How to approach the Schwinger limit using relativistic plasma mirrors

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Achieving a light source delivering intensities up to the Schwinger limit of 10^{29}W/cm^2 would allow exploring novel regimes of strong-field Quantum ElectroDynamics (QED) where the quantum vacuum is ripped apart. A promising candidate to build such a light source is the Curved Relativistic Mirror (CRM) concept that consists in: (i) inducing a Doppler upshift and temporal compression of a counter-propagating incident laser (ii) focusing the upshifted radiation down to a focal spot size much smaller than the one possible with the incident laser. Since its emergence in 2003 [1], many implementations of the CRM concept have been proposed. However, none has led to a detailed and feasible experimental proposal, mainly because they make use of idealized experimental conditions that are either not realistic or beyond present experimental know-how.

In this context, we recently proposed a novel and realistic all-optical scheme [2] to implement the CRM concept using so-called relativistic 'Plasma Mirrors' (PM) formed when an ultra-intense laser with high-contrast is focused on an initially-flat solid target. In this scheme, the PM surface is optically curved, either by radiation pressure or using secondary pre-pulse beams. As we demonstrate, this enables a considerably higher control of the PM shape than the one obtained with all other schemes proposed so far relying on the use of pre-shaped solid targets, which are beyond present State-Of-The-Art of manufacturing techniques.

In my talk, I first present the new scheme and its validation using cutting-edge 3D PIC simulations at an unprecedented scale using the pseudo-spectral 3D PIC code WarpX. These simulations show that Doppler boosted intensities between 10^{25}W/cm^2 and up to 10^{28}W/cm^2 can be achieved with a multi-PW laser.

I then present the latest simulation results obtained by my team on the interactions of a Doppler boosted multi-PW laser beam with a secondary solid target placed at PM focus [3]. Our simulations show that very clear SF-QED signatures could be obtained in experiments (gamma-rays, GeV relativistic positron beams) with already available PW lasers. At constant laser power, these signatures are more than 3 orders of magnitude higher to what would be obtained with a non-boosted multi-PW laser beam and should enable the probing of SF-QED dominated regimes in light-matter interactions in the near future.

References

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[3] L. Fedeli *et al*, PRL (in press), ArXiv:2012.07696 (2021)