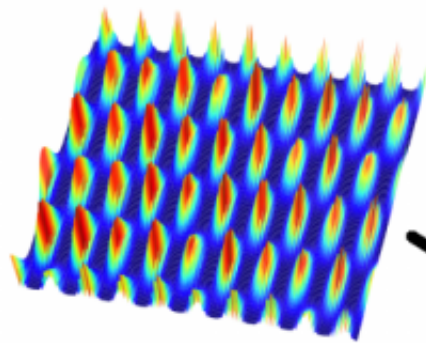


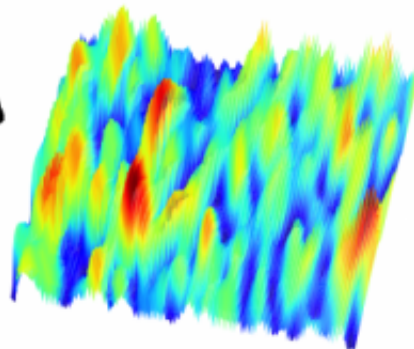
Combining lasers could shrink particle accelerators from kilometers to meters

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initial array of laser pulses



laser energy after incoherent mixing



There are snapshots of the laser energy density at the beginning of the simulation for the array of laser pulse (left plot), and after some propagation distance of the beamlets in the plasma (right plot), where the laser field exhibits a clear incoherent pattern. Credit: Carlo Benedetti/LBL

It took every inch of the Large Hadron Collider's 17-mile length to accelerate particles to energies high enough to discover the Higgs boson. Now, imagine an accelerator that could do the same thing in, say, the

length of a football field. Or less.

That is the promise of laser-plasma accelerators, which use lasers instead of high-power radio-frequency waves to energize [electrons](#) in very short distances. Scientists have grappled with building these devices for two decades, and a new theoretical study predicts that this may be easier than previously thought.

The authors are Carlo Benedetti, Carl Schroeder, Eric Esarey, and Wim Leemans, physicists at Lawrence Berkeley National Laboratory's Berkeley Lab Laser Accelerator (BELLA) Center. Their paper, "Plasma wakefields driven by an incoherent combination of laser pulses: A path towards high-average power laser-plasma accelerators," appears in the May Special Issue of *Physics of Plasmas*.

If their models prove correct, they could help lower the cost of high-energy physics research—the Large Hadron Collider cost \$9 billion—as well as many other industrial and medical applications of accelerators.

Laser-plasma accelerators work by blasting a powerful laser beam into a plasma, a cloud of unattached electrons and ions.

"The effect is like the wake of boat speeding down a lake. If the wake was big enough, a surfer could ride it," Leemans, who heads the BELLA Center, explained.

"Imagine that the plasma is the lake and the laser is the motorboat. When the laser plows through the plasma, the pressure created by its photons pushes the electrons out of the way. They wind up surfing the wake, or wakefield, created by the laser as it moves down the accelerator," he said.

The fast moving electrons leave the heavy ions behind. As they separate,

they create gigantic electric fields, 100 to 1,000 times larger than those in conventional accelerators.

This is how they accelerate electrons so rapidly. For example, Stanford's Linear Accelerator Center takes two miles to drive an electron to 50 billion electron volts (GeV). Leemans' experimental laser-plasma accelerator takes electrons to more than 1 GeV in slightly more than 1 inch.

It takes a lot of laser power to generate a wakefield. For example, BELLA's petawatt (1 quadrillion watts) laser has a 10 meter x 10 meter footprint. It generates 400 times more power than all the world's power plants combined, though only for 40 femtoseconds (40 quadrillionths of a second).

Unfortunately, it takes BELLA's laser a full second to recharge and send a second pulse. High-energy physics research requires tens of thousands of pulses per second. Many other applications would benefit from multiple pulses per second.

BELLA's laser has the highest repetition rate of any petawatt laser in the world. Building a faster petawatt laser would require a heroic feat of engineering.

Several European researchers have suggested using an array of smaller lasers to produce one enormous pulse. Since less powerful lasers recharge faster, they could produce hundreds or even thousands of pulses per second and sustain a wakefield over many meters.

The hurdle they needed to overcome was how to synchronize hundreds of lasers so they all pulsed within less than a femtosecond of one another.

Such precision would be expensive and presents serious technical problems. But the concept of combining lasers got Leemans' team thinking.

What if the beam was not perfect? What if it were just good enough to rapidly raise the photon pressure on the electrons? Could we get away with it, they wondered.

According to the model presented in *Physics of Plasmas*, they could. Leemans compares it to pushing a swing.

"Instead of one big push, we would give it many smaller pushes at roughly the same time. It's not quite perfect, but the swing doesn't really care. It averages over all these little pushes and up it goes."

Laxer timing would make larger and more sustainable accelerators practical. Leemans hopes to power them with a new technology based on highly-efficient fiber lasers. The power that off-the-shelf welding lasers offer demonstrates multi-kW capabilities but much work is needed to pack the power into ultrashort pulses needed for [laser](#) plasma accelerators. The paper offers an approach that gets us a step closer.

The new accelerators would offer new options to physicists trying to unravel how the universe is put together. It could lower the cost of industrial uses, and make high-energy accelerators more affordable for hospitals.

Just think of it as dreaming big by thinking small.

More information: "Plasma wakefields driven by an incoherent combination of laser pulses: a path towards high-average power laser-plasma accelerators" by C. Benedetti, C. B. Schroeder, E. Esarey, and W. P. Leemans. *Physics of Plasmas* May 27, 2014:

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