demonstrating the retention of stem-cell ability. Although both CD133+ and CD133− cells sustained a similar amount of DNA damage, activation of DNA-repair responses was greater in CD133+ cells.

Bao *et al.* went further, to foreshadow how this finding might be translated into therapy. They found that CD133+ cells could be rendered less resistant to radiation if two agents — the checkpoint kinases Chk1 and Chk2, which control pauses in the cell cycle to allow DNA repair to take place — were inhibited pharmacologically. The authors did not look at whether these cells lost the ability to subsequently initiate tumours *in vivo*. But their work, together with studies showing that leukaemia stem cells are resistant to chemotherapy[6,7], means that the idea that cancer stem cells are important because they are resistant to therapy now carries greater weight.

In their research, Piccirillo and colleagues[4] first showed that human glioblastoma cells express BMPs and their cell-surface receptors. Using culture conditions that support the growth of undifferentiated glioblastoma cells, they found that BMP treatment reduced cell proliferation and induced differentiation predominantly into cells resembling mature astrocytes. Treatment of cultured glioblastoma progenitor cells or CD133+ glioblastoma cells *in vitro* with BMP, or co-treatment of glioblastoma cells transplanted with beads soaked in BMP, reduced the size of the tumours grafted into mice and prolonged the animals' survival (Fig. 1b). The BMP-treated tumour cells engrafted into mice were more mature and less invasive. CD133+ cells could not be recovered from these small tumours, and such tumour populations were not capable of serial engraftment.

Although these results[4] are remarkable in showing that a differentiation-promoting agent is a potential treatment for brain tumours, some mice still developed tumours and died 3 months after BMP treatment. So it seems that certain cancer cells — presumably cancer stem cells — still escape BMP treatment. Will these cancer stem cells induce recurrence at a longer latency?

In both cases[3,4], definitive demonstration of a specific effect of treatment on glioblastoma stem cells will require improved purification of the tumours — the true stem cells are probably a subpopulation of the CD133+ fraction. But both studies add depth to the cancer-stem-cell hypothesis and illustrate the potential of re-examining cancer in the light of that hypothesis. Given the identification of CD133+ tumour-initiating cells from human colon cancer, published last month[8,9], it would seem that these approaches are ripe for testing in other human cancers. ■

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PLASMA PHYSICS

# On the node of a wave

Tom Katsouleas

**A compact electron accelerator can be made by the cunning use of laser pulses to let electrons 'surf' on a plasma wave. The problem has been controlling exactly how much the electrons are accelerated.**

In the early 1990s, off the north shore of Maui, Hawaii, Laird Hamilton and Buzzy Kerbox invented the sport of tow-in surfing, using jet skis to propel themselves into particularly large or fast waves. Catching these waves by paddling would have been impossible without becoming caught up in the waves' white water (Fig. 1). On page 737 of this issue, Faure and colleagues[1] describe a similar technique to inject electrons into a plasma wave created in the wake of a propagating laser pulse. The end result is a compact electron accelerator of astonishing stability that could one day find applications in fields from radiation therapy to radiography and femtosecond chemistry.

The authors' result is an improvement on the principle of the 'laser wakefield accelerator', which was used in 2004 to produce electron beams of a single defined energy[2–4]. The laser wakefield accelerator works by first using a single intense laser pulse to ionize a passive gas such as helium, forming a plasma of charged electrons and ions. Much in the manner of a speedboat passing through water, this pulse creates a wake as it displaces plasma electrons from its path. The wake can gain such a large amplitude that it 'breaks', forming the plasma equivalent of white water[5] — electrons that move with the wave, rather than just supporting it as it propagates. The large electric forces associated with the wake capture white-water electrons and accelerate them to energies of up to 200 megaelectronvolts (MeV) over a distance of just 2 mm. That distance is nearly 1,000 times shorter than the length of a comparable conventional accelerator driven by radio-frequency waves. Remarkably, the resulting electron beams are almost monoenergetic. They are also of high quality in the sense that their emittance, a quantity associated with a beam's angular divergence, is small.

Until the latest work, however, the beams produced by a laser wakefield accelerator were not stable: small changes in laser or gas conditions could lead to variations in the final beam energy of as much as 50%. Faure and colleagues' advance[1] is to stabilize the energy gain of the accelerator by introducing an equivalent of a jet ski for the electrons. This takes the form of a second laser beam that controls precisely the way the electrons 'surf' the plasma wave. The result is a high-quality electron beam with a single, well-defined energy that can be varied from 50 to 250 MeV.

To achieve this result, the authors first adjusted the parameters of the plasma and

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**Figure 1 | Surfing, tow-in style.** Pete Cabrinha takes a record-breaking ride on the 70-foot 'Jaws' wave off the north shore of Maui, Hawaii, on 10 January 2004, for which he won the coveted Billabong XXL.

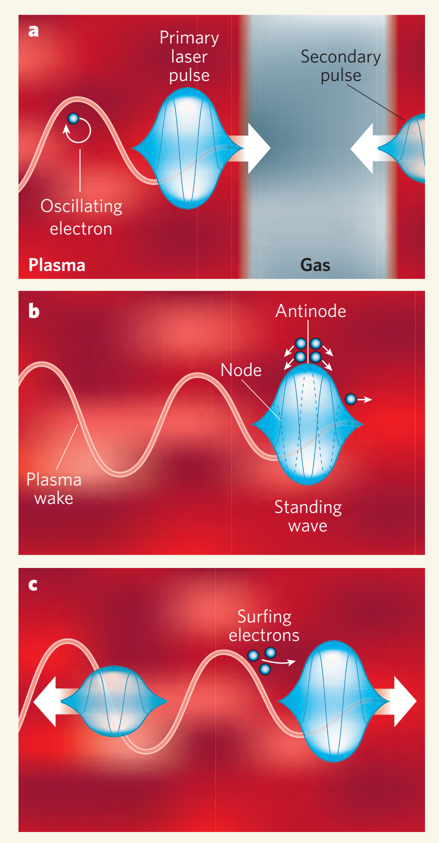


**Figure 2 | Surfing in a plasma wakefield. a,** In Faure and colleagues' experimental scheme[1], the primary laser wakefield pulse ionizes helium gas to a plasma. If the parameters of pulse and plasma are chosen appropriately, the electrons of the plasma oscillate about a fixed spot. **b,** If a second 'tow-in' pulse travelling in the opposite direction crosses the first, a standing wave forms. Electrons are pushed left and right in the standing wave from the antinodes to the nodes. **c,** Some electrons — those pushed to the right — gain enough speed to get caught up in the following wave crest and are accelerated forwards. The energy gain of the electrons is determined by how far they have to surf through the plasma, and so by where exactly along the plasma the two laser pulses cross.

initial laser pulse to keep the amplitude of the plasma waves just below the threshold for wave breaking. This means that no plasma electrons move fast enough to ride the waves. Instead, they just oscillate back and forth, as do water molecules in an ocean wave far from the beach. But when a second pulse is added, propagating in the opposite direction to the first, a temporary standing wave is formed with fixed maxima and minima, known as antinodes and nodes (Fig. 2). The radiation pressure caused by the momentum of the light pushes electrons at the antinodes of the standing wave towards the nodes. This slight extra push is enough to force some electrons into the wake of the first laser, where they become surfers at nearly the speed of light. The location of the overlap of the two lasers determines where along the plasma axis electrons first catch the wave, so the length of their ride, and hence their energy gain, can be easily controlled by adjusting the timing between the two lasers.

This idea of using a second laser pulse to slingshot electrons into a plasma wake dates back to 1996 (ref. 6) — not long after Hamilton and Kerbox were experimenting with jet skis to sling themselves into ocean waves. Several groups have attempted variations on the original idea, but Faure *et al.*[1] are the first to demonstrate high-quality beam injection. Interestingly, they succeed with the simplest of the schemes proposed so far.

The first idea was to cross two lasers at 90° and use the transverse radiation pressure of the second laser to inject electrons into the main laser's wake. But simulations indicated that it was the second laser's wake, rather than its radiation pressure, that caused injection[7]. The simultaneous use of counter-propagating and co-propagating secondary lasers for injection was then proposed[8]. It was thought that two lasers of frequencies differing by an amount matched to the resonant frequency of electrons in the plasma would be needed to create a slow plasma wave that would push electrons into the main wake. But further simulations[9] seemed to imply that radiation pressure from the standing field pattern produced with a single counter-propagating secondary laser could be sufficient. It is indeed this last and simplest scheme that has worked to such positive effect.

The approach does have limitations. The charge that can be accelerated in a single bunch amounts to just tens of picocoulombs, which is ten times less than the quantities typically accelerated without a stabilizing second laser. Although this much charge is adequate for many proposed applications[10–12], other groups in Britain, the United States and Japan are working with considerable success to stabilize the energy gain at higher charge levels using more precise control of the laser and gas conditions.

The rapidity with which barriers have continued to fall in the two years since the breakthrough[2–4] for monoenergetic acceleration of electrons in laser wakefields is astounding. Monoenergetic beams of ions have now been produced by laser irradiation of specially designed foil targets[13,14], rather than of gaseous targets as used for electron production. Work is also progressing towards showing that the plasma mechanisms can be scaled to higher energies[15,16], and particularly to the stringent requirements of a high-energy collider.

That energy frontier is still a long way off for laser-plasma technology. But thanks to work such as that of Faure and colleagues[1], the widespread use of compact plasma accelerators for medicine, industry and research may be much closer than we think. ■

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EVOLUTIONARY BIOLOGY

# Caught right-handed

A. Richard Palmer

**Are two penises better than one? Not so, implies a study of doubly endowed earwigs. An ancestral behavioural preference for the right penis might have facilitated the loss of the left in species that arose later.**

Human males may sometimes wonder about the size of their penis, but they rarely fret about which one to use. Not so for many arthropods, among them fairy shrimp[1], dragonflies[2] and spiders[3], some of which face a delicate choice before each tryst: "Left or right tonight?" Doubly endowed lizards[4] and snakes[5] seem ambivalent, although they tend to alternate between the right and left of their two members. Males of two theridiid spider genera (*Tidarren* and *Echinotheridion*) have a particularly radical solution to their quandary: they voluntarily rip off a palp at random and eat it, leaving only one behind.

Writing in the *Journal of Morphology*[6], Yoshitaka Kamimura describes his investigations of the private life of the doubly endowed male of the earwig species *Labidura riparia* (Fig. 1a). He shows that this earwig has a strong preference for its right penis: nearly 90% of field-collected and laboratory-reared males hold their intromittent organs in the 'right-ready'