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"TeV on a chip": X-ray wakefield accelerator in nanomaterials

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The laser-driven acceleration such as LWFA (laser wakefield acceleration) has demonstrated its capability of accelerating electrons (and other charged particles) to high energies over a very compact distance two-three orders of magnitude shorter than the conventional accelerator methods. Thus the typical LWFA experiments conducted in a gas plasma of density ˜ 1018 /cc gain energies of GeV over a matter of cm. The LWFA energy gain is inversely proportional to the plasma density Δε = 2mc2 a02 (ncr / n), where mc2 is the electron rest mass energy, a0 is the normalized vector potential, ncr the critical density (1021 /cc for a 1eV optical laser), and n is the electron density. On the other hand, the accelerating length of LWFA over one stage scales inversely proportional to the density power of n-3/2, making it longer for lower densities [Tajima/Dawson, 1979]. The introduction of a newly discovered path with X-ray (˜10keV) laser pulses [Mourou et al., 2014] allows us for the first time to choose an alternative and even more attractive path toward ultrahigh energies as an experimental possibility [Tajima, 2014]. Previously we lacked realistic X-ray drivers. Since the critical density ncr is proportional to the frequency of the laser squared ω02 , for the X-ray laser at 10keV, for example, the critical density is as large as ncr = 1029 /cc. This is why we now can choose a solid density (1023 /cc) material such as nanomaterials in place of gas plasma, leading to the prospect of an immense energy gain (TeV) over mere cm. In addition, we will discuss additional novel developments and applications of wakefield acceleration.

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