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# High Field Science in the Extreme Light: a Novel Path

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On the horizon is a new class of extreme light. In Europe and elsewhere we witness aspiration and proposals, and yes projects in laser development in subexawatts and beyond. We only briefly review some of these, as another talk is planned to cover the subject. Here we go over what it means and what we can do with it. We understand that by increasing the power from, say 1PW to 10PW or 100PW, we can increase the regime of light interaction into far stronger regimes, which is often called the relativistic (or even ultrarelativistic) optics regime[1]. Most of the ideas may be found in Ref.[1], so that we refer you to it. Here we further introduce a class of novel ways to accelerate (and manipulate) particles in fields ever higher than any in the past that have not been mentioned there. In the first version the intense laser converted X-ray laser propagates in a crystal in which X-rays induce intense wakefields in the medium of crystal electrons. In the second version we inject this intense X-rays into vacuum in which X-rays navigates the vacuum as a medium, creating an accelerating structure akin to the plasma fiber accelerators. With the new laser compression technology (Mourou et al.) we are capable of producing laser pulses of the class of 100PW with a (single oscillation) fs duration using the available compact intense laser technology. With this fs intense laser we can produce a coherent X-ray pulse that is compressed. This can be well into hard X-ray regimes (say 10keV) with the power of up to as much as 10EW. We suggest to utilize such coherent X-rays to drive acceleration of particles. Such X-rays may be focusable far beyond the diffractive limit of the laser wavelength. When we inject such X-rays into a crystal (a metallic electron plasma), laser wakefield acceleration in a metallic density plasma with the zeptosecond (or attosecond) X-ray pulse with up to EW power. In the ideal 1D theoretic framework the energy gain may be estimated as much as 10PeV over 50m. Not only the LWFA electron acceleration is possible, once we preaccelerate ions to beyond GeV, such ions are capable of accelerated in the above LWFA to similar energies over likewise distance. Such high energy proton (and ion) beams can induce copious neutrons, which can also give rise to intense compact muon beams and neutrino beams. These beams may be portable. Very efficient and high-energy gamma rays can be also emitted by this accelerating process, both by the betatron radiation as well as by the radiative-damping dominant dynamics with the brilliance many orders of magnitude over the brightest X-rays sources over a very compact size. With this exceptional new physical parameters enabled by this technology we envision a whole scope of new physical phenomena, which includes the possibility of laser pulse self-focus in the vacuum, neutron manipulation by the beat of such lasers, zeptosecond spectroscopy of nuclei, etc. Further, we introduce the second concept now vacuum as the nonlinear medium, the Schwinger Fiber Accelerator, which is a self-organized vacuum fiber acceleration concept, in which the self-focusing and defocusing and repeated processes of these in vacuum form a modulated fiber that guides this intense X-rays within it.

[1] G. Mourou, T. Tajima, and S. Bulanov, Rev. Mod. Phys. **78**, 309 (2006).