for light–matter interaction in free space.

Simplistically, the probability of exciting a quantum two-level system (which is, in some instances, a suitable description of atoms and molecules) depends on two things: the area of the light beam shining on the atom, and the atom's scattering cross-section. As the latter depends on the wavelength of the light, it is natural to expect that focusing the light onto an area that is small compared with the scattering cross-section would be enough to achieve strong coupling between the incident light beam and the atom in question.

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But things are complicated by the fact that the atom is sensitive only to dipolar components of the incident light. This can be understood by the fact that a dipolar transition from a two-level system would create a specific dipolar pattern and thus that an incident light beam containing a time-reversed version of this dipolar field would intuitively provide the most efficient excitation probability, owing to mode-matching arguments.

Zumofen and colleagues have investigated this and provide a theoretical analysis of the interaction between different types of light fields with a dipolar emitter. From explicit derivations of the scattering ratio between the power scattered by, and incident on, the emitter, as well as the transmittance, they predict that a classical point-like oscillating dipole can couple very strongly with a focused incident light beam. More importantly, they show that the coupling can even reach 100% efficiency when the illumination is a directional dipolar field.

Generalizing their classical results for the interaction of light with a quantum two-level system, they further conclude that even single-photon pulses could be fully reflected by a single quantum emitter, provided that the coherence time of the photon is long enough in comparison to the lifetime of the emitter's excited state. Quantum information processing using photons as information carriers may thus be viable.

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