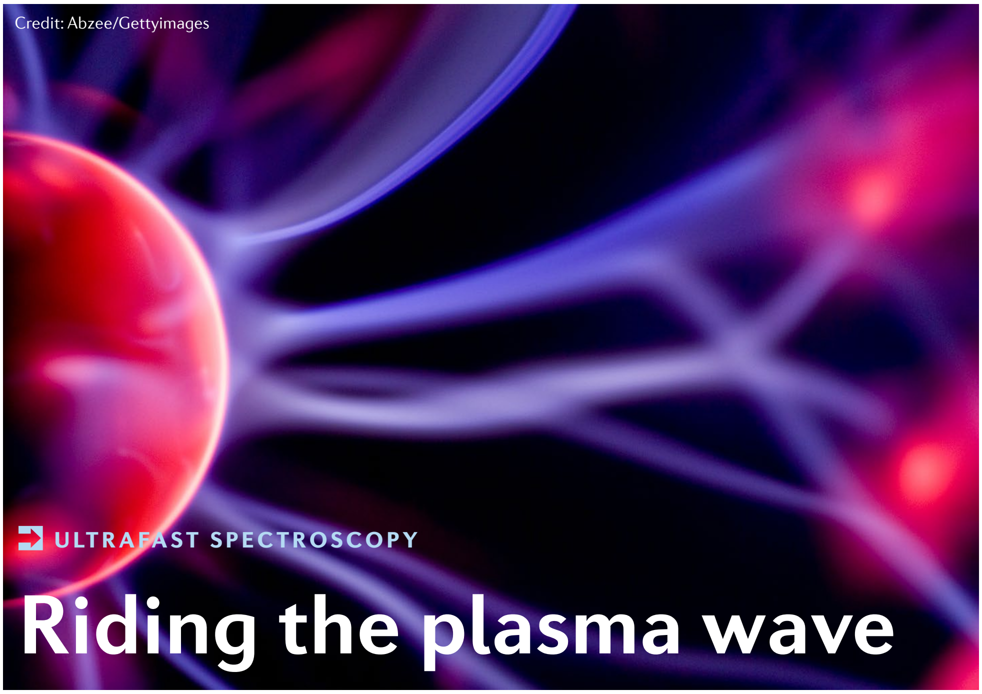
*Nature Reviews Materials* | https://doi.org/10.1038/s41578-019-0098-z | Published online 8 March 2019



Credit: Abzee/Gettyimages

ULTRAFAST SPECTROSCOPY

# Riding the plasma wave

> With the new configuration we introduced we can produce relativistic, dual-energy electron bunches in a single laser shot

Plasma-wave accelerators — laser-driven particle accelerators — are compact sources of high-energy electrons. Writing in *Nature Photonics*, Andreas Döpp, Stefan Karsch and colleagues report an innovative setup for ultrafast pump–probe experiments based on plasma waves, which produces two synchronized ultrashort beams with individually adjustable energies.

Pump–probe experiments, in which a pump pulse excites a system and a subsequent probe pulse characterizes its out-of-equilibrium behaviour, are instrumental for the investigation of ultrafast dynamical processes. Currently, these experiments are bound to low-energy pulses (infrared or optical) as pumps and extreme ultraviolet pulses as probes, which are very limited in terms of photon energy and intensity. The alternative is to use femtosecond X-ray pulses, which are only available at a few X-ray free electron laser facilities.

Plasma-wave accelerators represent a different paradigm. Charged particles are accelerated by the electric field associated with periodic charge density perturbations in plasma that is excited using a high-intensity laser. The plasma wave accelerates electrons in a similar way to bigger accelerators, but on much smaller length scales (millimetres compared with hundreds of metres), giving rise to brilliant X-ray emission. Such setups hold promise for affordable and compact accelerators that could be used in various fields, ranging from high-energy physics to medical physics and materials science. The breadth of feasible experiments would be dramatically expanded if several synchronized ultrashort beams could be produced.

The researchers generated twin beams with energies that are individually adjustable in a wide range, and a duration and mutual delay of only a few femtoseconds. "We demonstrated an unprecedented level of control for this type of accelerator," says Döpp. "With the new configuration we introduced we can produce relativistic, dual-energy electron bunches in a single laser shot." Electron bunches with these properties cannot be generated in any other accelerator and thus enable entirely new experiments. For example, this setup could be employed for sequential X-ray imaging to follow the changes in a rapidly evolving structure with very high time resolution. A more challenging possibility would be to perform pump–probe experiments on molecular systems: the large energy separation of the beams would be appropriate for this type of system, but whether it is possible to get the flux necessary to directly excite molecular systems is an open question.

"We are now commissioning an upgraded laser system, the ATLAS-3000 laser, which, at up to 3 PW at peak power, will be one of the most powerful laser systems in the world," explains Karsch. "Our plan is to further investigate the dual-energy scheme and try to increase the total electron and photon yield." The use of this setup will open up many opportunities for new experiments, but combining it with other sources will help to tap further into its potential. "Our setup can in principle be adapted to combine synchronized laser and electron beams with other kinds of secondary photon sources, from THz to gamma rays," concludes Döpp. "Maybe some readers can think of entirely different, new applications we haven't thought of yet."

*Giulia Pacchioni*

**ORIGINAL ARTICLE** Wenz, J. et al. Dual-energy electron beams from a compact laser-driven accelerator. *Nat. Photonics* https://doi.org/10.1038/s41566-019-0356-z (2019).