speeds might be challenging to achieve because higher acoustic frequencies are typically associated with smaller deformation amplitudes and acoustic modes of the order of the cavity size. However, deformation amplitudes could be resonantly amplified by deliberately coupling localized photonic and vibrational modes. For device applications, it might be useful to dynamically modulate an inhomogeneously broadened ensemble of optical emitters across the resonance of a laser cavity. Indeed, ongoing experiments by Manfred Bayer and his group (private communication) have shown that the photoluminescence of a quantum dot ensemble embedded in a planar microcavity can be strongly enhanced when these optical emitters are dynamically modulated across the cavity resonance using an ultrashort acoustic pulse.

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the accelerator to achieve maximum electron energy (giga-electronvolts). Several methods have been developed to help guide such high-intensity laser light over distances beyond the Rayleigh range.

The first technique takes advantage of the natural ability of high-intensity light to guide itself, through the mechanism of relativistic self-guiding3. In this case, the Gaussian radial profile of the light pulse causes the plasma medium through which it propagates to act as a lens; modifying the transverse quiver motion of the electrons creates a radial gradient in the plasma’s refractive index (Fig. 1b). In a laser-wakefield accelerator, this mechanism has been shown to be naturally present without the need for additional mechanisms, thus extending light propagation to well beyond the Rayleigh range4. Other light-guiding methods have also been investigated. For instance, the radial plasma-density gradient caused by a pre-heating electric discharge pulse in a dielectric capillary also causes a lensing effect. This mechanism has been used to accelerate electrons up to energies of around 1 GeV (ref. 4).

The technique of Genoud et al. also makes use of a dielectric (glass) capillary tube, but importantly without an electrical discharge pulse1. The glass capillary (typically 150–200 μm in diameter and 0.6–2 cm in length) acts not only as a cavity to confine the hydrogen gas used to form the plasma, but also as a multimode optical fibre, reflecting and refocusing some of the laser light from its walls. By utilizing the laser energy that is outside the central laser focal spot, the capillary extends the light propagation distance by 20–30% beyond what it would have been without the capillary (Fig. 1c), which could permit the use of drive lasers with lower energies and thus higher repetition rates. For example, Genoud et al. observed electron acceleration for peak laser intensities of (5 ± 2) × 10¹² W cm⁻² using the 10 Hz multiterawatt Ti:sapphire laser system (40 fs pulses containing 0.7 J of energy at a wavelength of 795 nm in a 50 μm focal spot) at the Lund Laser Centre in Sweden.

Numerical simulations of the interaction indicate that relativistic self-guiding still plays a primary role in guiding the laser light, despite the presence of the capillary. In fact, relativistic self-guiding may play the primary role in all present laser-wakefield accelerators — regardless of the target geometry — because the laser power must generally exceed the relativistic self-guiding threshold to effectively drive a wakefield6.

It may seem paradoxical to introduce a dielectric waveguide when the principal selling point of laser-based accelerators is that they dispense with the need for cavity walls, which can suffer from dielectric breakdown and thus limit the achievable acceleration. The resolution to this apparent paradox is that the capillary walls in the work of Genoud et al. did not need to be exposed to electric field strengths approaching the breakdown threshold. This is because the cavity was not serving its usual purpose — to convert the transverse oscillating electromagnetic field into an accelerating field, as in radiofrequency accelerators7, but instead merely refocusing the relatively small amount of laser energy in the wings of the pulse, which could not be self-guided. Consequently, the capillary’s inner diameter was kept large compared with the central self-focused laser focal spot and the field strength at the walls was kept below the breakdown threshold. It remains to be seen whether these capillaries can withstand such extreme conditions over extended periods of operation. If so, they could help to make the potential applications of laser-wakefield accelerators more practical. For instance, because of their micrometre-scale radiation source size, wakefield accelerators can dramatically improve the spatial resolution of X-ray images8. By increasing the accelerator efficiency, capillaries could help make this application practical for use in hospitals.

Further research will reveal which of the above methods for guiding light will ultimately prove best for future accelerator designs. In any case, although it is perhaps ironic that the relatively old technology of glass waveguides may benefit next-generation accelerators, it is nonetheless satisfying to see such a classic photonic solution come to the aid of a current research problem.

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