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Wakefields: laser, toilet science, and gamma-ray bursts

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Wakefields are nonlinear, robust, and stable entities that appear when the phase velocity of the excited waves is high (such as the speed of light, in which case it provides a relativistic structure). Laser wakefield in gas is capable of providing accelerating fields over GeV/cm, while that in solid driven by a single-cycled X-ray laser amounts to TeV/cm [1]. Experimental demonstrations began since 1995, while its applications proliferated. The aspiration for laser wakefield acceleration has driven ever more intense lasers, which in turn opened up the scientific field of High Field Science. While wakefields are of a high phase velocity phenomenon, if we manage to irradiate laser on a target in such a way to coherently slow down (e.g. with a thin film), the wave with slower phase velocity is capable of accelerating heavier ions (radiation pressure acceleration) [2, 3].

We are led to the realization that wakefield is perhaps the strongest coherent and dynamic structure the Nature provides us. As long as certain conditions are fulfilled, the excited wake in gas can be indestructible. Such a property is ideal to the application I would call "toilet science", i.e. the science to take care of the downstream waste after use (in this case high energies of spent beams) to adequately and nondestructively decelerate them over the shortest possible distance by wakefields [4, 5]. High energy particles may be stopped over a short distance without the beam dump radioactivated.

When we turn our eye to the Universe, we also realize that the Mother Nature has excited robust wakefields. In fact she had created wakefields before we did in our laboratories. In the accretion disk of a black hole (BH) (or a neutron star (NS)) we surmise that the magneto-rotational instability in the disk can cause a chunk of matter to accrete toward the central object, which triggers disruptive jet excitations that give rise to the wakefield acceleration along the jets. Thus high energy electrons can become gamma ray bursts [6]. Professor Barry Barish showed that disruptive accretion toward the compact star (BH or NS) emits gravitational waves, followed by gamma-ray bursts [7].

Finally, to visit a fusion plasma, in a Field Reverse Configuration plasma experiment where the magnetic field is weak and allows global particle orbits the strong ion beam injection is observed to excite large amplitude ion cyclotron (IC) waves. Because the beam-driven IC waves have high phase velocity, the high amplitude IC wave shows the ubiquitous wakefield saturation amplitude of the Tajima-Dawson field $E_{TD} = M\,\Omega_{ci}\,v_{ph}/q$. This is an ion branch of wakefield [8].

References

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